Utilizing multisensory integration to improve psychoacoustic alarm design in the intensive care unit

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Abstract: Sound exposure in the hospital can have deleterious effects on patients and practitioners.[1] Clinicians perform worse on tasks involving patient monitoring in noisy and highly attentionally demanding environments.[2,3] Research on the signal-to-noise ratio of alarms can decrease the overall sound exposure by decreasing the alarm fraction contribution of total sound.[4,5] (Word count: 50)

Poster/Oral Presentation Description: Alarms in the ICU sound frequently and 85-99% of cases do not require clinical intervention.[6] As alarm frequency increases, clinicians develop 'alarm fatigue' resulting in desensitization, missed alarms, and delayed responses.[7] This is dangerous for the patient when an alarm-provoking event requires clinical intervention but is inadvertently missed. Alarm fatigue can also cause clinicians to: set alarm parameters outside effective ranges to decrease alarm occurrence, decrease alarm volumes to an inaudible level; silence frequently insignificant alarms; and be unable to distinguish alarm urgency.[8] Since false alarm and clinically insignificant alarm rates reach 80-99%, practitioners distrust alarms, lose confidence in their significance, and manifest alarm fatigue.[9] Yet, failure to respond to the infrequent clinically significant alarm may lead to poor patient outcomes. Fatigue from alarm amplitude and nonspecific alarms from uniform uninformative alarms is the post-monitor problem that can be addressed by understanding the psychoacoustic properties of alarms and the aural perception of clinicians.[10]

Our experimental paradigm will determine near-threshold auditory perception of alarms, and then use clinical scenarios to determine the stimulus-response relationships for changes in auditory alarm intensity, spanning negative to positive signal-to-noise ratios (SNRs), when performing an audiovisual secondary task designed to tax attentional and decisional resources. The result will be a stimulus-response curve in dB above ambient noise.

Results show near-threshold auditory perception of alarms is around -27 decibels (dB) from background noise at 60 dB. Additionally, with visual offset of a patient monitor, there is preserved performance measured by an Inverse Efficiency Score (IES = Response Time/Accuracy) at -11 dB as compared with +4dB with worsening at more negative SNRs. Thus, clinician performance is maintained with alarms that are *softer* than background noise. These results can inform future work on alarm fatigue to address the music perception and cognition components of novel psychoacoustic alarm presentations in concordance with existing standards (IEC 60601-1-8).[11,12] (Word count: 306)

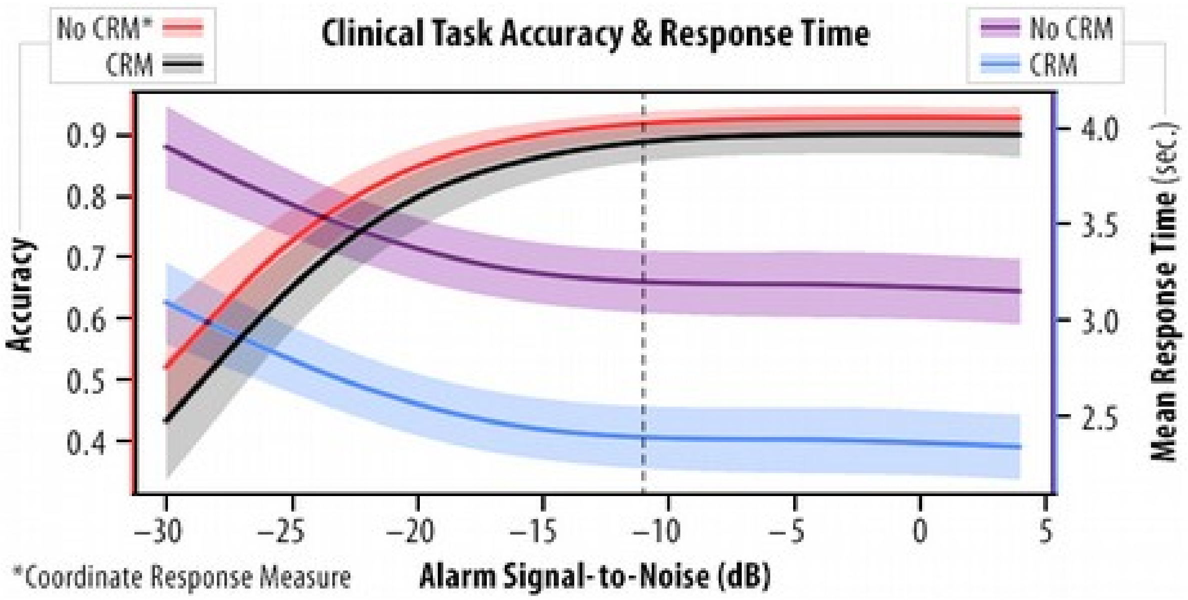

Figure: Clinician Performance (Response Time and Accuracy) Across Varying SNRs of Auditory Alarms

Keywords: Patient monitoring, music perception and cognition, signal-to-noise ratio, auditory medical alarms, aural perception (5 keywords)

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References

1. Xie H, Kang J, Mills GH. Clinical review: The impact of noise on patients' sleep and the effectiveness of noise reduction strategies in intensive care units. *Crit. Care.* 2009;13(2):208.
2. Schlesinger JJ, Stevenson RA, Wallace MT. Improving pulse oximetry pitch perception with multisensory perceptual training. *Anesth. Analg.* 2014.
3. Stevenson RA, Schlesinger JJ, Wallace MT. Effects of divided attention and operating room noise on perception of pulse oximeter pitch changes: a laboratory study. *Anesthesiology.* 2013;118(2):376-381.
4. Schlesinger JJ. In Response. *Anesth. Analg.* 2015;121(3):836.
5. Ross LA, Saint-Amour D, Leavitt VM, Javitt DC, Foxe JJ. Do you see what I am saying? Exploring visual enhancement of speech comprehension in noisy environments. *Cereb. Cortex.* 2007;17(5):1147-1153.
6. Cvach M. Monitor alarm fatigue: an integrative review. *Biomed. Instrum. Technol.* 2012;46(4):268-277.
7. Paine CW, Goel VV, Ely E, et al. Systematic Review of Physiologic Monitor Alarm Characteristics and Pragmatic Interventions to Reduce Alarm Frequency. *J. Hosp. Med.* 2015.
8. Edworthy JR, Edworthy JD. Audible medical alarms. *Anaesthesia.* 2015;70(10):1215.
9. Choiniere DB. The effects of hospital noise. *Nurs. Adm. Q.* 2010;34(4):327-333.
10. Helmholtz HL. *On the Sensations of Tone as a Physiological Basis for the Theory of Music.*: Cambridge University Press; 2009.
11. Block FE, Jr. "For if the trumpet give an uncertain sound, who shall prepare himself to the battle?" (I Corinthians 14:8, KJV). *Anesth. Analg.* 2008;106(2):357-359.
12. Sanderson PM, Wee A, Lacherez P. Learnability and discriminability of melodic medical equipment alarms. *Anaesthesia.* 2006;61(2):142-147.