

## **Distributed Listening in Intensive Care: Nurses' Collective Alarm Responses Unravelling through Auditory Spatiotemporal Trajectories**

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**Abstract :** Auditory alarms play an integral role in intensive care nurses' daily work. Most medical devices in the intensive care unit (ICU) are designed to produce alarm sounds in order to make nurses aware of immediate or prospective safety risks. The utilisation of sound as a carrier of crucial patient information is highly dependent on nurses' presence - both physically and mentally. For ICU nurses, especially the ones who work with stationary alarm devices at the patient bed space, it is a challenge to display 'appropriate' alarm responses at all times as they have to navigate with great flexibility in a complex work environment. While being primarily responsible for a small number of allocated patients they are often required to engage with other nurses' patients, relatives, and colleagues at different locations inside and outside the unit. This work explores the social strategies used by a team of nurses to comprehend and react to the information conveyed by the alarms in the ICU. Two main research questions guide the study: To what extent do alarms from a patient bed space reach the relevant responsible nurse by direct auditory exposure? By which means do responsible nurses get informed about their patients' alarms when not directly exposed to the alarms? A comprehensive video-ethnographic field study was carried out to capture and evaluate alarm-related events in an ICU. The study involved close collaboration with four nurses who wore eye-level cameras and ear-level binaural audio recorders during several work shifts. At all time the entire unit was monitored by multiple video and audio recorders. From a data set of hundreds of hours of recorded material information about the nurses' location, social interaction, and alarm exposure at any point in time was coded in a multi-channel replay-interface. The data shows that responsible nurses' direct exposure and awareness of the alarms of their allocated patients vary significantly depending on work load, social relationships, and the location of the patient's bed space. Distributed listening is deliberately employed by the nursing team as a social strategy to respond adequately to alarms, but the patterns of information flow prompted by alarm-related events are not uniform. Auditory Spatiotemporal Trajectory (AST) is proposed as a methodological label to designate the integration of temporal, spatial and auditory load information. As a mixed-method metrics it provides tangible evidence of how nurses' individual alarm-related experiences differ from one another and from stationary points in the ICU. Furthermore, it is used to demonstrate how alarm-related information reaches the individual nurse through principles of social and distributed cognition, and how that information relates to the actual alarm event. Thereby it bridges a long-standing gap in the literature on medical alarm utilisation between, on the one hand, initiatives to measure objective data of the medical sound environment without consideration for any human experience, and, on the other hand, initiatives to study subjective experiences of the medical sound environment without detailed evidence of the objective characteristics of the environment.

**Keywords :** auditory spatiotemporal trajectory, medical alarms, social cognition, video-ethnography

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