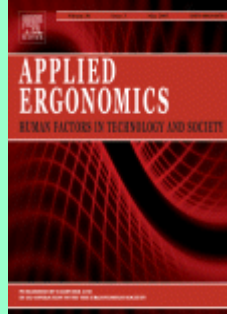


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Christopher B. Mayhorn, Michael S. Wogalter, Kenneth R. Laughery. ***Special issue on warnings : advances in delivery, application, and methods.***

This special issue of Applied Ergonomics concerns the topic of warnings, safety communications designed to decrease harm to people and property. The field has evolved over time, and with it there has been advancement in knowledge and application. The current special issue contains 14 articles that reflect three distinguishable areas within the warnings literature where such changes are taking place in the laboratories and workplaces of our international colleagues: (1) multimodality of warning delivery, (2) emerging application areas, and (3) new methodology. This special issue brings together a set of studies investigating various factors that might impact safety behavior in diverse settings and domains where warnings are likely to be encountered. It is our hope that the special issue will motivate to development and exploration of new ideas regarding warning design and their use in a variety of applications that improve safety.

- **Keywords:** Warnings; Safety; Individual differences

Carryl L. Baldwin, Bridget A. Lewis. ***Perceived urgency mapping across modalities within a driving context.***

Hazard mapping is essential to effective driver-vehicle interface (DVI) design. Determining which modality to use for situations of different criticality requires an understanding of the relative impact of signal parameters within each modality on perceptions of urgency and annoyance. Towards this goal we obtained psychometric functions for visual, auditory and tactile interpulse interval (IPI), visual color, signal word, and auditory fundamental frequency on perceptions of urgency, annoyance, and acceptability. Results indicate that manipulation of IPI in the tactile modality, relative to visual and auditory, has greater utility (greater impact on urgency than annoyance). Manipulations of color were generally rated as less annoying and more acceptable than auditory and tactile stimuli; but they were also rated as lower in urgency relative to other modality manipulations. Manipulation of auditory fundamental frequency resulted in high ratings of both urgency and annoyance. Results of the current investigation can be used to guide DVI design and evaluation.

- **Keywords:** Auditory warnings; Tactile warnings; Visual warnings; Driver–vehicle interface; Perceived urgency; Annoyance; Psychometric function; Multimodal comparisons

James P. Bliss, Eric T. Chancey. *An investigation of training strategies to improve alarm reactions.*

Researchers have suggested that operator training may improve operator reactions; however, researchers have not documented this for alarm reactions. The goal of this research was to train participants to react to alarms using sensor activity patterns. In Experiment 1, 80 undergraduates monitored a simulated security screen while completing a primary word search task. They received spatial, temporal, single sensor, or no training to respond to alarms of differing reliability levels. Analyses revealed more appropriate and quicker reactions when participants were trained and when the alarms were reliable. In Experiment 2, 56 participants practiced time estimation by simple repetition, performance feedback, or performance feedback and temporal subdivision. They then reacted to alarms based on elapsed time between sensor activity and alarm onset. Surprisingly, results indicated that participants did not benefit differentially from temporal interval training, focusing instead on advertised system reliability. Researchers should replicate these findings with realistic tasks and real-world complex task operators.

- **Keywords:** Alarms; Training; Reliability

Brannan R. McDougald, Michael S. Wogalter. *Facilitating pictorial comprehension with color highlighting.*

Pictorials can aid in communicating warning information, but viewers may not always correctly comprehend them. Two experiments focused on whether the use of relevant highlighting could benefit pictorial comprehension. A set of warning-related pictorials were manipulated according to three-color highlighting conditions: highlighting areas more relevant to correct comprehension, highlighting areas less relevant to comprehension, and no highlighting. Participants were asked to describe the purpose and meaning of each pictorial presented to them. The findings from both experiments indicate that comprehension of warning pictorials is higher for the relevant highlighting condition than the other two conditions. The highlighting of less relevant areas reduced comprehension compared to no highlighting. Use of appropriately placed highlighting could benefit the design of a complex symbol by pointing out pertinent areas to aid in determining its intended conceptual meaning.

- **Keywords:** Warnings; Highlighting; Color

Judy Edworthy, Rebecca Page, Andrea Hibbard, Sean Kyle, Paul Ratnage, Suzanne Claydon. *Learning three sets of alarms for the same medical functions : a perspective on the difficulty of learning alarms specified in an international standard.*

Three sets of eight alarms supporting eight functions specified in an international medical equipment standard (IEC 60601-1-8) were tested for learnability using non-anaesthetist participants. One set consisted of the tonal alarms specified in the standard. A second set consisted of a set of abstract alarms randomly selected from a database of abstract alarm sounds held by the authors. A third set of alarms was designed as indirect metaphors of the functions. Participants were presented with the alarms and then asked to identify them across ten blocks of eight trials. The results indicated a significant difference in learnability across the three sets of alarms. The indirect metaphors were learned significantly better than both other sets of alarms, and the randomly selected abstract alarms were learned significantly better than the alarms specified in the

standard. The results suggest therefore that there are more readily learnable possible designs than those proposed in the standard. The use of auditory icons in particular should be given serious consideration as potential alarms for this application.

- **Keywords:** Auditory warnings; Alarms; Auditory icons

Ulrike Schmunzsch, Christine Sturm, Matthias Roetting. *The warning glove : development and evaluation of a multimodal action-specific warning prototype.*

This paper has two objectives: first, to introduce the concept of multimodal action-specific warnings and its prototypic realization in the form of a warning glove and second, to present the main findings of a user study that was conducted to test the warning glove against a conventional warning system. Regarding the first goal, the combination of multimodality and action-specificity was implemented by attaching electronic actuators on a right-handed glove for transmitting visual, auditory and tactile feedback. For the second objective, a user study was conducted to test the hypothesis that the warning glove is capable of obtaining faster responses and to determine the perceptions of the users regarding the appropriateness of the warning glove. The results confirmed the assumption of faster response times and participants perceived the warning glove to be 'fairly appropriate'. These results warrant further development of this multimodal action-specific warning glove.

- **Keywords:** Multimodal warnings; Wearable technology; Maintenance errors

Michael S. Wogalter, Raymond W. Lim, Patrick G. Nyeste. *On the hazard of quiet vehicles to pedestrians and drivers.*

The need to produce more efficient and less polluting vehicles has encouraged mass production of alternative energy vehicles, such as hybrid and electric cars. Many of these vehicles are capable of very quiet operation. While reducing noise pollution is desirable, quieter vehicles could negatively affect pedestrian safety because of reduced sound cues compared to louder internal combustion engines. Three studies were performed to investigate people's concern about this issue. In Study 1, a questionnaire completed by 378 people showed substantial positive interest in quiet hybrid and electric cars. However, they also indicated concern about the reduced auditory cues of quiet vehicles. In Study 2, 316 participants rated 14 sounds that could be potentially added to quiet alternative-energy vehicles. The data showed that participants did not want annoying sounds, but preferred adding "engine" and "hum" sounds relative to other types of sounds. In Study 3, 24 persons heard and rated 18 actual sounds within 6 categories that were added to a video of a hybrid vehicle driving by. The sounds most preferred were "engine" followed by "white noise" and "hum". Implications for adding sounds to facilitate pedestrians' detection of moving vehicles and for aiding drivers' awareness of speed are discussed.

- **Keywords:** Quiet Vehicle; Auditory warnings; Pedestrian safety

Sally Turner, Julie Wylde, Martin Langham, Andrew Morrow. *Determining optimum flash patterns for emergency service vehicles : an experimental investigation using high definition film.*

An investigation of how emergency vehicle lighting (EVL) can be improved is reported with reference to an analysis of police vehicle road traffic accidents (Study 1). In Study 2, 37 regular drivers were shown film clips of a marked police vehicle, in which flash rate (1 Hz, 4 Hz) and pattern (single, triple pulse) were varied on the blue Light Emitting Diode (LED) roofbar. Results indicate a 4 Hz flash rate conveys greater urgency than a

1 Hz rate, while a 1 Hz, single flash combination was ranked the least urgent of all combinations. Participants claimed they would leave significantly more space before pulling out in front of an approaching police car (gap acceptance) in the 4 Hz single pulse condition in comparison to other EVL combinations. The preliminary implications for which flash characteristics could prove most optimal for emergency service use are discussed with regard to effects on driver perception and expected driving behaviour.

- **Keywords:** Emergency service vehicle lighting; Flash pattern; Urgency perception

E. Hellier, J. Edworthy, L. Newbold, K. Titchener, M. Tucker, E. Gabe-Thomas. *Evaluating the application of research-based guidance to the design of an emergency preparedness leaflet.*

Guidelines for the design of emergency communications were derived from primary research and interrogation of the literature. The guidelines were used to re-design a nuclear emergency preparedness leaflet routinely distributed to households in the local area. Pre-test measures of memory for, and self-reported understanding of, nuclear safety information were collected. The findings revealed high levels of non-receipt of the leaflet, and among those who did receive it, memory for safety advice was poor. Subjective evaluations of the trial leaflet suggested that it was preferred and judged easier to understand than the original. Objective measures of memory for the two leaflets were also recorded, once after the study period, and again one week or four weeks later. Memory for the advice was better, at all time periods, when participants studied the trial leaflet. The findings showcase evaluation of emergency preparedness literature and suggest that extant research findings can be applied to the design of communications to improve memory and understandability. Statement of relevance: Studies are described that showcase the use of research-based guidelines to design emergency communications and provide both subjective and objective data to support designing emergency communications in this way. In addition, the research evaluates the effectiveness of emergency preparedness leaflets that are routinely distributed to households. This work is of relevance to academics interested in risk communication and to practitioners involved in civil protection and emergency preparedness.

- **Keywords:** Risk communication; Emergency preparedness

Michael S. Wogalter, Eric F. Shaver, Michael J. Kalsher. *Effect of presentation modality in direct-to-consumer (DTC) prescription drug television advertisements.*

Direct-to-consumer (DTC) drug advertising markets medications requiring a physician's script to the general public. In television advertising, risk disclosures (such as side effects and contraindications) may be communicated in either auditory (voice) or visual (text) or both in the commercials. This research examines presentation modality factors affecting the communication of the risk disclosures in DTC prescription drug television commercials. The results showed that risk disclosures presented either visually only or both visually and auditorily increased recall and recognition compared to no presentation. Risk disclosures presented redundantly in both the visual and auditory modalities produced the highest recall and recognition. Visual only produced better performance than auditory only. Simultaneous presentation of non-risk information together with risk disclosures produced lower recall and recognition compared to risk disclosures alone—without concurrent non-risk information. Implications for the design of DTC prescription drug television commercials and other audio-visual presentations of risk information including on the Internet, are discussed.

- **Keywords:** Advertisements; Drug commercials; Risk communication

Sandra Carpenter, Feng Zhu, Swapna Kolimi. *Reducing online identity disclosure using warnings.*

In an experimental design, we tested whether written warnings can reduce the amount of identity information exposure online. A psychological attack on information privacy that has been shown to be effective in previous research was launched. This attack took advantage of the fact that people respond to certain types of requests in a relatively automatic, or mindless, fashion. The experiment manipulated the word that was used in the alert header: "warning", "caution", or "hazard". All warnings proved to be effective in reducing disclosure, but "hazard" proved to be most effective. Also warnings were more effective in reducing disclosure of driver's license numbers than email addresses. The discussion (a) provides tentative conclusions why these patterns were obtained, (b) suggests how to design warnings in cyber-environments, and (c) addresses future possibilities for research on this topic.

- **Keywords:** Warnings; Cybersecurity; Identity protection

Tal Oron-Gilad, P.A. Hancock, Jessica Helmick-Rich. *Coding warnings without interfering with dismounted soldiers' missions.*

Objectives: Warnings are an effective way to communicate hazard, yet they can also increase task demand when presented to operators involved in real-world tasks. Furthermore, in military-related tasks warnings are often given in codes to avoid counter-intelligence, which may foster additional working memory load. Background: Adherence to warnings in the military domain is crucial to promote safety and reduce accidents and injuries. The empirical question arises as to how aspects of coding the warning may interfere with the primary task the individual is currently performing and vice versa. Method: Six experimental conditions were designed to assess how warning-code storage format, response format, and increasing working memory demand (retention) affected both performance on the primary task and the rate of compliance to warnings, considered here as the secondary task. Results: Results revealed that the combination of warning-code storage and response format affected compliance rate and the highest compliance occurred when warnings were presented as pictorials and responses were coded verbally. Contrary to the proposed hypotheses, warning storage format did not affect performance on the primary task, which was only affected by the level of working memory demand. Thus, the intra-modal warning storages did not interfere with the visual/spatial nature of the primary operational task. However, increase in working memory demand, by increasing the number of memorized warning codes, had an effect on both compliance rate and primary task performance. Conclusions: Rather than warning code storage alone, it is the coupling of warning storage and response format that has the most significant effect on compliance.

- **Keywords:** Military; Warning; Retention; Task demand

Patrick Waterson, Alice Monk. *The development of guidelines for the design and evaluation of warning signs for young children.*

We report a study which aimed to provide further development and refinement of a set of guidelines (Waterson et al., 2012) for the design and evaluation of warning signs and other visual material for young children (i.e., aged 5–11 years). The study involved a set of semi-structured interviews and focus groups with the parents of young children, teachers, human factors experts and other groups (n = 38). The findings from the study provided broad support for the guidelines, as well as highlighting a number of issues which need to be addressed. These included the need to consider the target audience in more detail and provide additional guidance covering possible tie-ins with safety campaigns, sign location, age differences, gender and children's special needs. Similar findings were obtained with regard to the evaluation guidelines and their coverage of

methods and activities for testing signs (e.g., simulation, role playing). We discuss our findings within the context of a revised set of guidelines and a set of suggestions aimed at working towards a more comprehensive approach to the design/evaluation of signs for young children. The paper concludes with a set of future topics for research including a discussion of ways forward in terms of improving support for design and evaluation including behavioural testing with children, their parents and other care givers.

- **Keywords:** Warnings; Signs; Children; Safety; Guidelines; Methodology

Arisara Jiamsanguanwong, Hiroyuki Umemuro. *Influence of affective states on comprehension and hazard perception of warning pictorials.*

The purpose of the present study was to examine the effect of positive and negative affective states on comprehension and hazard perception of warning pictorials. The International Affective Picture System (IAPS) was used to manipulate the affective states of sixty male undergraduate and graduate student participants. We used sixteen standard industrial warning pictorials, which were representative of a variety of industries, to assess changes in comprehension and hazard perception. Participants in the positive affect condition perceived greater hazards from the warning signs than those in the neutral affect condition or the negative affect condition. Post-hoc analyses confirmed this finding. We discuss implications for warning pictorials and future research.

- **Keywords:** Affective; Hazard perception; Warning pictorial

Emília Duarte, Francisco Rebelo, Júlia Teles, Michael S. Wogalter. *Behavioral compliance for dynamic versus static signs in an immersive virtual environment.*

This study used an immersive virtual environment (IVE) to examine how dynamic features in signage affect behavioral compliance during a work-related task and an emergency egress. Ninety participants performed a work-related task followed by an emergency egress. Compliance with uncued and cued safety signs was assessed prior to an explosion/fire involving egress with exit signs. Although dynamic presentation produced the highest compliance, the difference between dynamic and static presentation was only statistically significant for uncued signs. Uncued signs, both static and dynamic, were effective in changing behavior compared to no/minimal signs. Findings are explained based on sign salience and on task differences. If signs must capture attention while individuals are attending to other tasks, salient (e.g., dynamic) signs are useful in benefiting compliance. This study demonstrates the potential for IVEs to serve as a useful tool in behavioral compliance research.

- **Keywords:** Safety signs; Behavioral compliance; Virtual reality