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Alarm Fatigue: Causes and Effects

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Abstract. The term "Alarm fatigue" is commonly used to describe the effect which a high number of alarms can have on caregivers: Frequent alarms, many of which are avoidable, can lead to inadequate responses, severely impacting patient safety. In the first step of a long-term effort to address this problem, both the direct and indirect impact of alarms, as well as possible causes of unnecessary alarms were focused. Models of these causes and impacts were developed using a scoping review which included guided interviews with experts from medical informatics, clinicians and medical device manufacturers. These models can provide the methodical grounds for the definition of targeted interventions and the assessment of their effects.

Keywords. Alarm fatigue; Clinical Alarms; Clinical Alarms: organization and administration; Sociotechnical System; Critical Care; Patient Safety

1. Introduction

Physiological monitoring offers more and more data for the surveillance of patients' vital signs. With this, a corresponding increase in clinical and technical alarms can be observed. Almost inevitably, this also results in a growing number of alarms which do not require any action by the caregiver, i.e. non-actionable alarms. But even alarms which do require an action can be avoidable. Improper electrode placement, for instance, can lead to technical alarms which require a reaction (replacement of the electrode) but are preventable nonetheless. In the remainder, we will refer to both non-actionable and avoidable alarms together as "unnecessary alarms". In this study, we focused on Intensive Care Units (ICUs), but similar problems exist in all care areas where patients are being monitored [1; 2]. Of the 150 to 350 alarms per day and patient [3-5] as many as 80 % to 95 % are non-actionable (or "false": the used definitions vary) [6-8]. The workload from managing hundreds of alarms per work shift, including the mental stress from evaluation and prioritization of many alarm conditions in parallel, is often regarded as the main contributing factor for a fatigue in healthcare workers called "Alarm fatigue" [9]. We argue that Alarm fatigue should not be seen as a condition of an individual healthcare worker, but rather as a state of the sociotechnical system ICU where caregivers exposed to too many unnecessary alarms become more likely to react inadequately to alarms. The term "cry-wolf effect" has become common to denote the

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psychologically plausible – though rarely demonstrated in empirical settings (but see [10]) – mechanism by which high rates of false alarms lead to inadequate responses. While in the US the Emergency Care Research Institute lists "alarm hazards" in the top three of the "Health Technology Hazards" for several years responses [11-13], and while the FDA Manufacturer and User Facility Device Experience (MAUDE) database reports 566 "alarm-related deaths" between 2005 and 2010 [14], outside the US the awareness of the problem and regulatory attempts to improve the situation appear to be sparse.

Quite a few publications focus on advice to reduce unnecessary alarms [10; 15], mostly based on concrete improvement projects, but a comprehensive model of the causes and the effects of these alarms is still a desideratum.

The aim of this study was to develop such models since they are a necessary precondition for the development of a systematic approach to reduce unnecessary alarms.

2. Methods

We conducted a scoping review including a MEDLINE search and guided interviews with clinicians, experts from the field of medical informatics and medical device manufacturers, as described by Arksey and O'Malley [16]. We followed the six stages model for scoping reviews. We divided the study concerning two different goals. First, it was necessary to get an understanding of the underlying causes of unnecessary alarms on ICUs. Second, we used the same method, to elicit input to investigate the effects of unnecessary alarms on ICUs. We grouped the causes of avoidable alarms in a 6M-Ishikawa diagram, with the categories slightly adapted to better match the ICU setting. A potential cause was identified if it was mentioned as such during the focus group sessions or in the literature. However, we did not find explicit mentions of causality very often. More frequently, the literature rather recommends activities to mitigate the problem of unnecessary alarms by addressing a particular topic. We included these "inferred" topics into the model if they were regarded as plausible by focus group members. For the effect model, we used a causal map [18] showing all effects mentioned in the literature. Causal links which were suggested by at least two articles were included in the model, as was a self-evident one ("unnecessary workload" leading to "inefficiencies"). The resulting models were reviewed by the experts.

3. Results

Many publications report experiences from concrete improvement projects [4; 8], sometimes with a stepwise approach so that practice changes and outcome metrics can be correlated [14]. We did not find any publication to relate the baseline status of assumed causes to a general model of possible causes. Other publications give practice recommendations, drawing on past experiences, [19] but they also do not link their suggestions to any causal model. The scoping review shows that a comprehensive overview of all possible causes of unnecessary alarms is missing. The causal contributors to unnecessary alarms identified in the scoping review are shown in Figure 1. This figure has a low granularity with the terminal nodes still covering rather diverse phenomena. Figure 2 shows the identified direct and mediated possible effects of unnecessary alarms. While some of the effects and their causal relations are self-evident or common sense in

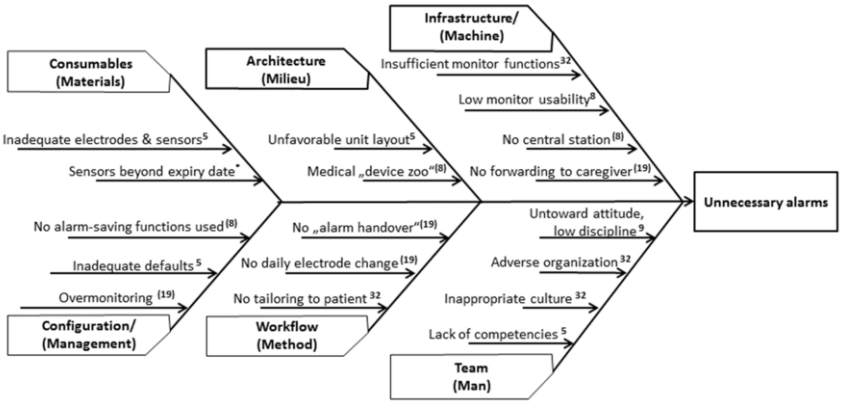

Figure 1: Two levels of the root cause model of unnecessary alarms; references in parentheses denote "inferred" causes, one cause marked with "*" was only mentioned during focus group sessions

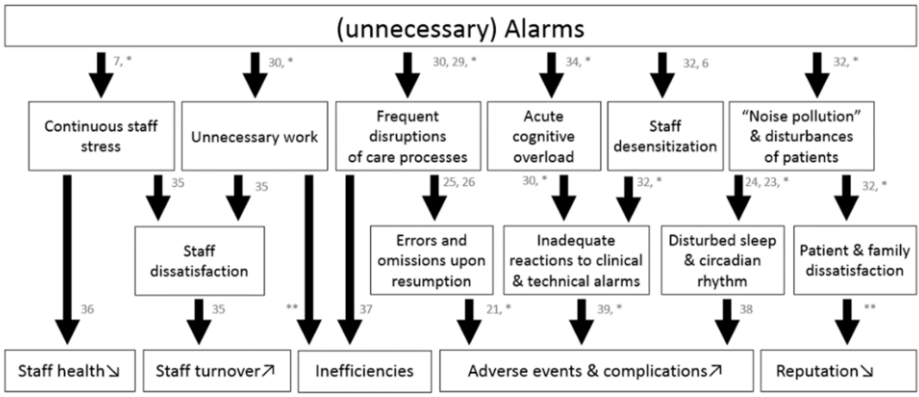

Figure 2: Potential impacts of unnecessary alarms. Not all causal relations are shown. Impacts mentioned during focus groups sessions are marked with "*", self-evident impact is marked with "**", only part of the supporting evidence from literature is referenced due to space limitations.

the literature, others may be less obvious. For instance, the relationship between disruptions of care processes and increased error rates has been demonstrated for some tasks in Healthcare settings (e.g. [20]), but only a few of them included ICU nurses [21].

Please note that, for a better readability, not all identified causal relationships are explicit shown in the figure. The impact of interruptions on stress, perceived workload and job satisfaction, for instance, is well established, but not depicted in the figure.

4. Discussion and Conclusion

Comprehensive models of both the contributing causes to unnecessary alarms and effects of these alarms are needed to guide the development of systematic approaches to address alarm fatigue. In the literature, we found only root cause models for particular units and events [22], but none that would aspire to cover the entire breadth of causal factors. Two general models, one for causes and one for effects of unnecessary alarms were developed,

based on a scoping review and expert interviews. The cause model shows that the root causes are located in very diverse areas: While some causes are related to technology and technical infrastructure, others stem more from the workflow/process domain. Another, often overlooked source of problems is associated with the ICU as a sociotechnical system and people working in a team: Their attitude and discipline, technical and clinical competencies as well as collaboration and communication within the team. The two models allow to causally link root causes to undesirable consequences, avoiding the need to establish a consented and measurable model of Alarm fatigue as a condition of individual healthcare workers. The obvious fact that any of the diverse root causes may be present or absent in a unit also explains the fact that Alarm fatigue so far defeated many attempts of a unified solution: Only if the concrete unit at hand is understood regarding all of the possible root causes, one can try to improve the situation with reasonable hope of success. It must be noted that while the literature provides many recommendations to reduce unnecessary alarms, there seems to be a "blind spot" regarding actionable advice to influence behavioral factors of caregivers and teams.

Further work is needed to map the impacts of unnecessary alarms to indicators which are routinely measurable on an ICU and which cover all (or most of) the dimensions of the effect model. Work on a first set of such indicators has already started in the AlarmRedux project. These indicators will also allow transitioning from generic and unconditional advice dominating the literature (e.g. in *[19]*) to specific interventions addressing identified root causes.

Conflict of Interest

Dirk Hüske-Kraus is working at Philips Healthcare. Wolfgang Schlauch is working at Bitsea GmbH. The other authors state that they have no conflict of interests. All authors are part of the AlarmRedux-Project (www.alarmredux.de) founded by the Federal Ministry of Education and Research (BMBF). (Code: 16SV7501)

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