SAFETY RESEARCH IN THE 20TH CENTURY – HAVE WE MADE A DIFFERENCE?

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INTRODUCTION

Marc L. Resnick, Ph.D.

Safety has been recognized officially as an important concern for over 100 years. The Railway Safety Act was enacted in the US in 1893. In 1908, U.S. Steel began a corporate safety program (Hammer, 1989). In order to satisfy the safety needs of both the industrial worker and the public, researchers have evaluated and investigated the principles of safety. Many publications have suggested that safety can be improved by applying a particular method or design.

However, there has been some question as to whether many of the results of safety research are applicable in applied settings. Post-modernist thinking suggests that research must be conducted in the particular environment of its intended application to be appropriate. This "systems approach" has long been recognized in the Human Factors profession (Meister, 1988) in general, but not always applied in practice. A discussion among safety professionals at the 1998 Safety Technical Group Business Meeting questioned whether safety research has provided much of use to the design community. For example, studies have reported that ANSI Z535.3 standard warning icons are often not well understood by users (Deppa and Martin, 1997; Martin and Deppa, 1997). This is not a new debate in Human Factors (Boff, 1988; Rouse, 1987) but is critical as we set a research agenda for the new millennium.

This panel addresses the progress of safety research over the past one hundred years. Panelists present their views on the applicability of safety research in several application areas, including safety warnings, consumer products, industrial workplaces, and automotive systems. Panelists represent academia, government and consulting. Particular attention is placed on the applicability of existing research in practice.

HAZARD COMMUNICATIONS: WARNINGS RESEARCH, APPLICATION, AND EVALUATION

Curt C. Braun, Ph.D.

Although the volume of warnings research continues to grow, many questions still remain concerning their effectiveness. Research findings, injury data, and litigation all paint different pictures of how warnings impact behavior. In many instances, it is impossible to reconcile information from these sources. To advance warnings research, application, and effectiveness, the research community needs to develop methods for determining injury incident rates rather than frequencies; translate research findings into guidelines and standards that are usable by the designers of warnings; and employ large-scale evaluation efforts similar to clinical trials used to evaluate drug interventions.

The academic community has made considerable progress toward understanding hazard communication and behavioral compliance. Empirical findings and the development of hazard communication models such as the Communication-Human Information Processing (C-HIP) model have created a foundation for future research. Despite a growing body of literature, there is a common perception that warnings play only a small role in injury prevention. Mounting injury prevalence data and litigation tend to support this conclusion. Unfortunately, neither source of information is appropriate to determine warning effectiveness. Three areas of research and application must develop before warning effectiveness can be assessed confidently.

Prevention of personal injury and property damage are fundamental goals of warnings. The measurement of prevention, however, can be difficult. Although prevalence data have motivated research, the utility of these data with respect to warning effectiveness is limited by the absence of exposure data. Without knowing the extent to which individuals are exposed to hazards, it is impossible to determine how warnings impact prevention. To advance our understanding, warnings researchers must develop and validate methods for determining incident rates that consider both the frequency of incidents and the level of exposure.

A second area of development centers on the translation of research findings into warning design tools. The academic community has identified a variety of factors that affect the behavior of research participants. The mechanism for translating research findings into directions for the design of warnings requires further development. The academic community must build on existing interactions with standards organizations (e.g., American National Standards Institute) by establishing an understanding of the individuals tasked with the design of warnings.

Finally, the traditions of academic research must be expanded to encompass larger research populations. Similar to clinical trials used for drug testing, researchers must be able to demonstrate that warnings have the intended effect within the population at risk. Larger samples of individuals who use products or participate in hazardous activities will provide researchers with the opportunities to examine further: a) characteristics of individuals who comply with warnings; b) the circumstances surrounding unintentional injuries or property damage; c) hazardous aspects of the product or activity; and d) the impact of warnings on the prevention of injuries and property damage.

SAFETY NEEDS OF PUBLIC SERVANTS ARE NOT RESEARCHED DUE TO COMMUNICATION GAPS

Shelley Waters Deppa, CHFP

From the perspective of my public servant roles for twenty years, safety research has been lacking. These roles included working both for a federal regulatory agency and on voluntary standards committees. The U.S. Consumer Product Safety Commission develops product safety standards or requires product recalls after analyzing incident data and evaluating product designs and warnings. The ANSI Z535 Committee on Safety Signs and Colors develops formats for warning labels and standardized safety symbols. Since the scopes of both organizations cut across product types, manufacturing trade associations generally do not sponsor non-product-specific research. Thus, public servants must depend primarily on safety research being performed by universities.

The public servant perspective is that professors and students scramble for research topics for masters and doctoral theses, often not knowing actual safety research needs. This might explain why HFES publications often contain academic research only remotely related to actual needs, which unfortunately affects not only public servants, who cannot use the research, but also students, whose research is not applied.

Attempts to make public safety research needs known have included raising the issue at HFES-sponsored focus groups and HFES Technical Group meetings, publishing research needs in the HFES Proceedings, and informally approaching professors at HFES Annual Meetings. Only the latter approach has been successful. In 1995, safety symbols needed to be comprehension tested for revising an ANSI Z535 standard. As a Subcommittee Chairman, I sought and identified a "publish or perish" professor, and together we developed a work program mutually beneficial to the voluntary standard and to his students. Since the results were published in the voluntary standard, the students saw their work applied.

A formalized communication system is needed where public servants can publicize their safety research needs and professors and students know where to look to obtain needed research topics. Such a system would be mutually beneficial to public servants and students. An organization is needed to set up, maintain, and publicize such a system. The HFES headquarters staff or Technical Groups are likely candidates for performing this work and locating the information exchange in their web pages or newsletters.

PROBLEMS AND PROGRESS IN EVALUATING THE EFFECTIVENESS OF OCCUPATIONAL INJURY INTERVENTIONS

Brenda L. Greene, MMSc., PT, OCS
David M. DeJoy, PhD

In spite of recent interest and support for intervention effectiveness research within the occupational safety and health research community, convincing demonstrations of effective injury prevention interventions remain difficult to achieve. Several recent reviews have discussed the complexities of evaluating occupational safety interventions (e.g., Goldenhar & Schulte, 1994; Shannon, Robson, & Guastello, 1998; Zwerling, Daltroy, Fine, Johnston, Melius, & Silverstein, 1997). For evaluation studies to have both scientific and practical significance, several standards must be met. First, studies need to be internally valid; that is, it must be possible to convincingly link outcomes to interventions. Randomized controlled trials (experimental designs) provide the best evidence of intervention effectiveness, but even good quasi-experimental studies are difficult to implement in workplace settings. Other methodological issues involving unit of analysis, statistical power, treatment/control contamination, and follow-up duration also plague intervention research in this area. Second, external validity considerations often limit the usefulness or generalizability of intervention results. Shannon and colleagues (1998) highlight three problems in particular: 1) the need to clearly specify and describe the subject population, 2) the need to carefully describe the intervention and how it was implemented, and 3) the need to present sufficient detail about the work context or climate that formed the backdrop for the study.

A third factor involves the need to provide data on financial outcomes, including cost effectiveness (CDC, 1992). Fourth, there is a need to carefully select and use relevant and standardized outcome measures, and to specify and justify surrogate and precursor measures. Limitations on the dependent variable side often hamper the comparability of findings from occupational safety studies. Fifth, occupational safety studies often fail to include a process evaluation component. Process evaluation essentially examines how the intervention or program was implemented, and such data can be invaluable in understanding what went "right" or "wrong" with the intervention.

Intervention research on work-related upper extremity and neck disorders provides a good demonstration of many of the above difficulties (Kilbom, 1988; Westgaard & Winkel, 1997). Intervention studies in this area can be conveniently grouped into four categories: 1) participatory ergonomics, 2) task/work redesign, 3) individual or worker-focused interventions, and 4) multi-component interventions (e.g., training and participatory ergonomics). A preponderance of studies has consisted of descriptive and non-experimental designs. Sample selection, follow-up periods, and dependent measures have all varied widely, and the lack of procedural and other details often makes it difficult to compare or generalize results. Using participatory ergonomic studies as a case in point, interventions suggest some effectiveness in decreasing risk factor exposure and creating a productive team process. However, the definition of what qualifies as a participatory ergonomic intervention differs from one study to the next, and the statistical rarity of actual injury outcomes in any given work setting often necessitates the use of precursor or surrogate measures. Some of these measures are more directly linked to injury outcomes than are others. The task/work redesign studies are a little more complete in the description of the intervention, but still lack detail about the work climate and the process by which intervention strategies

were developed. The majority of these studies had a follow-up period of one week or less which is clearly not enough time to assess effectiveness. The individual or worker-focused intervention studies lack detail about the intervention making replication difficult. The presence of few and dissimilar studies limits the conclusions about the effectiveness of worker-focused interventions.

At this time, intervention effectiveness research on upper extremity injuries is mostly preliminary and descriptive, but this body of work does suggest several possible directions for larger-scale and more definitive research. One promising area involves interventions that combine participatory and engineering/redesign efforts. A second area involves interventions that are more theory-based and more closely linked to identified injury mechanisms. And third, research might benefit from a more ecological or systems focus that would acknowledge interactive links between worker, task, organizational, and extra-organizational influences.

THE PROGRESS OF OCCUPATIONAL SAFETY RESEARCH: KNOWLEDGE AND GAPS

Hongwei Hsiao, Ph.D.

Occupational injuries pose a continuing major threat to the health and well being of American workers. On a typical day, an estimated 16 workers are killed and more than 36,000 workers are injured (Jenkins et al., 1993). The associated economic costs are high, costing the nation more than AIDS and as much as cancer and heart disease (Leigh et al., 1997). Yet the investment in occupational injury preventions is slim compared to resources dedicated to disease prevention research (NIOSH, 1998). Approaches for reducing occupational injuries and their cost in the workforce may include redesign of work practices, work environments, equipment, and tools to eliminate hazards. For hazards that cannot be eliminated, such as exposure of fire fighters to fires, the personal protective equipment (PPE) is served as the last line of defense for the worker (Hsiao and Halperin, 1998).

The influence of some factors on the safety performance of occupational tasks has been studied for more than 50 years (NIOSH, 1988). The results have been developed into standard industry practice and guidelines to reduce the risk of occupational injury. However, the etiologies of many occupational injuries are still not clear, particularly when human-environment/ system/ task interactions are involved. The author will discuss the knowledge we now possess and certain critical gaps concerning occupational injury control. The safety research activities in NIOSH will also be presented. These thoughts are derived from literature as well as from several NIOSH-organized workshops (NIOSH, 1998; Pizetella and Hsiao, 1998; Hsiao et. al., 1997).

TRANSPORTATION HUMAN FACTORS

Rudolf G. Mortimer

Traffic fatalities in the US have been reduced from about 56,000 in 1967 to 42,000 in 1997 in spite of steadily rising miles of travel. Human Factors research has played a role, though it would be difficult to quantify. Initial thinking by safety researchers in the 1930s was that there were accident prone drivers who caused a substantial proportion of crashes, and, hence, personality factors should be studied. Later statistical studies did not confirm accident proneness which led to an emphasis on human factors and the traffic system.

Research on the size, width, color and contrast of letters used to ensure adequate legibility of signs for route guidance was among the first by human factors researchers to have a direct impact, and forms the basis for recommended standards of such installations.

By studying the overtaking behavior of drivers, HF researchers in the 1940's and 50's began to learn about the basis of those judgements and their accuracy, which helped to provide guidelines for passing zones as well as identifying the need for means to aid drivers in making passing decisions. Such aids are still sorely needed.

Traffic signs have received considerable attention by HF researchers whose work has defined the current symbolic, diagrammatic and verbal signs in studies that have evolved over many decades.

Motor vehicle design, including brake systems, headlighting and other vehicle lighting as well as the driving compartment, controls and displays have benefited from HF research and application. One example, that has been often cited as a human factors success is the high-mounted stop lamp. However, this is also an example where human factors research was used to require an apparently beneficial change in the design of the motor vehicle rear lighting system that did not live up to its original expectations, although it has contributed to a modest reduction in rear-end collisions.

Human factors research has also been applied to reduce alcohol as a factor in crashes. This includes the recommendations for improved roadway delineation for better lateral control of vehicles on the road especially at night, alcohol ignition interlocks that can prevent inebriated drivers from starting their vehicles, and basic research that has shown how drivers' visual search is affected by alcohol.

The advent of new technologies poses new challenges. Human factors research under the general rubric of Intelligent Traffic Systems (ITS) has been concerned with, among others, the development of guidelines for the design of on-board mapping and guidance devices. Clearly, such devices take away some of the driver's attention from the basic driving task while, at the same time, providing useful information that can reduce the driver's uncertainty and thereby allow more attention to be paid to the basic task and reduce stress and anxiety. It can allow drivers to plan ahead so that they can position their vehicle for a future maneuver. Studies of telephone use by drivers have shown that they distract from the driving task. Turning the vehicle into a mobile office can have similar negative effects and will require human factors design to minimize those effects.

Computer technology and improved sensors also allow the development of systems that can relieve drivers of aspects of the driving task. Cruise controls that automatically adjust the spacing between vehicles by acceleration and deceleration and that apply the brakes, if needed, have been studied and are

in production. Their full effects on driver behavior have not been established. Clearly, they can have beneficial and harmful effects on traffic safety. Anti-locking brakes provide an aid to drivers in maximum braking situations by allowing the driver to retain steering control. Other applications of computers in vehicles enhance vehicle stability in ways unknown to the driver to improve handling and traction. As drivers become more aware of the benefits of some of these applications that enhance the vehicle's performance will they react by taking up the slack in the system by extracting more performance from the vehicle to the detriment of safety, as proponents of risk homeostasis would suggest, or will there result a net balance in favor of improved safety? That is why it is so important that human factors are thoroughly investigated and exploited to ensure that good human factors produces good economies, performance and safety.

CONCLUSIONS

Marc L. Resnick, Ph.D.

The panelists have identified many achievements of safety research that have saved the lives and health of many workers and consumers. In transportation, hazard communication and workplace safety, advances have decreased accident rates, injury incidence and property damage. But clearly, we have a long way to go. In the past, much of the safety research in academia has gone forward without sufficient input from industry and government. Industrial and government research has often been determined by political and short term objectives. Research in all areas may not have had the statistical and methodological rigor necessary to be truly valid and generalizable across workplaces and industries. The Safety Technical Group of the Human Factors and Ergonomics Society should work towards the development of a blueprint for safety research. We should call together the leading safety researchers and policy makers from academia, government and industry to overcome the challenges outlined by this panel to set a direction for the future. By benchmarking our statistical and methodological practices and coordinating the focus of our research activities we can enhance the effectiveness and applicability of safety research for the next century and beyond.

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