International Journal of Industrial Ergonomics 41 (2011) 136–146

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Heterogeneity in auditory alarm sets makes them easier to learn

Judy Edworthy [a,*], Elizabeth Hellier [a,1], Kirsteen Titchener [b,2], Anjum Naweed [c,3], Richard Roels [d,4]

[a] School of Psychology, University of Plymouth, UK
[b] Centre for Accident Research and Road Safety, Queensland University of Technology, 130 Victoria Park Road, Kelvin Grove, Queensland 4059, Australia
[c] Department of Psychology, University of Sheffield, Sheffield S10 2TP, UK
[d] Rail Safety and Standards Board, Evergreen House, 160 Euston Road, London NW1 2DX, UK

ARTICLE INFO

Article history:
Received 30 October 2009
Received in revised form
5 August 2010
Accepted 14 December 2010
Available online 15 January 2011

Keywords:
Alarms
Auditory warnings
Design
Learning

ABSTRACT

The primary objective of the experiments reported here was to demonstrate the effects of opening up the design envelope for auditory alarms on the ability of people to learn the meanings of a set of alarms. Two sets of alarms were tested, one already extant and one newly-designed set for the same set of functions, designed according to a rationale set out by the authors aimed at increasing the heterogeneity of the alarm set and incorporating some well-established principles of alarm design. For both sets of alarms, a similarity-rating experiment was followed by a learning experiment. The results showed that the newly-designed set was judged to be more internally dissimilar, and easier to learn, than the extant set. The design rationale outlined in the paper is useful for design purposes in a variety of practical domains and shows how alarm designers, even at a relatively late stage in the design process, can improve the efficacy of an alarm set.

1. Introduction

There have been considerable advances in the theory, design and application of auditory warnings in a range of environments in recent years. Major developments in the use of auditory icons (e.g. Belz et al., 1999; Graham, 1999; Keller and Stevens, 2004), 3D sounds and head-up displays (e.g. Begault, 1993) and the use of sonification (e.g. Walker, 2002; Watson and Sanderson, 2004) have all broadened the envelope for the designer. In addition, there has been progress in bringing useful design methods into play in the alarms area, for example the application of Ecological Interface Design (EID) principles to the design of medical monitoring devices (Watson and Sanderson, 2007) as well as the potential use of adaptive interfaces in broader arenas in which both visual and auditory alarms might be used (Letsu-Dake and Ntuen, 2010). The topic of stimulus–response compatibility with alarms across modalities is also of considerable interest and relevance (Lee and Chan, 2007; Chan and Chan, 2009).

Early work on auditory warnings (e.g. Edworthy et al., 1991; Hellier et al., 1993) showed how to design a set of abstract alarms using Patterson's (1982) design protocol so that the urgency of the alarms varies on a predictable basis. This allows warnings to be mapped to situations according to their urgency, so that urgent-sounding warnings are associated with urgent situations and less urgent-sounding warnings with less urgent situations. This is useful in situations where people do not necessarily know the meanings of the situation being signalled (e.g. Momtahan et al., 1993). More recently, Guillaume et al. (2003) have shown that urgency is a primary determinant of judgements of difference and similarity between the set of alarms developed by Edworthy et al. (1991). Therefore urgency in abstract warnings may be a salient dimension under some circumstances because it not only allows differentiation of urgency, it also allows differentiation between warnings *per se*.

In designing alarms, the designer may choose for example to focus on broad findings relating to learnability and memorability of alarms. There is evidence which suggests strongly that some types of sound are easier to learn than others. Leung et al. (1997) and Ulfvengren (2003) have shown that different classes of alarms vary in the ease with which they are learnt. Both of these studies show the same general pattern of results. Abstract alarms are very hard to learn, speech is easy, and auditory icons, usually everyday sounds, are much easier to learn than abstract alarms and almost as easy as speech. Sounds which bear a closer semantic relationship with their meaning as alarms appear to be the easiest of all to learn. Speech has the

* Corresponding author. Tel.: +44 1752 584818.
E-mail addresses: jedworthy@plymouth.ac.uk (J. Edworthy), ehellier@plymouth.ac.uk (E. Hellier), kirsteen.titchener@qut.edu.au (K. Titchener), a.naweed@sheffield.ac.uk (A. Naweed), richard.roels@rssb.co.uk (R. Roels).
[1] Tel.: +44 1752 584818.
[2] Tel.: +61 713 1384565.
[3] Tel.: +44 114 2226513.
[4] Tel.: +44 207 983 6750.

0169-8141/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2010.12.004