Being Human: Approaching the Human Context

Greg Hart
Human Effort
Calgary, Alberta CANADA

Human beings have not changed substantially for the last hundred thousand years, but culturally our behavior is shifting at a ever accelerating pace. The result of this has been an ever wideneing disparity between our evolutionary position and our cultural behavior. Ergonomics has spent the last few decades attempting to fit tasks to people, but in many respects it has been a process of fitting tasks to the cultural and not the evolutionary position of human beings. We have become emersed in a number of symptom relieving strategies when the fundamental solution lies in closing the gap between work and our evolutionary context and between our cultural change and evolutionary context. We have supported these notions with reductionist research purporting to understand effects in complex systems. An outline for the evolutionary context of human beings and potential measurement strategies are outlined.

INTRODUCTION

The challenge of helping people stay healthy as the world moves into the next millennium is really what ergonomics is going to be about. When you look around the world and identify the threatening challenges that confront us you will see things such as health, criminal behavior, environmental concerns and employment. Is it possible that the reasons that we face many of these challenges hinge on the chance that we have taken for granted the things that we are most intimate with? Is it also possible, that in our pursuit of studies to prove or disprove every specific application of knowledge, we have dropped the yardstick and ignored the things we already know?

It is not within the scope of this paper to address all the maladies that ail the planet Earth and its passengers. Indeed, it is not within the scope of this paper to address even all the issues facing workers. The purpose of this paper is to present an alternative concept for understanding ergonomics and the impact science has on its good practice. There will be a special emphasis on the continuing rise of so-called Repetitive Strain Injuries (RSI), Work Related Musculoskeletal Disorders (WRMSD), Repetitive Motion Injuries (RMI) and Cumulative Trauma Disorders (CTD). For the purposes of this discussion, the paper will refer to these issues as being CTDs and will refer to members of this group of injuries (i.e. tendinitis, neuropathies and muscle strains) separately as well as to the Australian definition as a “syndrome” of some sort. Injuries to the spine will also be considered to be cumulative for the purposes of this paper.

THE PROPOSITION

The evolved structure of the human being and the behavioral choices we take have become increasingly divergent in the last 50 years. That trend continues today - perhaps ever accelerating due to the rapid spread of computer technology. The only hope we have to stem the tide of many challenges facing human existence today is to begin to close the gap between cultural change and evolution. There are well defined limits to human function in the physical realm as well as with respect to mental, socio-emotional and spiritual dimensions. There is considerable individual variation within these limits, but they do exist. If significant behavior change outpaces evolutionary change, what are the consequences? Is the glut of CTD injuries a symptom of behavioral change outstripping the adaptive capability of evolution? More critically, is the reliance on behavioral change so significant that humans have stopped adapting and have instead begun to rely on behavior to protect themselves?

If we are to consider an attempt at a total solution to what is obviously a complex multi-factorial problem, we must consider a fresh perspective. This need not be a perspective that retires the focuses and techniques of the past and present, but frames them and elevates them according to a new model. This approach should not be tied to the work or the individual or the interaction, but to a dynamic external model - The Human Context. Rather than bringing the work and the worker together, we should attempt to bring the work and the worker closer to the Human Context.

The Human Context refers to a dynamic state in which the individual operates with optimal effectiveness featuring a minimized risk of developing dysfunctional adaptations. These adaptations occur not only in the physiological realm but also in the spheres of spiritual, emotional and mental functions - spheres that are widely recognized as being interdependent. This is not a cultural context, but an evolutionary one.

In many respects, modern ergonomics already does this. However, in many other ways, it acts in diametric opposition to this principle. This presentation will advocate the definition of the Human Context with respect to spiritual, socio-emotional, mental and physical domains

There are very few places where the gap between human evolution and human behavior are more apparent than with respect to health.

Ergonomics Today and Tomorrow

Ergonomics has traditionally been described as "fitting the person to the task" . It is certain that much of the investigation and application in this diverse field has been carried out with a distinct emphasis on the "task". There are probably a number of reasons for this. They include the engineering and psychology based growth of ergonomics and a reticence to tangle with the complex notion of the human doing the work. It is much easier to change the shape of a widget or the process in which it is produced than to work with the individual doing the task.

Presently, most ergonomic interventions are labeled under the headings of "administrative" and "engineering" and are often referred to as "controls". The National Institute for Safety and Health (NIOSH) has developed a tool for determining the suitability of manual handling loads to the human spine. It is a conservative, two-dimensional assessment of compression in the spine and recommends the implementation of administrative and engineering controls at certain thresholds. An administrative control would include having two people execute a lift or change the process to increase the break time between lifts. An engineering control would include building a device to handle or assist in handling the load. The basic idea is to keep loading low enough to project that the vast majority of the average population would be able to safely handle the loading. With this in mind, we often look for ways to always decrease load. Yet, an examination of human function tells us we need to be challenged physically.

Are we relieving a symptom and worsening the fundamental problem?

Since we regularly consider "fitting the task to the person", perhaps we should begin thinking about "fitting the person to the person". This is another way of saying "bring behavior in line with evolution". There is an additional possibility. This possibility involves fitting both the person and the task(s) to the context of being human. Fitting the task to the person has increasingly meant reducing the amount of energy required to accomplish a given set of tasks. This is the danger of fitting tasks to the current cultural definition of being human and not the evolutionary definition. Bringing the human and the work closer to the evolutionary reality of humanness will be helpful.

EVOLUTIONARY CHANGE AND BEHAVIORAL/CULTURAL CHANGE

It is self - evident that the behavior of a species can change with alarming speed. Indeed, it is often cited as one of the most terrifying aspects of living in the latter part of the 20th century (Reid, 1996). Evolutionary change does not occur quickly at all. It proceeds through a highly inefficient and indirect process of natural selection. Humans of today are essentially the same (in the modal sense) to the Cro-Magnon humans of 100,000 years ago (Gould, 1996). This is a normal process for a species that establishes itself successfully in its environment (Gould, 1996). Species in this position, are capable of manipulating their environment, depend less on processes of evolutionary adaptation and depend more on behavioral adaptation. Our cultural behaviors have changed dramatically. Stephen Jay Gould, the respected Harvard Professor of Zoology, puts it this way:

> "Everything that we have accomplished in the unmeasurable geological moment of the last ten thousand years - from the origin of agriculture to the Sears Building in Chicago, the entire panoply of human civilization for better or for worse - has been built upon the capacities of an unaltered brain." (Gould, 1996)

Also built upon the capacities of an unaltered body. The unprecedented technological change that has consumed and largely shaped our culture since the end of the Second World War is also built upon the capacities of the same human organism. This human organism is clearly limited by biomechanical and physiological

constraints. It is also clearly evolved for certain purposes. Physically, that certain purpose is movement. In a 1996 article, Steven Blair, an epidemiologist, stated:

> "Humans evolved to be active animals, and we may be physiologically unsuited to life in modern society. I believe that the high prevalence of physical inactivity in many countries around the world is one of the most serious threats to health we face." (Blair, 1996)

The entire physical presentation of a human being is set out with movement in mind. The bulk of tissue in the body (muscle, nerve, connective tissue and bone) is there to facilitate movement. Countless epidemiological studies have demonstrated that physical inactivity increases all-cause mortality and serious disease morbidity (Blair et al, 1995).

CTD injuries are really as much about inactivity as they are about repetitive activity. These injury mechanisms are characterized by low variability overuse of small distal structures. They also involve proximal structures working in a static fashion while avoiding much of the dynamic work they are normally assigned to.

THE HUMAN CONTEXT

Being human is self-evidently a complex and interdependent undertaking. It is intradependent within individual domains and interdependent between domains. For example, metabolic physiology is interdependent with structural anatomy in the physical domain just as the physical domain is interdependent with the mental and socio-emotional domains.

To adequately develop the argument for each domain would be exhaustive and well outside the scope of this presentation. I will endeavor to fashion an introductory understanding of each of these domains with heaviest emphasis will be focused on the physical domain and concepts. Reference will be made to its interdependent relationship with the other domains.

Mental Domain

The human mind is one area where our experience may, in fact, lie a great distance from a terminally defined limitation. The brain functions in a number of domains, but mental will be defined as thinking, cognitive and creative activity. Like the physical domain, the mental domain appears to crave activity (Covey, 1990).

Learning appears to be an activity that is important to mental health. An accumulation of literature in the twentieth century suggests that if the mental processes remain unchallenged, they too will fall into a pattern of disuse and leave the individual vulnerable to dysfunction.

Spiritual Domain

Some would argue that this domain doesn't really exist, but centuries of discussions around hope, religion and beliefs would perhaps indicate otherwise. Some of the most profound work on spirituality has grown out of the psychological doctrine of logotherapy. This term was created by Victor Frankel, a survivor of the Nazi concentration camps of the Second World War. This branch of psychotherapy believes that loss of hope or meaning in a person's life is the primary catalyst for declining spiritual and/or mental health. It can also impact physical health directly and indirectly. According to Frankel, those with nothing to live for often die much sooner than those with a sense of meaning in life (Frankel, 1955).

Socio-Emotional Domain

Humans are well-known as creatures of social organization and much has been written over the centuries about our relationships as large groups, as pairings and as other small numbered relationships. This has been researched since the birth of Sociology in the late nineteenth century when Durkheim discovered that suicides could be related to societal connectedness (Teevan, 1984). Subsequent investigation has illuminated these relationships further. It is widely believed that gang involvement is related to a lack of social cohesion in a more "normal" sense as in a family unit (Teevan, 1984). Psycho-social dysfunction seems to occur when people are disconnected. An emerging issue in this generation is the rapid rise of telecommuting where people work at home and are connected via fibre optic cable to there work and/or friends. Most people in modern society satisfy a large part of their socialization need through work relationships. What there be consequences when we begin to substitute cyberspace socialization for physical socialization?

The field of evolutionary psychology and the understanding of the subtle interplay of nature and nurture is an emerging field of inquiry. It is helping us further understand why humans behave in the ways they do. Frank Sulloway's landmark discussion of the effects of birth order on behavior, Born To Rebel (1996), is a

remarkable scientific treatment of these issues. Based on birth order and exposures in environment, Sulloway has developed actual equations to predict personality in adults with alarming accuracy.

Physical Domain

This is the domain where most of the more obvious dysfunction occurs. A system as organically and mechanically complex as the human body must be expected to suffer breakdowns of varying scope on a regular basis. Significant problems begin to appear when repair falls behind the pace of damage. In preventing damage we should turn to attempting to stay as aligned as possible with the evolutionary design of our structures and physiological functions. The overwhelming issue in this respect must be movement. Humans are suited to movement. It has become very clear that lack of physical activity contributes significantly to all-cause mortality, morbidity and significant injury (Blair et al, 1995). As an example of domain interdependence, level of physical activity is a significant predictor for "mental health" as well (Blair et al, 1995).

The human body is a highly adaptive mechanism and requires constant stimulation to maintain optimum function. This may be, in part, due to the popular tenet of Complexity Theory that suggests complex systems exist on the 'edge of chaos'. If they go to far they descend into a chaotic state and collapse. If they are not challenged enough they also collapse into rigidity and negative stasis. By examining many of the physical injuries that are legion in the workplace and society in general, they can be traced to lack of conditioning in the organism or lack of movement in a large and varied sense. CTD injury situations can be characterized as involving high repetition of small movements in the extremities, but they can be also characterized by immobility. Much of the emerging evidence links these injuries to blood flow decreases (Armstrong et al, 1993). These decreases are often created by immobility. Overexertion of the distal extremities can easily occur because of inadequate participation of the proximal structures in initiating movement and contributing transferred forces.

In attempting to understand CTD, Armstrong et al (1993) published a model based upon a dose-response relationship. It is an ecological model composed of internal and external events and the capacity of the individual and the individual components to tolerate and respond to these events.

The following are areas of knowledge (functional and pathological or dysfunctional) for fundamental understanding:

- anatomical/structural
- biomechanical
- neuromotor
- metabolic
- endocrine
- cognitive/perceptual (linked to mental domain)
- nutrition effects

There are a number of basic characteristics of human physical existence that we understand the conditions required for healthy function. It is out of the scope of this introductory discussion to list them all. It is safe to say that they all circulate around the issue of movement. The Centre for Disease Control in Atlanta recently reported that only 25% of children in American High Schools are involved in Physical Education classes (Personal Communication, 1997). It has become evident that the workplace exacerbates the risk of CTD, but it is also evident that our lifestyle predisposes us to it in the same way it predisposes us to heart disease and cancer.

Below are some examples of applying the human context to current issues in ergonomics.

EVIDENCE AND APPLICATION

In Micheal Crichton's novel, The Lost World, Dr. Malcolm - the complexity mathematician, laments the "fuzzy-mindedness" that has come to characterize much of modern science or as he calls it - "sappy science". Peter Senge discusses the dangerous misinterpretation of data and being able to differentiate between what actual data is versus an extrapolation of data (Senge, 1990). The critical element of this is in correlating different pieces of data to be meaningful. The danger of correlative findings is well documented in the literature and any statistics course. Many studies are efforts in cause and effect which is not poor science. What is suspect is cause-effect research being carried out in complex systems where causes and effects can be separated by time, events and implied secondary relationships. This is the danger of reductionism in science, we lose the ability to see the whole picture as we are overwhelmed by the details. There are many examples of these mistakes in the ergonomics literature.

Reductionism vs. Systems Thinking

Reductionism is often appropriate for determining specific underlying principles. For example, studies carried out by Noyes et al (1974) examining the nature of anterior cruciate ligament failure deliver very important information about the behavior of biological materials under load. Thousands of research endeavors of this type have been conducted for over one hundred years and have contributed to our understanding of the underlying thresholds and capacities of a number important issues, organic and otherwise. With this information, we can then begin to understand the combined systems effect by understanding as much of the basic, contributing information as possible.

I will use three recent studies as examples of some of the difficulties encountered. They will illustrate two key problems with some of the current research. There is a high propensity in studies to gauge "subject comfort" and determine outcomes based on this information. Worker comfort is an important piece of information to collect in understanding some of the subjective reaction in the system, but it is not a scientific measure of any direct cause and effect. The second and third studies deal more with making inferences from data in a casual manner and building on an inappropriate research design.

The first example is an examination of the impact of keyboard design on comfort and productivity in a text-entry task (Swanson et al, 1997). There were two separate issues under consideration: 1) comfort and 2) productivity. The second element is an important research question as one of the concerns with alternative keyboard styles is the impact on productivity. The first question is also important as comfort during clerical tasks has become an arena of intense study. The study found that there were short term decreases of productivity which were eliminated in the second day with the alternative keyboards utilized in the study. This is an important finding since losses in productivity would be associated with the introduction of a different process. As for comfort, they found no appreciable difference in the comfort of keyboarding, which is not surprising considering the keyboard is only one element of a complex system leading to discomfort. However, the study period was only two days and one would expect that many of the comfort changes associated with the new keyboard to occur over a much longer exposure period than that. Additionally, there was no discussion of work station design in a functional sense. Of greatest concern was the elimination of certain upper extremity postures based on their association with "discomfort", a subjectively reported and system based outcome. Discomfort can be created by a single event or a variety of events acting in concert. The postures outlined (such as wrist extension and excessive pronation) all produce increased stress to a variety of neuralmusculoskeletal structures. These stresses have been understood in careful studies to have consequences with relation to such things as increased pressure in the Carpal Tunnel during wrist extension. There are good reasons to avoid these postures for physiomechanical performance concerns. Why do we use comfort as a gauge?

The second study was an attempt to determine whether the use of a computer mouse was a cause of upper extremity injuries. The study was retrospective and examined insurance claims to determine the answer. Upon the completion of the review they determined that there was no evidence that mouse use was the culprit (Fogelman and Brogmus, 1995). Insurance data is highly unreliable in establishing injury cause because it is removed from the multifactorial root of the origin which is cumulative in nature. The significant issue here is that mouse use may indeed be a significant contributor to CTD, but it is a tool that can be utilized properly. Perhaps a more descriptive inquiry would consider the position of the mouse or the capability of outdated furniture to support the mouse utilization. The mouse, keyboard or any other tool can contribute to injury, but surely it is common sense to now understand that utilization is almost always more critical than the tool.

The final study examines EMG responses of the trapezius and infraspinatus muscles to paced repetitive arm work (Sundelin and Hagberg, 1992). There were a number of conclusions drawn from this piece of work relative to static muscle load and fatigue. The task involved moving the arm to 90 degrees of flexion to grasp a 15 gram cylinder and deposit in a hole in the table. The cycle time of the whole task was 1.46 seconds (Sundelin and Hagberg, 1992). Trapezius muscle fatigue increased steadily as did reported discomfort. This would be expected since the upper trapezius is recruited almost constantly to stabilize the shoulder and elevate the arm above the box with the shoulder 90 degrees flexed. Toward the end of the Discussion a comment is made as follows: "It is therefore suggested that dynamic work movements do not protect the muscles in the shoulders and neck from fatiguing processes in highly repetitive work" (Sundelin and Hagberg, 1992). The only dynamic movements at the shoulder were in muscle groups that they were not monitoring (i.e. anterior deltoid, biceps). The trapezius and infraspinatus muscles would be virtually static or in

occasional, very short range movement. Additionally, the arm position required creates very high mechanical loads on the shoulder flexors. It may have even significantly exceeded their load handling capability causing the stabilizers to work even harder. The cycle time was very short and there was no rest involved.

Raising the impact of dynamic movement on muscle fatigue is an important issue because dynamic activity is likely a better choice with respect to "normal" human function. Nothing in the Sundelin and Hagberg study put that to the test. If they had measured all tissues involved and had brought the work into acceptable ranges for working, perhaps then the results would have been more useful and not so misleading. Much has been said about trapezius tension, but most studies conclusions are significantly weakened by their design. This has become an issue with respect to forearm/wrist/arm support strategies in ergonomics.

Forearm Supports and Back Support

Wrist rests, "floating" forearm supports and chair armrests have become increasingly popular in many repetitive work environments. Their use has been based upon studies demonstrating the static load on the upper trapezius in unsupported positions. Wrist rests, in particular, have emerged to assist individuals in maintaining "neutral" wrist posture to avoid Carpal Tunnel Syndrome. If we consider the human context for movement, where is the evidence that we have evolved to require external support? There is none, but the argument may be that we never used to be required to do the tasks we are asked to do now. There is no doubt that this is true, but to respond by offering an externally engineered solution, is to invite the development of a system archetype described by Peter Senge as the "Shifting the Burden" archetype (1990). This archetype basically says that in order to relieve a symptom we implement a solution that really has no bearing on the actual root of the problem. The remarkable side effect of this system is that the engineered solution often contributes to a worsening of the fundamental problem or generates additional effects.

In the case of the forearm support, it relieves the static tension in the shoulders and neck almost immediately, thus relieving the symptom. However, the resulting side effects are a required increase in forearm and hand motion and load to accomplish tasks as the shoulders and the rest of the body have been taken out of the "kinetic chain". This provokes more weakening of these structures (shoulders and back) as well as decreased extensibility and vascularization. Increased dynamic movement in the upper extremities within reasonably neutral movement ranges needs to be examined as a fundamental solution.

Backrests in chairs may also produce similar burden-shifting effects in an attempt to rest all the musculature of the torso. The torso musculature is well-placed to provide stability for the spine and prevent buckling (McGill and Norman, 1992) and modify compression. McGill and Norman (1992) indicate that the human spine is managed best when it is in a neutral posture that preserves the wedge shaping of the discs and most vulnerable when in a flexed and passive posture. An attempt has been made in chair design to provide this neutral spine support without contribution of the paraspinal musculature. Little research has been conducted to evaluate the effectiveness of the chair in preserving this posture. A preliminary investigation by Bendix et al (1996) actually demonstrated evidence to the effect that anterior curvature in lumbar support leads to greater flexion in the lumbar spine. Unsupported sitting produced much more lordosis. Again a systems view must be considered. Bendix et al (1996) hypothesized that the increased lumbar kyphosis may have been caused by the tendency of the individual to push their back against the backrest to generate a better feeling of stability. They also notices that the buttocks slid forward which increases pelvic tilt and lumbar kyphosis.

There is clearly a paradox at work here. To protect the mechanics of the spine (and much of the rest of the body) higher energy outputs are required and the tissues involved in that activity must be conditioned to meet that demand.

LIMITS AND VARIATION

Stephen Jay Gould's book, Full House (1996) presents a well supported discussion of statistics with a particular focus on the limits and variation in systems. He speaks of left and right walls as absolute limits in biological systems with the right wall representing the highest achievement and the left, the lowest. There are a number of issues to consider with respect to human beings. One consideration should include a bell curve of humanity with respect to physical capacity, generally and on a system by system level. The left wall of this chart would be indicative of total loss of function and the right wall would be indicative of the fully developed limits of human capacity. It is my suspicion that as a group, humanity's "bell" (and median value) is sliding closer to the left wall all the time. If this were the case, external demands would

have to generate lower demands to place the same relative impact against individuals with higher capacity and higher demands. As evidence of this decline, a study has estimated that the average decrease in energy expenditure in the United Kingdom over the last twenty years has been 800 kcal per person (James, 1995). If this is accurate, people would have to walk for three hours a day to make up that difference! In recent testing of prospective applicants for a sanitation collection job, we found average Maximum Aerobic Power scores to average 31.0 ml/kg/min (Hart, 1996). Well below the demands of the job.

Of course there are certain individuals who occur further out on the tail of the curve toward the right wall. These individuals should have higher resistance to demands placed on them. In taking a systems view of that assertion, we must understand that all factors of the human being, physical and otherwise, must be functioning optimally with high capacity. An example of recreational triathletes who are employed as Paramedics is instructive. These individuals have very high aerobic metabolic fitness, but lower lean mass, strength and anaerobic development. They are also exposed to extremely high training volumes and are possibly in a state of overtraining for significant periods of time. These individuals have higher rates of musculoskeletal injury and lost time than many "overfat" members of the service (Personal Communication, 1995). The work requires high levels of immunity, high levels of strength and anaerobic power. These are all things that the triathletes are poorly developed for.

Work processes and fixtures that are designed closer to the right wall of human capacity stand a very good chance of generating dysfunction in larger proportions of the population. Just as fixtures that are designed for 95th percentile height will be difficult for most people to use. These walls exist for all the domains of human existence and care must be taken to try and optimize the marriage of task demands and human capacity.

MEASUREMENT

Measuring the "humanness" of either work or people is something that we have been doing in bits and pieces for several years. We need to create some relatively simple, but valid and effective means of assessing these issues so that we can reliably gauge the positions of both the humans and the work. Awareness of the full breadth of the human component in ergonomics has continued to climb for the last decade with the emphasis on more macroergonomic approaches discussed by Hendrick (1995). Nagamachi and Imada (1994) have demonstrated the powerful effects of a safety program that features high levels of attention being paid to what they call "humanware" in addition to software and hardware.

A measurement system should feature all five domains of being human and assess both the impact of the task and the impact of the human in sensing the degree of alignment that exists. This will allow for a differentiated approach to problem solving and identify responsibility. It must be based on the best principles known in each domain and not multifactorial outcomes like "comfort". An outline would appear like this:

Physical Domain

- Identification of risk postures created by human, created by work
- Overall activity and rest/variability of
- Understand capacities of human, demands of work, closeness of the two

Mental Domain

- Identify perceived challenge of the job activities
- Identify perceived support for different styles of learning

Spiritual Domain

- Identify sense of meaning in work tasks
- Identify personal meaningfulness

Socio-Emotional

- Assess inter-worker compatibility, opportunities for variation
- Assess individual connectedness

These are simple beginnings to understanding this multi-factorial concept of being human. Exploration of different ways of assessing these qualities should be undertaken to determine optimal application of the concept.

CONCLUSION

An increased emphasis on what it means to be human is required to improve the disintegrating relationship between current cultural behaviors, human evolutionary capacity and the work activities we are required to do. Recognizing the basic principles of human existence across all domains is a critical first step to achieving this improvement. This will involve more focus on underlying principles and the testing of their application than complex outcomes like comfort. It also means an admission that while a hammer is obviously designed to

hit things, the human structure is set to move. Movement must increase in society and for that to happen, energy expenditures must also rise as must the capacities of individual persons. Work should be designed to optimize its relationship with the evolutionary reality of humans and not with the current cultural bias of low energy, sedentary existence.

This is not something that can happen within work alone, although it is arguably the most powerful force for social change in Western Society. Public policy must also play a role by recognizing the value of reconnecting with the evolutionary realities of being human and encourage people accordingly. Ergonomics professionals will be in a position to lead this change or contribute to a worsening disparity between human cultural change and evolutionary reality.

Finally, ways of measuring this alignment must be explored and validated because, to paraphrase another, if it isn't getting measured, it certainly won't matter.

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