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introduction, outline, and research agenda**

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LETTER



Shaping critical care through sound-driven innovation: introduction, outline, and research agenda

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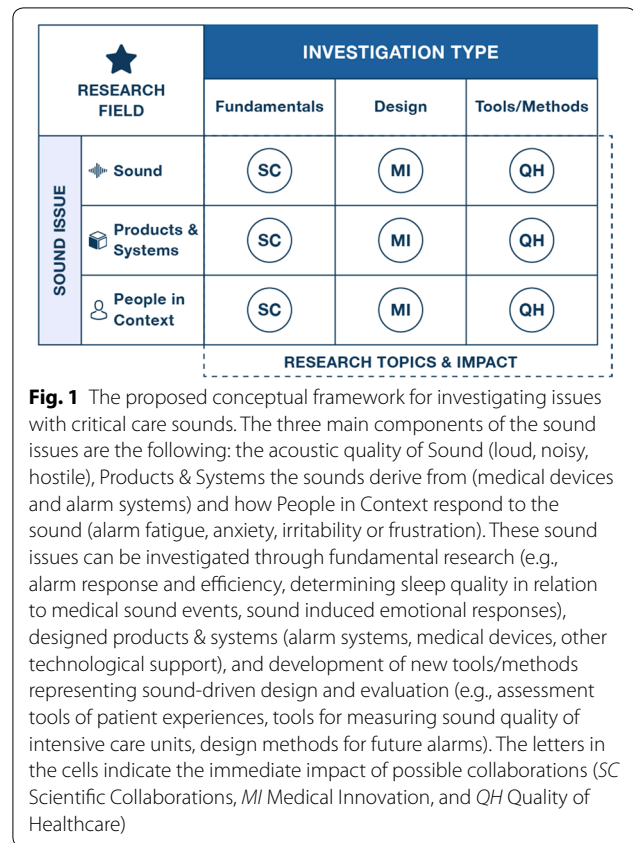
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Dear Editor,

Excessive noise has become one of the most publicly debated issues in critical care over the last 10 years [1]. Beeping alarms, conversations, droning support devices and the care giving activities that clatter, buzz and ping turn intensive care units into an acoustically hostile environment in which neither can patients recover comfortably nor can medical staff operate safely and efficiently [2, 3]. Keeping the patient alive and stable with the help of advanced technology comes at a price: health conditions such as anxiety, post-traumatic stress, noise fatigue and possibly delirium are linked to excessive noise. It is our plea to foster medical innovation that focuses not only on patients' medical and safety needs, but also on human needs/values such as pleasure, dignity, sense of achievement.

In Fig. 1, we propose a conceptual framework that depicts how sound issues could be resolved through scientific and industrial investigations and be integrated in human-sensitive technological solutions for healthcare and open doors for larger collaborations and shape the vision on policies [4]. Investigating fundamentals incites scientific collaborations to offer an integrated body of knowledge supporting advancement in human-sensitive healthcare systems. Designing new solutions—without the limits of safety-focused policies/regulations, but with motivation to incite positive experiences—inspires medical innovation. Our approach yields new paradigms/tools/methods to measure and represent sounds to have

immediate impact on quality of healthcare. For example, the management struggle with clinician's loose utilization of alarms and pressure from accreditation agencies



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requires a holistic and inclusive approach. Accordingly, we put the framework in action [4, 5] collaborating¹ with intensivists, design engineers, psychologists, health-tech companies, artists and policy-makers. We developed audible alarms for the new international standard (IEC 60601-1-8) that are less intrusive, but empirically proven to be more informative, offered nurses musical updates to reduce false patient monitor alarms (CareTunes) or silenced the alarms completely in the patient room by redesigning a user-sensitive patient monitor (Ultimo), tackled changing nurse behavior through artful warnings that indicate (un)acceptable sound levels (Doplor) and cultivated sound-conscious behavior with an awareness campaign.

Our aim is to familiarize relevant stakeholders (e.g., policy-makers, product developers, scientific/medical institutions, patient organizations) with sound issues in critical care and offer them a platform for collaborations (e.g., grant applications and scientific inquiries, lobbying for improved policies, redesigning healthcare systems). We envision broad implications for empirical research such as perception of care (e.g., sleep, feeling of loneliness), observable changes in behavior (sleep quality measured by EEG, movement during the day, time in bed), and even clinical outcomes (e.g., length of stay at the ICU/hospital). We plan to correlate design interventions with sounds to such patient outcomes. Without a strict timeline, the success of our vision depends on the urgency of the topics that the stakeholders have co-created and their potential for direct impact on the quality of patients/clinicians lives. With this letter, we call interested colleagues, media, scientific authorities and

political bodies of the society for action to combat noise/ alarm fatigue in critical care with human-sensitive and evidence-based technological solutions that cater for better recovery and improved clinical flow.

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Compliance with ethical standards

Conflicts of interest

All authors declare that they have no conflicts of interest.

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¹ The collaborations took place between two intensive care units (Erasmus Medical Centre Rotterdam, NL; Vanderbilt University Medical Center, USA), a design engineering school (Delft University of Technology, NL), school of psychology (University of Plymouth, UK), health-tech companies (Quietyme, USA; New Compliance, NL), artists (Sen Sound, USA) and regulatory agencies (AAMI, USA).