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Experimental Evidence Shows That Auditory Icon Clinical Alerts Work Better Than Tones

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ABSTRACT

Clinical auditory alarms have traditionally been beset with a range of problems caused by technological restrictions, slow-to-progress standards, and reluctance to move beyond the use of tones and beeps. Accumulating evidence shows that sounds which more closely resemble everyday sounds, which therefore allow us to listen and respond to them in the way that we naturally process sound, perform considerably better than tones in an alarms context. This paper reviews that evidence.

Keywords: *Clinical alarms, auditory alarms, alarms, alarm tones, auditory icons*

1. INTRODUCTION

Auditory alarms are seen as a boon to safety and are therefore used throughout industry and healthcare. However, they tend to be over-used, leading to the well-known phenomenon of 'alarm fatigue' which has been particularly problematic in healthcare [1]. There are several sources of alarm fatigue including high rates of false alarms, inappropriate calibration of alarms, incorrect alarm settings, alarms triggering too early, confusing alarm sounds, masking of alarm sounds by other sounds, inattentional deafness and other factors. Without doubt, one of the sources of the problem is that the auditory alarms themselves have traditionally been limited to a relatively small number of sounds before the advent of digital technology, and even in the age of digital technology, abstract tones with little variation.

More recently, the loudspeakers used to reproduce alarm sounds have been of higher quality, removing earlier restrictions. However, for a number of reasons the use of sounds other than beeps and tones as alarm signals is progressing only slowly. One group of sounds, auditory icons, which are everyday sounds acting as metaphors for their functions, are now incorporated in the global medical device safety standard, IEC 60601-1-8. There is considerable and growing evidence that these auditory icon alarms outperform tonal alarms by a considerable margin. The remainder of this paper outlines this evidence.

2. EXPERIMENTAL EVIDENCE

As the auditory icon alarms were developed for the purposes of supporting the 2020 update of the global standard, considerable evidence was collected to show that these alarms were superior to tonal alarms in almost all dimensions [2]. Auditory icons are much easier to learn and retain than tonal alarms, they are easier to localize, they are easier to recognize in simulation environments, are extremely audible, and are less tiring and irritating. None of these findings are surprising, but are a consequence of auditory icons being similar to everyday sounds. They therefore have a dense and complex harmonic structure, represent enormous variability across sounds, and are closely linked to the events making those sounds.

2.1. Effect on secondary tasks

Research carried out since the initial work supporting the adoption of the alarm signals into the standard suggests that auditory icons, while performing at least as well if not better than tonal alarms in terms of their ability to attract attention to a problem, do not divert attention away from other tasks as noticeably as tonal alarms. Studies by Bruder et al [3 show that when trained clinical participants are required to carry out two or three tasks at the same time, auditory icons are at least as good at attracting attention to the primary, clinical

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task while performance on tasks being performed at the same time, such as vigilance tasks, are less disrupted by auditory icons than by tonal alarms.

2.2. Prioritizing and sequencing

Subsequent studies have shown that there are further advantages to be found with auditory icon alarms in comparison with tonal alarms. A study comparing participants' ability to recognize either tonal or auditory icon alarms when presented either singly or in pairs [4] showed that performance was considerably better in both conditions with auditory icons (Table 1).

More recent evidence explored an unfolding clinical scenario where alarms might represent new clinical problems, or be repeated alarms from existing problems. Tbe findings showed that responses to auditory icons were both more accurate and faster than tonal alarms [5] (Table 2).

Table 1. Comparison of tonal and auditory icon alarms when heard singly and in pairs [4].

Alarm formation	Score (max = 1)
Single tonal	0.41
Single auditory icon	0.78
Paired tonal	0.20
Paired auditory icon	0.59

Table 2. Comparison of tonal and auditory icon alarms when heard in clinical sequences [5]

Alarm type	Accuracy (max = 12)	Response time (ms)
Auditory icons	10.7	2917.5
Tones	9.6	3544

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