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Human Factors / Ergonomics: Some Basic Concepts

by
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This paper on Human Factors is written as a survey paper to introduce some of the basic concepts of human factors, to provide a better understanding of the role human factors plays in safe equipment design, and to highlight how human safety performance is in part based on human factors theories and mechanisms.

What is Human Factors? Human Factors Engineering?
The WEB site (www.hfes.org) of the Human Factor's and Ergonomics Society (HFES) describes Human Factors/ Ergonomics in their introductory text as the study of:
"…human cognitive and physical capabilities and then applying the knowledge gained from that research to systems, tools, products, and environments"
to…" *help to ensure that people's interactions with technology will be productive, comfortable, and effective.*

One of the key basis human factors publications "Human Factors Design Handbook," by W. Woodson (1992) describes the area as:
".. the intent of human factors engineering on the whole is to focus on and resolve human-product interface problems and solutions wherever or whatever they are. Philosophically then, human factors engineering looks at a design from the standpoint of user efficiency, or total human-product effectiveness."

What is the difference between Human Factors and Ergonomics?
In a general sense, there is no meaningful difference between the two terms, other than in their origins and academic usages (and therefore we will use the term "human factors" to refer to both terms in the balance of this article).

The term Ergonomics has its origins in Europe, whereas the term Human Factors was more commonly used in the Americas. In the early years of the development of this area, there was some separation of the two terms, mostly in the context of professional societies and journal terminology; but in the last two decades the terms have been used interchangeable and the primary professional association (HFES) has incorporated both terms in their name. In some academic circles, the term ergonomics may have a greater association with industrial situations, but has been broadened to include "consumer products, the home, road traffic and safety."[1]

While these two terms have merged together, there is some natural division between 1) the terms and measurements associated with humans, and 2) the cognitive actions of people in negotiating their environment.

Human Dimensions vs. Cognitive Actions, Are They a Part of Human Factors?
Some of the early and basic concerns of human factors addressed the size, magnitude, and physical dimensions of humans, and their needs; not the cognitive basis for human actions.

In the Eastman Kodak publication from the early 1980's "Ergonomic Design for People at Work", an emphasis is placed on the physical parameters of humans in terms of *".. striving to assemble information on people's capacities and capabilities for use in designing jobs, products, workplaces and equipment."*[2]

Publications like "Humanscale"[3] and the extensive U.S. government's library of measurements of military and service personnel support the importance and continued utility of knowing how big, small we are; how flexible and strong we are; and how our environment needs to be dimensioned for safety and efficiency reasons. This collection of information is often referred to as anthropometry and is the basis for the size of buttons to the height of handrails.

Such dimensional information may be useful when performing such tasks as designing a seatbelt to accommodate both the 5%tile and 95 %tile height of car users. (Note: In this context, 5%tile represents a size where only 5% of the population is smaller; 95%tile represents a size where 5% are larger). Numerous other data sets contain 5 and 95%tile data for a broad range of humans. Hand dimensions, for example, are the basis of determining the opening sizes allowed in OSHA approved guards.

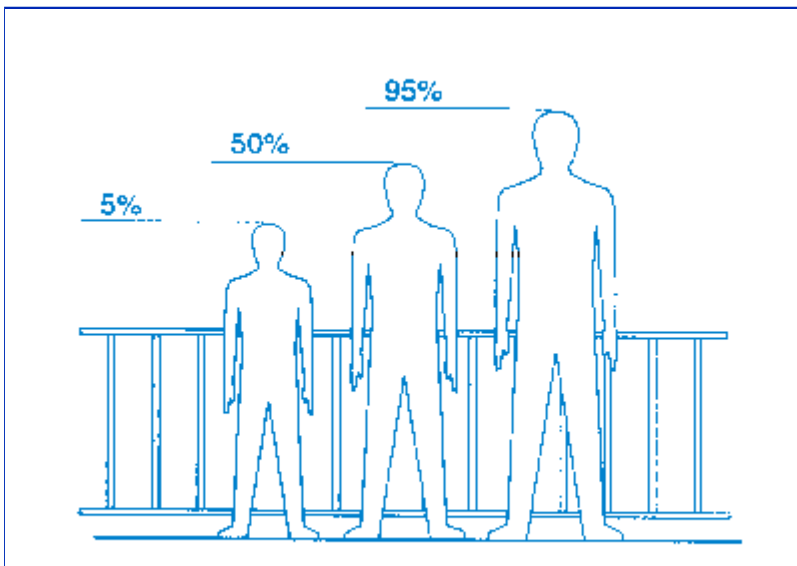

Fig. 1 "Standard" height railing may not be the best height for different height people.

These dimensional considerations mean it is important to remember that a railing that is too low and not in compliance a railing that is too low and not in compliance with an OSHA rail code, may be the perfect height for a person of short stature.

"Cognitive Action" concepts in human factors most often refer to the mental/ logic nature of humans; that is not just how well we see, but how well we can detect a target by vision; not just are warning on the equipment, but how we understand the meaning of the warning; not that we simply made a safety decision but was it the appropriate decisions. Wickens, in the second edition of "Engineering Psychology and Human Performance"[5], dedicates twelve chapters to cognitive aspects of human factors; including issues ranging from perception to human errors. Mark Sanders, et. al., merges both the dimensional and cognitive in “Human Factors in Engineering Design,”[6] with chapters on human error, accidents, and safety.

In many ways these “cognitive actions” and their impact on both worker and user safety are the more interesting issues in human factors from a safety perspective. With the increased dependence on OSHA “procedural” safety criteria[7], an appreciation of these cognitive human factors considerations is more important for equipment designers, providers, and are appearing in various code text.

The recent edition of the National Fire Protection Agency (NFPA), for example, provides criteria in NFPA 79, “Electrical Standard for Industrial Machinery” on several human factors issues of perception, mental modeling, consistency, and compatibility. Paragraphs; 3.50) defines “insight” distances; 3.74) a “safe working procedure”; 4.3.3) the need for “block diagrams” to facilitate the mental understanding of the equipment; and 7.8) the consistent location “mounting” of disconnecting means. In several recent machine accidents, the lack of a consistent human factors approach for electrical disconnects, resulted in workers relying on emergency stop controls for lockout and tag out safety.

Exemplar Human Factors Concepts based on Cognitive Skills

A) Avoidance Behavior

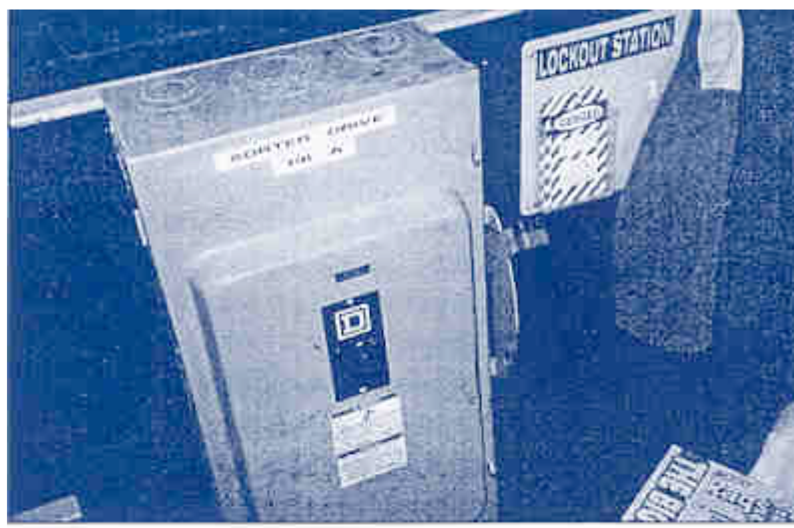

Fig. 2: Lumber mill conveyor lockout/tagout with tags available.

A significant percentage of equipment users will “learn” to avoid hazards that they can appreciate. This “learning” can be in the form of “instructional training”, and/ or “experience (hands on) training”. Some tasks can be only taught through an introductory training effort, while other activities require hours of experienced-based training. The necessary avoidance behavior to safely operate a car cannot be fully taught in a instructional classroom, and requires the actual behind the wheel experience training. Both learning processes take time, and are key components in preventing injuries to workers who are new on the job. It is reasonable to expect workers to avoid dangers if they have the incumbent training and experience with the specific hazard, and OSHA’s “General Duty Clause” requires employees to follow their safety training and recognized avoid hazards. Hahn[8] conceptualizes this “avoidance of hazards” behavior in terms of an “avoidance gradient” where the avoidance behavior changes as one approaches a negative goal. Just as a college student may work harder in the last days of a semester in an attempt to prevent a poor grade; workers tend to put more attention assets into recovering from a bad situation, as that situation continues to deteriorate.

B) Compatibility/ Incompatibility.

Sanders[9] defines "compatibility" in terms of human expectations; humans have certain expectations, and when processes and/ or equipment does not follow these expectations, an incompatibility problem may manifest itself in an error or accident. He simply states …"people like things that work the way they expect them to." When electrical plugs and receptacles do not match because of a 3 prong configuration, or flared prong, there is an incompatibility problem. Sometimes "incompatibilities" are resolved by unsafe behaviors, like the removal of a grounding prong. The lack of a convenient lockout and tagout (LOTO) location on a large machine; may result in an incompatibility problem and alternatives to LOTO may tend to be employed. Incompatibility can cause accident causing behaviors; designs incorporating compatibility can result in fewer errors.

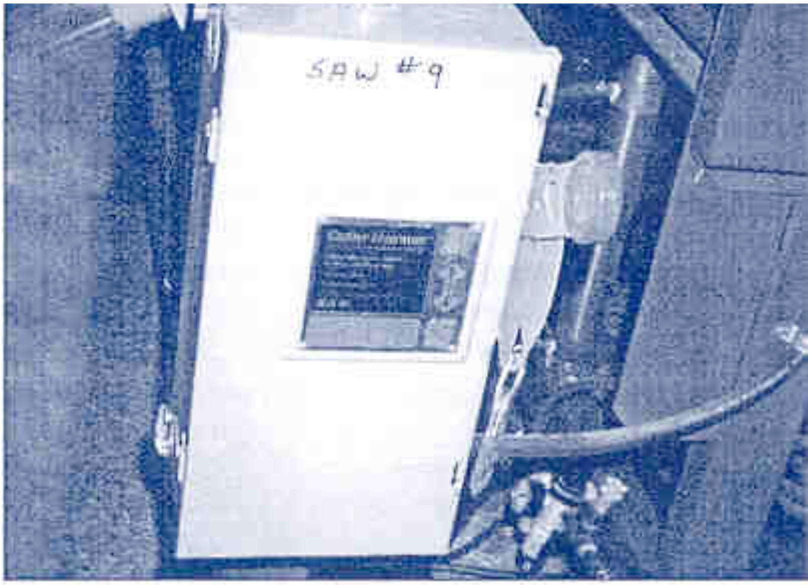

Fig. 3: Traditional lockout/tagout box with lever and hasp for lock (used on industrial saw).

C) Consistency/ Inconsistency
Consistency is a sub-element in user expectations. Even if a design does not always match user expectations (see below), the repeated exposure to a particular consistent configuration offers some safety characteristics. Hence e-stops which are colored coded "red." Mixtures among safety configurations/ hardware can result in some additional accident scenarios. SAFE JOURNAL In a family with a mixed fleet of cars, there is the common problem of inconsistency in control location, horn actuation points, and brake responses. In an industrial setting, there are possibilities of hazards not being consistently protected by interlocks or other safeguarding methods. A fleet of different machines each with different codes requirements about interlocks could set up a condition where workers become habituated to relying on interlocks; then encounter a noninterlocked hazard and become injured. One might question if, for consistency reasons, ground fault circuit interrupters (GFCI) should be used in bathroom wall outlets; or rather on electrical appliances used in bathrooms.

D) Decision Making
Equipment and product designs should facilitate good/ safe "decision making" by users and consumers. Appropriate safety decision making can be affected by time delays, distractions, or the misunderstanding of displayed information. Several codes and guidelines for safe design of equipment focus on providing means and facilities for good

decision making for operators. For example, designs that provide timely and meaningful information can prevent accidents. In a recent accident investigation, the operator of an asphalt plant needed to remember the size of the discharged load because it was only temporarily displayed at the control panel. A truck driver would position his vehicle under the discharge silo and if the operator forgot the size of the load, and the equipment could not re-display the load size, an overloading accident was inevitable.

Fig. 4: Lockout/tagout supplies.

E) Expectations (Reasonable & Unreasonable)

If people had to evaluate each and every action they took, we would become mired down in evaluating every situation. Therefore, people have developed sets of experiences (sometimes referred to as schemas) which allow them to generalize when confronted with a situation. This generalization results in certain expectations. Increased experience typically results in our ability for more and better generalizations. Experiencing unusual conditions can result in more complicated, and perhaps better defined generalizations. Examples: If we encounter a large diameter rope, we expect that it will be stronger than a thinner rope. A knot is a rope is not necessarily perceived as significantly decreasing the strength of a rope. Users of rope need to know that the diameter of rope is not the determining factor in its strength; hence labeling of rope with tensile strength information is important. A single knot in a rope can have as much as a % reduction in rope strength.

F) Mental Models[10]

While expectations may be generalized appreciations of how things work; mental models are a person's concept of how a specific mechanism operates. In a recent dual carbon monoxide death; it appeared that the users may have had a mental model that the tent they were to sleep in was breathable; and hence any carbon monoxide produced inside the tent from a propane heater would be diluted and made safe by air infiltrating through the tent's walls. Mental models can be reinforced or altered based on experiences. A possible basis for such a notion of a breathable tent would be the thinness of the tent skin material, the easy with which exterior odors could penetrate into the tent, or the way sounds could permeate the skin of the tent. A mental model by the decedents as to the extent a tent's skin

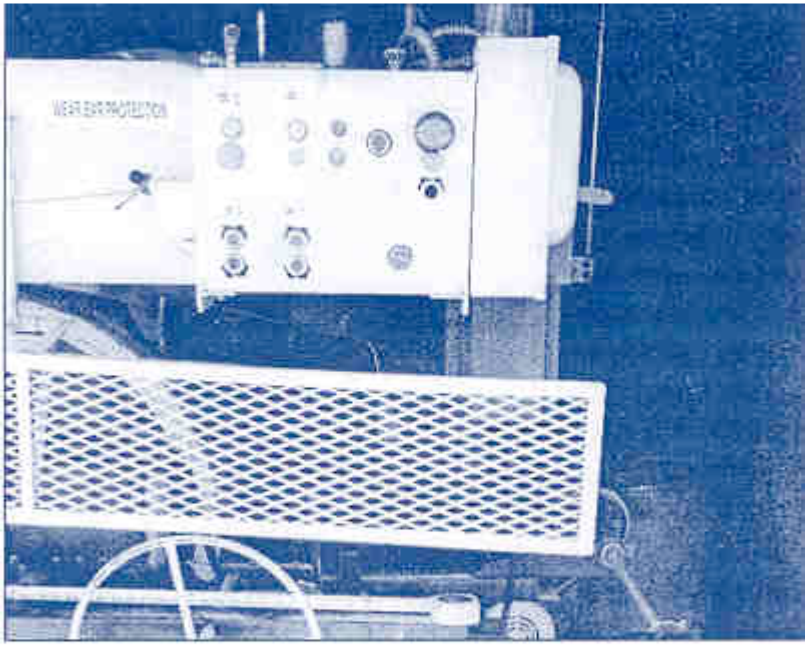

Fig. 5: Lockout/tagout adjacent to controls on large industrial saw.

acted as a barrier may have been a significant explanation as to why they might consider a tent a "well ventilated" location. Terms like "meaningfulness" and "reinforcing" are used to describe how mental models may be supported or altered. Previous uses of the heater in a tent without consequences may have "reinforced" its use even though there was a written prohibition against such a use.

G) Recognition

Our ability to recognize certain features or conditions can enhance or detract from safety. A hidden sharp edge on a metal stamping may cause serious hand cuts because they are not easy to detect or even felt at the initial point of engagement. Having been exposed to "near" accidents can allow some individuals to better recognize hazards that more naive users might not appreciate. In situations where users may not "recognize" a particular hazard, signage and/ or alarm mechanisms , for example, may provide added help. Signage and/ or alarms also play a role in "reminding" users of already known hazards and/ or to changing conditions. Warnings signs may be less useful if the exposed individual already knew of the hazards; but the sign could be useful in a redundant fashion as a last effort to remind a potentially exposed individual of a hazard they may already recognize. Alarms can fool workers if their detection is confusing in noisy environments. Recognition influencing factors include: distractions, camouflage, haste, emergency conditions, and fatigue.

CLOSURE

Our physical capabilities and geometry influence our personal safety status. There is significant body of research into cognitive actions, such as how we engage hazards based on our perceptions, experiences, evaluations, and expectations. An improper matching of these cognitive actions can cause, be neutral to, or preventative towards safety. In addition to dimensional human factors issues, designers and those responsible for equipment safety need an appreciation of both the dimensional and cognitive aspects of human factors.

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