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HUMAN FACTORS IN BASIC RESEARCH AND R&D

THE HUMAN FACTORS OF QUALITY AND QA IN R&D ENVIRONMENTS

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ABSTRACT

Achieving quality is a human activity. It is therefore important to consider the human in the design, development and evaluation of work processes and environments in an effort to enhance human performance and minimize error. It is also important to allow for individual differences when considering human factors issues. Human Factors is the field of study which can provide information on integrating the human into the system. Human factors and quality are related for the customer of R&D work, R&D personnel who perform the work, and the quality professional who overviews the process of quality in the work.

INTRODUCTION

Achieving quality is a human activity. Regardless of whether "quality" is defined as "conformance to requirements" [1][1] or "user satisfaction" [2], there is at least one person involved. The person may be the producer of the product or the performer of the task, the person who maintains equipment, the end user or customer, or the individual responsible for assuring the quality of the product or process. Therefore, it is appropriate to discuss humans and quality and their interrelationship. The focus of this paper will be on considering humans and human factors in the "quality process."

WHAT IS HUMAN FACTORS?

What is Human Factors? At first, this question seems ungrammatical -- shouldn't the question be "what *are* Human Factors?" In this case, no. Human Factors is a discipline and field of study which is concerned with the human and with considering the capabilities and limitations of

[1]Numbers in brackets refer to similarly numbered references in bibliography at end of paper.

people in their interactions with equipment, environment and work processes. Several statements are presented to give a more complete idea of what Human Factors is:

- Human factors is "...the systems engineering and scientific discipline devoted to integrating people into systems. It has as its major objective the design and development of systems and system elements in terms of the capabilities and limitations of the personnel who will operate, maintain and manage the systems. ... [S]ystems personnel are to be considered as elements of the system to be integrated with other elements through the process of system design." [3]

- "Human factors is the discipline that tries to optimize the relationship between technology and the human." [4]

- "The central *focus* of human factors relates to the consideration of human beings in carrying out such functions as (1) the design and creation of man-made objects, products, equipment, facilities, and environments that people use; (2) the development of procedures for performing work and other human activities; (3) the provision of services to people; and (4) the evaluation of the things people use in terms of their suitability for people.

  The *objectives* of human factors in these functions are twofold, as follows: (1) to enhance the effectiveness and efficiency with which work and other human activities are carried out; and (2) to maintain and enhance certain desirable human values (e.g., health, safety, satisfaction). The second objective is essentially one of human welfare and well-being.

  The central approach of human factors is the systematic application of relevant information about human abilities, characteristics, behavior, and motivation in the execution of such functions." [5]

As can be seen, such phrases as *designing for human us*[illegible] *rgonomically designed*[2], and *optimizing people's working and living conditions* can give some [illegible]avor for what human factors is about.

It is important to understand that human factors encompasses a very broad area of study and application. It includes both *physical* and *mental* capabilities and limitations, and looks at the application of such information in areas such as personnel selection, training, design of equipment, procedures, work-rest cycles, and test and evaluation of equipment and processes. The fields to which such information has been applied are many. Military systems have traditionally been human factors engineered, but many other fields have made use of human factors as well. These include the fields of nuclear power, automotive engineering and manufacture, aerospace, computer hardware and software, and consumer products.

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[2] Ergonomics is "the study of man's behavior in relation to his work" as defined in [6]. The word "ergonomics" has been used primarily in Europe to mean, in essence, what "human factors" has been used for in the United States. Although some would argue that ergonomics is a subdiscipline of human factors, focusing on physical capabilities and limitations in industrial settings, many others would argue that both phrases describe the integration of humans in systems. In this paper, both human factors and ergonomics are used in the broadest sense and are considered to mean essentially the same thing.

KEY CONCEPTS

Several important concepts may be of particular interest in this discussion. These are the concepts of human performance, human error, and individual differences.

Human Performance

Most human factors information results from a study of *human performance*. What do people do and how do they behave in a given situation or environment? Human performance can be thought of in terms of the performance measurements used, such as time to complete a task and accuracy of the performance. Such performance measures can provide information on how "well" people performed, but they may not give information on "how" people performed and the process used in accomplishing a task. In this case, a model of human performance may be useful in thinking about how people accomplish tasks. One such model of human performance is the "input-action" model, illustrated in Figure 1 [7]. In this model, human performance is made up of five sequential steps: input detection, input understanding, action selection, action planning, and action execution. Such a model of human performance can be (and has been[3]) used in the investigation of accidents to get at causative issues involving humans.

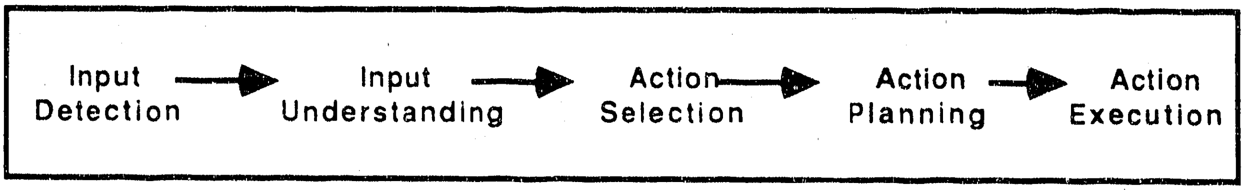

Figure 1. The input-action model.

Human Error

A related topic to human performance is that of *human error*. It is not uncommon to hear that accidents, such as airplane accidents reported in the news, are a result of "human error." Often, however, this statement of cause is too simplistic and the human factors researcher investigates much further. When considering the role of the human in accidents, it is important to distinguish between active errors and latent (or passive) errors [8]. Active errors are those that are associated directly with operators of complex systems and the effects of which are felt almost immediately. Latent errors, on the other hand, are those that are removed in time and space from the direct operation, and are errors in design, construction, installation, planning or maintenance. These create a latent condition, or "resident pathogen" within the system [9]. The important distinction is that latent errors, in some sense, are accidents waiting to happen, while active errors are those operators commit and have immediate effects.

Active errors can be further classified as errors of omission, where a task or part of a task is not performed (i.e., something is left out), and errors of commission, where a task is performed

[3]J.L. Harbour and O.R. Meyer, personal communication, March, 1990.

incorrectly [10]. Errors of commission can include:

a. extraneous acts -- a task that should not have been performed.
b. sequential errors -- a task performed out of sequence.
c. time errors -- a task performed too early, too late, or not within the time allowed.

People make errors, no matter how the errors are classified. One objective of the application of human factors information is to minimize the number as well as the impact of possible human errors. From the human factors perspective, the goal is to identify where errors might be committed by people and design to obviate the chance of error, or plan defenses so that a single error will not have catastrophic consequences. There are also methods available to quantify the probability of human error (i.e., human reliability analysis).

Individual Differences

Another important concept is that of *individual differences*. Basically, the phrase "individual differences" suggests that individual people are different from one another. They come in all different sizes, shapes, abilities, ways of thinking, etc. Sometimes it is useful to characterize many individuals into a group that all share something in common, for example, age or education. Some groups have different characteristics, capabilities, and limitations as illustrated by the different capabilities among the elderly, middle-aged individuals and infants. Therefore it is important to understand who is the group of interest and the special characteristics of that group. However, the differences among individuals can not be forgotten. People have different ways of behaving. These may be based on training, education, experience or on different ways of thinking. From the human factors perspective, individual differences cannot be ignored, but rather they should be acknowledged and planned for.

Upon occasion, reference is made to the "normal" or "average" person. In many respects, the concept of an "average person" is fallacious [11]. If, for example, one used the average height of the U.S. population to determine required doorway clearance, then, by definition, half of the population would be unable to fit through the door without stooping. Similarly, if instructions are written for the average intelligence, then the instructions will be too difficult for half of the people and too simplistic for the other half.

A more useful approach is to design for or target a range of people. For example, design a range of operation sufficiently large to accommodate 95% of the defined user group . Understand that people are different in many ways and allow for some of those differences. It is usually more productive to try to *fit the task to the human* rather than trying to fit the human to the task.

THEORETICAL AND EMPIRICAL BASES FOR HUMAN FACTORS PRINCIPLES AND STANDARDS

So far in this paper, the field of human factors has been presented and three key concepts have been described. The value of human factors is not only in the perspective of considering the human in any activity, but also in the human factors principles and standards which exist and can be used in design, development and evaluation of environments, processes, hardware and software. The information and principles presented in human factors guidelines and standards are not just numbers "pulled from a hat," but, in general, are theoretically and/or empirically based. Not everything is known, and researchers continue to add data to the human factors knowledge base.

However, the discipline of human factors uses scientific methodology to form, test and evaluate hypotheses about human performance, human error, and individual differences. It is upon such scientifically conducted research that many human factors principles and guidance are based. Some examples of well-known human factors guidelines are:

Human Engineering Guide to Equipment Design [12]

Human Factors Design Handbook [13]

Human Engineering Design Criteria for Military Systems, Equipment and Facilities [14].

The application of human factors is not just "common sense." Human factors relies on a large background of solid research data and experience.

EXAMPLES OF HUMAN FACTORS APPLICATIONS

There are many areas where human factors principles have been applied, and many areas where human factors deficiencies have been found as well. A few brief descriptions of applications and deficiencies will illustrate how humans have or have not been considered in systems.

Video Display Terminals

The widespread use of computer terminals and personal computers (generically called video display terminals or VDTs) has introduced new problems in the workplace [15]. Often VDTs are placed on a desk top, although this may place the monitor and keyboard too high for an appropriate working posture. People who wear glasses, particularly bifocals, may have difficulty seeing the screen well. Bifocal wearers may be forced to tilt their heads backwards in order to see through the reading part of the glasses, causing neck and shoulder muscular discomfort. Glare on the screen may also be a problem when VDTs are placed without thought as to the relative locations of the VDT and light sources. There are ways to avoid some of these problems with known human factors principles.

Nuclear Control Rooms

Much has been written about human factors deficiencies found in nuclear control rooms. Some operator tasks are made more difficult by inadequate equipment design. Some of these tasks are: reading indications, reaching controls, transforming information, activating controls, interpreting coding, locating individual displays and controls, and responding to alarms [16].

An example of a human factors problem in activating controls is the violation of operator expectations. People expect, based on past experience, to have certain control movements result in certain actions. For example, most Americans expect flipping a switch *upwards* will result in turning the equipment "on". If controls are designed which do not conform to operator expectations, errors may be made, particularly in emergency conditions when stress is high. (Such an error may be considered a latent error because the inadequacy was designed into the system.)

In fact, operators have taken matters into their own hands in some instances such as using draft beer handle tops to differentiate among three control levers which otherwise looked identical although they controlled three different pieces of equipment.

Consumer Products

Some consumer products have been designed with the human specifically in mind. For example, the design of telephones has been greatly influenced by human factors research. Research has been done on how best to lay out the telephone push button pad and the size, weight, weight distribution and "cradle-ability" (i.e., holding the handpiece between the chin and shoulder) of the telephone handpiece. Some toothbrushes have been designed using research on the most appropriate size and shape of the handle, the angle of the brush in relationship to the handle and the size and shape of the brush head.

On the other hand, there are many stories and personal experiences relating the difficulties of setting alarms on clock radios, programming video cassette recorders (VCRs) or operating copy machines. With research on how people use such devices, what design features make them easy or difficult to use and clearer, more understandable instructions, the difficulty in use need not exist.

HUMAN FACTORS, QUALITY, AND QUALITY ASSURANCE

Now we should turn to how human factors affects quality and what role it plays in quality assurance. Obviously, humans are an integral part of achieving quality and assuring quality in their tasks. Therefore, human factors principles and information can be useful in enhancing human performance and minimizing the potential consequences of human error. The objective is to use processes, hardware, software, procedures, etc. that have been designed by taking into consideration human capabilities and limitations and knowledge of how humans behave.

Human Factors and Quality: Users/Customers

The user or customer of the output is expecting to be satisfied. A necessary condition is to define who your target audience is and identify all the relevant characteristics of the audience. Using those characteristics in the design, development and evaluation of the output will aid in satisfying the customer. The characteristics of the audience will include both who they are (e.g., physical attributes, education, experience), but also how they will be using the output and under what conditions. As the customer perceives that the output was produced for them, that it is a little easier to understand and use, that less errors are made, it takes less time to use, the user's memory isn't taxed during use, it is adaptable for both naive and experienced users, etc., the customer will perceive a "quality" product.

That extra something that differentiates one product from another can be the result of considering the human user and implementing human factors principles and information.

Human Factors and Quality: R&D Personnel

People will not produce their best work in environments where they develop headaches and sore necks when using a computer terminal, where procedures are ambiguous and hard to follow, where needed information is not readily available. By considering what people need to do and how they accomplish it, performance can be enhanced and the opportunities for error minimized. By thinking ahead, the consequences of error can be identified and planned for. It is equally important to allow for individual differences. Not all individuals approach work in the same way. Some take advantage of automated tools (e.g., electronic calendars), others prefer paper and pencil. By providing processes and environments in which peoples' preferences, capabilities and limitations are considered, and allowance made for individual differences, performance can be enhanced and errors minimized.

Human Factors and Quality: Quality Professionals

Quality professionals have the task of overviewing the line responsibility of quality. A part of quality assurance can be enhanced by seeking to identify and eliminate both latent errors and active errors in the work processes and environments.

There is human factors information available on such topics as inspection (see, for example, *Human Factors in Quality Assurance* [17]). There is also information on writing procedures [18]. A wealth of information exists that can be tapped in the effort to provide working processes and environments that will enhance human performance and minimize errors. Rather than constantly rework errors that are found, or disagree with individuals on how particular processes should be accomplished, upfront consideration of how humans behave can have impact in the effectiveness and efficiency with which work is carried out and, at the same time, promote the personal satisfaction and well-being of people.

HUMAN FACTORS IN R&D ENVIRONMENTS

It is easy to think about the role of human factors in process control operations and maintenance, in aircraft cockpit design, in manufacturing systems. However, the role of human factors is equally important in research and development environments. People are performing tasks in physical environments. Certainly some of the human factors concerns in the physical environment are straightforward:

Is there sufficient light and illumination for the required task?
Is there too much glare?
Is the noise level acceptable?
Is the thermal environment comfortable?
Is there adequate ventilation?
Is there enough space to carry out required activities?
Are workstations (e.g., desks, chairs, computer workstations) adjustable for the individuals?
Does anyone develop eye strain, headaches, or musculoskeletal discomfort or injury because of working posture or equipment (e.g., VDTs)?
Is computer software well-designed for the human?

There are human factors concerns in other areas, too. Many of these concerns are in the work process:

Are procedures unambiguous and understandable?
Are forms designed for the people who fill them out?
Are individual differences considered in work environment and process?
Is required information conveyed in a timely and understandable manner?
Do organizational requirements facilitate or restrict communication?
Is research facilitated by considering the human in research libraries (e.g., using automated card catalogs)?

People who work in research and development are subject to the same issues of human performance, human error and individual differences as people who work in manufacturing, military, or process control environments. The tasks and tools used may be different; some group characteristics such as education and experience may be different; but it is still important that human needs and characteristics be considered in designing and performing work requirements and processes.

CONCLUSION

Achieving quality is a human activity. It is important and worthwhile to consider humans in the design of research and development environments as well as in the design of quality assurance processes. Effectiveness and efficiency, as well as personal well-being, can be enhanced. The field of human factors can provide information on ways to study human performance to get at issues which may affect human performance and the probability of human error, while allowing for individual differences. Applying human factors principles will not solve all problems nor assure quality. However, it is believed that not considering human factors will make the achievement of quality more difficult. Humans have special and unique characteristics which make them different from machines. Those special and unique characteristics should be taken advantage of in accomplishing work and achieving quality.

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