HUMAN FACTORS AND GLOBAL PROBLEMS: A SYSTEMS APPROACH

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Summary

The discipline of human factors has traditionally been concerned with a wide variety of problems that require knowledge of human capabilities and limitations. However, the knowledge base that has been developed by the discipline has rarely been applied to global problems that contemporary society is facing. Thanks to the work of Nickerson (1992) and Moray (1993, 1994), this is now beginning to change. These authors have convincingly argued that many global problems have a strong human component, and that therefore, the discipline of human factors has a unique (but certainly not privileged) role to play in the interdisciplinary effort that is required to deal with these challenging problems.

This article reviews some of this work, focusing on a systems approach to applying human factors to global problems. Two design principles, behavior-shaping constraints and salient immediate feedback, were proposed as powerful ways to induce people to change their behavior patterns in a functional direction, thereby contributing towards the solution of the pressing problems facing society. Several applications of these design principles were presented, not as final solutions, but rather as illustrations of the type of impact that human factors can have.

1. Introduction

Traditionally, the discipline known as human factors (or ergonomics) has been concerned with the design of devices and workplaces that take into account human capabilities and limitations. Human factors have been applied to a wide variety of problems, from the design of control rooms for nuclear power plants to the design of the Reach toothbrush. Based on the knowledge generated by the discipline, many textbooks and handbooks have been written over the years. However, if one examines the contents of these books, one will find very little that is directly relevant to the solution of global problems. Human factors have not traditionally been concerned with such issues, despite the fact that many global problems have an obvious human component to them.

Thanks to the seminal work of Nickerson (1992), and more recently Moray (1993, 1994), this is beginning to change. This chapter describes how the human factors principles being developed by these researchers can be adopted to make a unique and significant contribution to the solution of some of our most pressing global problems. A key idea which is beginning to emerge in this area is the notion of behavior-shaping constraints, which has its foundations in systems theory. This systems approach can lead to novel methods and ideas for addressing global problems from a human factors perspective.

The remainder of the chapter is organized as follows. First, a justification for why human factors can contribute to global problems will be provided. This is an important point to make since few people have made the connection between this discipline and these pressing challenges. Second, some of the key principles that have been derived from a systems approach to human factors will be described. These principles provide a source of insight that can be used to address a wide variety of problems. Third, several hypothetical examples showing how these principles can potentially be applied to global problems will be provided.

Much of the inspiration and conceptual content of this chapter is derived from the work of Nickerson (1992), and especially Moray (1993, 1994). The interested reader is referred to these works for a more detailed treatment of this topic. Also, see Norman (1988) for an easy to read and well illustrated treatment containing numerous examples based on similar design principles but in the context of more traditional application areas.

2. Why Can Human Factors Help Solve Global Problems?

The fact that human factors as a discipline has a unique role to play in addressing global problems has not occurred to most people, not even most human factors researchers and practitioners. Thus, it is important to explain this relationship clearly.

Moray (1994) has arguably been the one to make this point in the most direct and vigorous fashion in his keynote address to the International Ergonomics Association meeting: "the solutions to the problems of the 21st Century absolutely require the redesign of society to change human behaviour" (p. 4). Examples of such desired behaviour changes include: having less children, producing less waste, consuming less electricity and water, being more understanding of other cultures, recycling more frequently and efficiently, maintaining and making full use of the available arable land on earth, ceasing from polluting the environment, and designing safer technological systems that do not lead to ecological disasters. All of these problems have a human component to them.

Moray goes on to explain that traditional human factors can actually be viewed as the engineering discipline concerned with changing human behavior. Although this is an unorthodox description of human factors, it is a productive one to adopt since it makes the connection to global problems more obvious. Take a typical design problem that human factors engineers have been concerned with, such as designing a remote control for a programmable VCR. There is an obvious technological dimension to this problem, but the role of the human factors engineer is to design a remote control that will be easy to learn and use, thereby reducing the probability of errors. This is accomplished by manipulating certain features of the device (e.g., the size, position, and organization of the buttons; the wording of the labels; the logic of the programming sequence; the feedback provided by the VCR). By arranging these design features in a manner that is consistent with well established human factors principles, the engineer can induce desired functional behaviors, namely efficient and reliable use of the device. On the other hand, by arranging these designs features in a way that violates existing knowledge about human capabilities and limitations, the engineer can induce (probably unwittingly) dysfunctional behaviors, namely inefficient and error prone operation of the device. This example should make it clear that human factors are "in the business" of designing workplaces and devices to induce functional changes in human behavior.

From this perspective then, applying human factors to global problems is not such a foreign concept. The goal is still to change human behavior; the only thing that is really different is the nature of the problems, and thus, the type of behaviors that need to be induced. Rather than shaping interaction with a VCR remote control, human factors engineers can, and should, be concerned with shaping the interaction between humans and other humans and between humans and their environment.

This is not to say that human factors can lay a privileged claim to solving these challenging problems. Global problems cannot be solved by a single discipline. The important point, however, is that the discipline of human factors has a unique contribution to make since it is especially qualified to deal with the human dimension of these problems.

What can happen if the human factor is ignored? The answer is simple. If the desired behavior changes are effortful to make, people generally will not perform them. A simple case is that of recycling. Early efforts at recycling failed because they demanded more effort on the part of people than they were generally willing to expend. Thus, the desired change in behavior was achieved in the vast majority of the population. As Moray (1994) observes, "people are not very good, over the long term, in undertaking difficult, inconvenient and demanding patterns of behaviour on a voluntary basis" (p. 10). To create the conditions that are required to make desired behaviors natural and easy for people requires a great deal of knowledge about human capabilities and limitations. The next section describes some of the principles that have been developed in human factors to achieve this important goal.

3. A Systems Approach: Design Principles

How can functional behaviors be induced in people so that progress can be made on global problems? There are several obvious candidates, such as public information, education, and legal legislation. While all of these have their place, they all suffer from various disadvantages. Public information campaigns are frequently not heeded. Education is a very slow process and is probably only likely to succeed with younger generations who have not yet settled on dysfunctional patterns of behavior. Laws are difficult to pass because of special interest lobby groups, and even when they are passed, they may not be completely effective if they demand effortful behavior (e.g., seat belt laws in the 1970s when the designs were more cumbersome to use). Thus, it is important to search for alternative ways of changing people's behavior over the long term.

This section describes two important human factors design guidelines that can be used to elicit desired behaviors: behavior shaping constraints, and immediate, salient feedback.

3.1 Behavior Shaping Constraints

As mentioned earlier, a key idea that is beginning to emerge in applying human factors to global problems is that of behavior shaping constraints. This idea has its origin in systems theory. However, it also has ties to the concept of affordance, originally developed within the school of psychology known as ecological psychology but which is also recently beginning to exert an influence on the human factors community. An affordance is a possibility for action offered by an object, whether that action is functional or dysfunctional. For example, a chair affords sitting to an adult human, but perhaps not to a toddler. The concept of affordance is important because it is a way of discussing the properties of an object in terms that are relevant to human action. This derives from the fact that affordances are defined with respect to the action capabilities of a given actor. As the preceding example makes clear, a given object can have an affordance for one actor but not for another. Moreover, one object can, and usually does, have multiple affordances. For instance, a chair not only affords sitting to an adult but it can also afford throwing (if it is light enough) or burning (if it is made of wood and the actor has a match).

It is possible to restate the objective defined earlier in terms of the concept of affordances: the goal of human factors should be to design objects that have easy to perceive and easy to use functional affordances, but that do not have any dysfunctional affordances. The design of affordances is equivalent to the design of behavior-shaping constraints. We should be designing systems that will elicit the desired behaviors that will help ameliorate global problems, whether or not people voluntarily undertake those behaviors.

This may seem like a magical concept, but a few simple examples should suffice to illustrate its value and feasibility. At least one automobile manufacturer has designed its keys in such a way that it is essentially impossible to insert the key into the lock in the wrong direction by virtue of the fact that the key is symmetrical; as long as the key is aligned with the lock, it will go into the lock, regardless of whether it is "upright" or "upside down". In fact, these adjectives, which can be used to describe many keys that are not designed this way, are not meaningful for this design - there is no such thing as upside down. Thus, the key-lock system has an easy to perceive and easy to use, functional affordance. Or alternatively, it is designed to make it easy to do the right thing and very difficult to do the wrong thing. This is the fundamental idea behind the concept of behavior shaping constraints.

Another example can be used to illustrate the wide applicability of this design concept. Many computer notebooks have removable rechargeable batteries that are rectangular in shape. Because the shape of the battery is symmetrical about several axes, there may be several ways to insert it back into the computer. In contrast with the key example, symmetry is an undesirable feature in this case because there is only one orientation that will allow the battery to function properly once it is inserted into the computer. Thus, it may be easy to insert the battery in the wrong way. At least one computer manufacturer has addressed this problem by constructing the battery shape in such a way that it has several notches in it that deviate from what would otherwise be a symmetrical form. As a result of this design, the battery will only physically fit back in the computer in one orientation. As with the previous example, it is very difficult to do the wrong thing and very easy to do the right thing. Norman (1988) provides other examples illustrating this basic idea.

The two examples just describe shape behavior by physically constraining human behavior. However, it is possible to induce functional actions in another way, namely by making it easy to "do the right thing", despite the fact that dysfunctional actions are equally easy. A very good example of this type of behavior-shaping constraint is cited by Moray (1994). Apparently, in Australia some toilets are designed in such a way that they can be operated in two modes. In one mode, only half a tank of water is flushed, whereas in the other mode, a full tank of water is flushed. Each mode has a different handle associated with it, each with an appropriate iconic label. The handle with an icon that is only half-shaded operates the more economic mode, while the handle with the fully shaded icon operates the other mode. In this design, the user always has the choice of which handle to depress for any given usage. However, the design is structured in such a way as to encourage users to utilize the more economic mode after urinating and the "full tank" mode after defecating. The design is wonderfully simple, yet very compelling. It makes it very easy to "do the right thing", thereby representing a prototypical example of behavior-shaping constraints that do no violate free will. The following section will provide several examples illustrating how the idea of behavior-shaping constraints can be applied to ameliorate a global problem. First, however, another human factors design principle, which can be considered a special case of behavior-shaping constraint, will be described.

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Bibliography

Carr, C. (1993). The ingredients of good performance. *Training*, (August), 51-57. [Research indicating that the single most important factor in modifying performance in a company is to give each employee a way of developing a standard of their own.]

Flach, L., Hancock, P., Caird, J., & Vicente, K. (1995). *Global Perspectives on the Ecology of Human-machine Systems*, Vol. 1. Hillsdale, NJ: Erlbaum. [A theoretical introduction to the ecological approach to human factors.]

Fox, B. (1994). "Green" computer standards need monitoring. *New Scientist* **141**, 22. [A discussion of computer use and energy conservation.]

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston: Houghton-Mifflin. [One of the seminal references on ecological psychology, including a discussion of the concept of affordances.]

Grolier (1993). *Grolier Multimedia Encyclopedia*. New York: Grolier Electronics Publishing. [A computer-based encyclopedic reference.]

Guilfoyle, J. R. (1977). What design has done for the toothbrush. *Industrial Design*, (November/December), 34-38. [A description of the design rationale behind the Reach Toothbrush.]

Hancock, P., Flach, J., Caird, J., & Vicente, K. (1995). *Local Applications of the Ecological Approach to Human-machine Systems*, Vol. 2. Hillsdale, NJ: Erlbaum. [An empirical introduction to the ecological approach to human factors.]

Hung, S., Ng, S., So, J., & Woo, C. (1995). *The SMART Meter*. (Unpublished manuscript). Toronto: Department of Industrial Engineering, University of Toronto. [An example of how human factors might be applied to conserve home energy consumption.]

Kuk, D., Cowley, J., & Beserve, F. A. (1994). *Human Factors: Two Different Directions in Energy Conservation* (Unpublished manuscript). Toronto: Department of Industrial Engineering, University of Toronto. [An example of how human factors might be applied to conserve computer energy consumption.]

Light, V., Rajenthiram, U., & Schwartz, E. (1995). *Reducing Water Waste in Faucets* (Unpublished manuscript). Toronto: Department of Industrial Engineering, University of Toronto. [An example of how human factors might be applied to conserve home water consumption.]

Long, C., Ramsahai, D., Bhujwalla, Z., & Wright, J. (1994). *Redesigning Photocopiers to Reduce Paper Wastage* (Unpublished manuscript). Toronto: Department of Industrial Engineering, University of Toronto. [An example of how human factors might be applied to conserve paper consumption.]

Moray, N. (1993). Technosophy and humane factors. *Ergonomics in Design*, 33-39. [An introduction to how human factors can be applied to global problems.]

Moray, N. (1994). "Ergonomics and the Global Problems of the 21st Century," Keynote Address Presented at the 12th Triennial Congress of the International Ergonomics Association, Toronto, August, 1994. [A more detailed account of how human factors can be applied to global problems.]

Newsham, G. R., & Tiller, D. K. (1994). The energy consumption of desktop computers: Measurement and savings potential. *IEEE Transactions on Industry Applications* **30**, 1065-1072. [Energy consumption in computer usage.]

Nickerson, R. (1992). *Looking Ahead: Human Factors Challenges in a Changing World*. Hillsdale, NJ: Erlbaum. [The seminal reference on how human factors can be applied to global problems.]

Norman, D. A. (1988). *The Psychology of Everyday Things*. New York: Basic Books. [An introduction to some basic human factors design principles.]

Ontario Hydro (1993). *1993 Load Forecasts Report*. Toronto: Ontario Hydro, Load Forecasts Department. [Statistics on energy consumption in Ontario.]

Rasmussen, J., Pejtersen, A. M., & Goodstein, L. P. (1994). *Cognitive Systems Engineering*. New York: Wiley. [An advanced monograph on cognitive systems engineering.]

Shrubsole, D., & Tate, D. (1994). *Every Drop Counts*. Cambridge, Ontario: Canadian Water Resources

Association. [A discussion of water conservation issues.]

Ullman, E. (1994). Turn power users into power savers. *Datamation* **40**, 53-55. [Saving energy consumption in computer usage.]

Salvendy, G. (Ed) (1997). *Handbook of Human Factors and Ergonomics*. Hoboken NJ, Wiley. [An edited reference text for human factors engineering.]

Sheridan, T. B. (2002) Humans and Automation: System Design and Research issues. John Wiley & Sons, Hoboken NJ, 2002 [A very worthy book on human factors in systems design by one of the pioneers in the field.].

Van Cott, H. P., & Kincade, R. G. (1972). *Human engineering guide to equipment design, rev. ed*. Washington, DC: American Institutes for Research. [A reference text for human factors engineering.]

Vicente, K. J. (1992). Multilevel interfaces for power plant control rooms I: An integrative review. *Nuclear Safety* **33**, 381-397.[An example of how human factors engineering has been applied to safety-critical design problems.]

Vicente, K. J. (2004). *The Human Factor: Revolutionizing the Way People Live with Technology*, Routledge (Taylor and Francis), New York (2004).

Yates, S. M., & Aronson, E. (1983). Social psychological perspective on energy conservation in residential buildings. *American Psychologist* **38**, 435-444. [Motivational factors in energy conservation behaviors.]

Biographical Sketch

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