"I Want My Control Room To Be…": On the Aesthetics of Interaction in a Safety-Critical Working Environment

Nadine Flegel
N.Flegel@hochschule-trier.de
Trier University of Applied Sciences
Trier, Germany

Jonas Pöhler
jonas.poehler@uni-siegen.de
University of Siegen
Siegen, Germany

Kristof Van Laerhoven
kvl@eti.uni-siegen.de
University of Siegen
Siegen, Germany

Tilo Mentler
T.Mentler@hochschule-trier.de
Trier University of Applied Sciences
Trier, Germany

ABSTRACT

Control rooms are safety-relevant working environments characterized by complex IT infrastructure. With regard to the interaction of operators with control room systems, usability has been the major criteria for decades. However, there is increasing discussion about the extent to which the concept of user experience (UX) also plays a role in such safety-critical contexts. What is still largely missing is the application of concrete UX-specific methods in the context of control rooms. This paper explains how and with what results 9 operators used an interaction vocabulary focusing on pragmatic and hedonic qualities to complete the sentence "I want my control room to be…". Results first suggest that pragmatic, i.e., usability-oriented, attributions are of greater importance to operators. However, especially the more UX-specific terms of the interaction vocabulary, which were initially not found to be so relevant, yielded many valuable hints and inspiration for the future design of control room workplaces. By reflecting on the process of discussing the aesthetics of interactions in such a safety-critical working environment, recommendations are provided for considering UX in safety.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; • **Security and privacy → Human and societal aspects of security and privacy**.

KEYWORDS

Interaction Vocabulary, User Experience, Control Room, Safety-Critical Systems

ACM Reference Format:
Nadine Flegel, Jonas Pöhler, Kristof Van Laerhoven, and Tilo Mentler. 2022. "I Want My Control Room To Be…": On the Aesthetics of Interaction in a Safety-Critical Working Environment. In *Mensch und Computer 2022 (MuC '22), September 4–7, 2022, Darmstadt, Germany.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3543758.3547562

MuC '22, September 4–7, 2022, Darmstadt, Germany

ACM ISBN 978-1-4503-9690-5/22/09…$15.00
https://doi.org/10.1145/3543758.3547562

1 INTRODUCTION

Control rooms and other "location[s] designed for an entity to be in control of a process" [9], e.g. cockpits, operating rooms or ship bridges, are complex working environments and of central importance to many work domains (e.g. crisis management, healthcare, power supply). They are associated with high demands on people, technology and organization in order to ensure efficient regular operation and manageable exceptional operation. These demands will become even more stringent in the future, as tasks and responsibilities of control room operators in many domains grow (e.g., low-voltage power grids in energy supply, deployment volume in larger jurisdictions for fire and rescue services).

In the context of human-computer interaction in control rooms, usability, as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [5], has been the essential criterion of evaluation for decades [16, 18, 20]. User experience (UX), as the "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service" [5], has been discussed sporadically in terms of better and safety-enhancing design solutions and operators' well-being [7, 10, 12, 19]. Even if the importance of the issue "UX in safety" seems to be clear, there is still a lack of applying UX-specific methods (e.g. empathy maps, user journeys) to safety-critical working environments. Human needs like autonomy, expertise or safety provide a promising starting point and could serve as inspiration for designers.

In this regard, this work makes two contributions. First, it explains how 9 operators used an interaction vocabulary focused on pragmatic and hedonic qualities to complete the sentence "I want my control room to be…". Second, there is guidance on the application of UX-specific methods in safety-critical contexts in general by reflecting on the process. Methods and results are described in sections 2 & 3. Results, limitations and future work are discussed in section 4.

2 METHODS

This section will provide details on the experiment design in terms of participants, methods, materials and procedure.

Table 1: Overview of participants' working areas and years of experience.

Control Room ID	Person ID	Area	Experience with control room activities in years
CR1	1	Head of control room (fire and rescue services)	>15
CR1	2	Dispatcher and system administrator (fire and rescue services)	>10
CR1	3	System administrator (fire and rescue services)	1
CR2	4	Former Head of control room (energy control room)	>10
CR2	5	Head of control room (energy control room)	>10
CR3	6	Department head grid management (energy control room)	15
CR4	7	Head of control room (energy control room)	8
CR5	8	Head of control room (fire and rescue services)	20
CR6	9	Head of control room (fire and rescue services)	28

Table 2: Interaction Vocabulary attributed to pragmatic/ hedonic/no specific quality (PQ/HQ/-) by [10] (Translated from German)

slow (-)	-	fast (PQ)
stepwise (HQ)	-	fluent (-)
approximate (-)	-	precise (PQ)
gentle (-)	-	powerful (-)
instant (PQ)	-	delayed (-)
stable (PQ)	-	changing (HQ)
mediated (-)	-	direct (PQ)
spatial separation (-)	-	spatial proximity (HQ)
incidental (PQ)	-	targeted (HQ)
covered (-)	-	apparent (PQ)
undemanding (PQ)	-	attention-seeking (HQ)

2.1 Participants

According to the taxonomy of Mentler et al. [13] which focuses on the location of control rooms as well as the number of operators working in parallel, we consider control rooms with fixed locations as a starting point. A total of 9 control room professionals from two types of these control rooms were recruited in our study (see Table 1), and interviewed in-person or online. As these control rooms are still very much a male-dominated domain, the gender-biased, all-male distribution is representative of the domain context considered. Participants were recruited in a variety of ways as part of the research project PervaSafe Computing [6], including following up on an online survey of control room staff and through direct contact with control room representatives who have made public appearances through presentations.

2.2 Materials

The aim of this study was to gain insight into the fundamental requirements that control room operators have of the complex IT infrastructure they use ("the control room") as a whole. It was considered from a holistic viewpoint and not just related to functionality. Individual applications and user interfaces were not to be the subject of consideration. For this purpose, the Interaction Vocabulary by Diefenbach et al. [2] was used in the version published in 2010. Consisting of 22 terms that can be understand as 11 pairs of words (see Table 2), it serves as "a repertoire of interaction qualities to choose from" [3] and "establishes the notion of an aesthetic of interaction beyond efficiency and beyond an obsession with the currently most fashionable interaction technologies" [4]. The Interaction Vocabulary is guided by the research model introduced by Hassenzahl et al. [8] distinguishing hedonic and pragmatic qualities of interactive systems. While pragmatic quality (PQ) is closely related to usability aspects (effectiveness, efficiency), hedonic quality (HQ) is characterized by appealing visual design, creation of new possibilities of use, or communication of a desired identity.

According to a study by [2], specific dimensions of the Interaction Vocabulary with particular relevance for hedonic and pragmatic quality can be identified. However, ambivalences of individual dimensions became evident, e.g. while a "stable" interaction is associated with a high pragmatic quality, "changing" interaction is considered as hedonic quality. The same applies to "incidental - targeted". Since the word pairs are not used here as opposites (see the following section), the corresponding attributions, where present, are used without discussion of these tensions.

There are 2 arguments that speak for the use of the Interaction Vocabulary in this context: (1) The approach is technology independent. Results could potentially be transferred to control room concepts that go beyond the state of the art, e.g., smart control rooms [14, 17] or pervasive computing environments [6]. (2) Terms different aspects of UX, specifically both pragmatic and hedonic qualities. They are not limited to functionality provided by current technology and usability-related measures (effectiveness, efficiency, satisfaction). For these reasons, this approach seemed well suited to provide operators with a suitable tool to complete the sentence "I want my control room to be...".

2.3 Procedure

Data was collected in two different ways (workshops in-person, expert interviews online) due to the pandemic-related restrictions in force at the time in 2021. Workshops were conducted by 3 members of the research team in-person in one fire and rescue service control room and one energy control room. As one part of the workshop each participant sorted the terms printed on paper for themselves (n=5; Person ID 1-5). The expert interviews consisted of

Table 3: Results of the Interaction Vocabulary term sorting (N=9; HQ: hedonic quality; PQ: pragmatic quality; -: no direct attribution, Yes: fits, —: don't know, No: doesn't fit)

		1	2	3	8	9	4	5	6	7	In total (#yes)
term	PQ/HQ/-	fire and rescue services					energy control room				
targeted	HQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
precise	PQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
fast	PQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
stable	PQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
instant	PQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
mediated	–	Yes	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes	8
direct	PQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	8
changing	HQ	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	7
apparent	PQ	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	–	7
attention-seeking	HQ	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
powerful	–	Yes	Yes	Yes	–	–	Yes	Yes	Yes	No	6
fluent	–	Yes	Yes	No	–	Yes	Yes	Yes	No	Yes	6
spatial proximity	HQ	Yes	Yes	No	No	Yes	Yes	Yes	No	No	5
spatial separation	–	No	Yes	No	Yes	Yes	No	No	Yes	Yes	5
stepwise	HQ	Yes	Yes	Yes	–	Yes	–	No	Yes	No	5
gentle	–	Yes	Yes	No	Yes	No	–	Yes	No	No	4
undemanding	PQ	No	No	No	Yes	No	No	No	Yes	No	2
incident	PQ	No	Yes	No	No	No	No	No	No	No	1
approximate	–	No	No	No	No	Yes	No	No	No	No	1
delayed	–	No	No	No	No	No	No	No	No	No	0
slow	–	No	No	No	No	No	No	No	No	No	0
covered	–	No	No	No	No	No	No	No	No	No	0

3 parts with different subjects. Interaction Vocabulary was one part. During these, participants (n=4; Person ID 6-9) had the same task as the workshop participants conducted on an interactive collaborative online board. In both cases, there was no time limit or other restrictions since the scope and nature of the task were classified in advance as not time critical. The 22 terms have not been explained because no explanation exists from the authors [2] and this is not foreseen in this approach. Rather, participants were asked to act according to their own understanding. Comments expressed by participants during the conduct of the study were recorded with their consent as part of the higher-level workshop or interview documentation (see section 3).

The 22 terms of the Interaction Vocabulary were provided individually. The authors of the Interaction Vocabulary themselves propose two variants of use [1]. On the one hand, as cards with word pairs printed on both sides in the sense of a either this or that decision. On the other hand, as a questionnaire in the sense of a semantic differential scale. Our approach is based on the first variant but does not require the exclusion of individual terms by choosing others. Instead, participants were asked to sort each of the 22 terms into one of three categories (doesn't fit, don't know, fits) with respect to the start of the sentence "I want my control to be…". The reason for this is that we are not examining a specific simple function such as an interaction concept for the function "control of a light" [3], but a broad field of interaction and experience possibilities in control rooms as safety-critical working environments.

3 RESULTS

The following describes the classification of the terms of the Interaction Vocabulary by the operators. In addition, comments and remarks of them regarding individual terms of the Interaction Vocabulary are given. Finally, further remarks are summarized, which are not directly represented in the Interaction Vocabulary. Table 3 shows the results for each participant's Person ID grouped by the domain and sorted by the terms that were rated most appropriate.

Of the total 198 possible assignments (22 items, 9 participants), 96% were assigned to the categories "fit" or "doesn't fit". Five terms were classified as "fit" by all participants: targeted (HQ), precise (PQ), fast (PQ), stable (PQ) and instant (PQ). Three terms were classified as "doesn't fit" by all participants: delayed (-), slow (-) and covered (-). For the remaining terms, assignment was not clear-cut, even though some were considering more "fitting" to the statement "I want my control room to be…" and some with only slight one. Individual terms were explicitly commented. In detail:

The term incidental (PQ) was considered appropriate by one participant. CR1-2 justified the positive attribution by stating that an operator needs a focus in the control room and certain things are inevitably incidental as a result.

CR6-9 stated that the term undemanding (PQ) could be understood in two ways: In the sense of employees, he would classify it not suitable, because they are engaged in a demanding activity every day. In the sense of technology, however, he would find it suitable because the handling of technology should be undemanding in order to make fewer mistakes.

Some participants laughed at the term "gentle" (-); CR4-7: "A control room is not a petting zoo!", others saw an important quality in this term regarding the operators; CR1-1: "The control room must treat its employees with care".

There were differences in the way the terms spatial proximity (HQ) and spatial separation (-) were considered. CR1-3 ranked both terms as not matching, CR1-2 and CR6-9 ranked both as matching and the rest ruled out one of each. Spatial separation (-) could be understood in the sense of the COVID-19 pandemic as the spatial separation of workplaces. Possibilities such as working in a home office or using other rooms (e.g. a seminar room) were often used for the first time. CR1-1: "During the pandemic, we were sometimes divided into groups and some people sat alone or in pairs in other rooms. It was hard to get them away, they could adjust everything individually, the light, the heating, the volume. And it worked well.". Another way of looking at it is the spatial separation of a control room from its copy as a training control room or a "backup control room" in case the system should fail. Spatial proximity (HQ) is assessed by some to mean that it is necessary for all staff to be in one room. CR6-9 describes that spatial proximity (HQ) is suitable for him in the sense that there is a redundant system of the control room in another nearby room in case the system fails.

Some people associated the term stepwise (HQ) with the prioritisation of telephone calls. In a fire and rescue control room, for example, emergency calls are prioritised highest, followed by other callers, such as the police.

During discussions with operators, it became clear that they have wishes about how new control rooms should be designed. In reality, this often fails due to a lack of communication between operators as users, manufacturers, and organisations which run control rooms. Participants named specific characteristics they would consider to descriptive for an ideal control room. The collection of all terms are as follows: big, organized, critical, competent, safe, open to new ideas, solution-oriented, failsafe, resilient, technically up to date, clean, generous, flexible, modern, bright, tidy, accessible, clearly arranged, team player/team oriented, high feel-good factor, expandable and extendable.

4 DISCUSSION

The aim of this study was to gain first insights on the aesthetics of interaction in the safety-critical working environment of control rooms from an operators' point of view and in due consideration of pragmatic and hedonic qualities. The results suggest that operators generally give higher weight to pragmatic quality, i.e. focused on aspects such as effectiveness and efficiency. This is not surprising at first, since safe procedures and the associated requirements are of central importance and this also corresponds to the self-image of the responsible activity of operators. Simply put, a control room that provides visual stimulation (hedonic quality), for example, but does not enable fast task completion (pragmatic quality) is unsuitable. Operators are well aware of that. Research in the broader field of usable safety and security basically confirms this, e.g. statements like " dependability cannot be compromised for user experience [...]" [15] or "result of use takes precedence before the experience of the users" [11]. However, comments on terms, which are not primarily aimed at pragmatic quality, show that the range of requirements for an ideal control room from the operator's point of view is broader (e.g. "The control room must treat its employees with care"). This impression is further strengthened if one includes comments that were free and not linked to the Interaction Vocabulary. Physical space and working atmosphere were described with adjectives such as large, bright, tidy and quiet; followed by other adjectives with character traits that could also be attributed to a work colleague, such as competent, team player, resilient, open to new ideas, and solution-oriented. The phrase "high feel-good factor" sums up this broader claim well.

In addition to content aspects, implementation and suitability of the methodology needs to be discussed. None of the operators refused to participate, although the Interaction Vocabulary task was not explicitly announced in advance. They did not have any difficulties according to the assessment of the researchers present. In almost all cases, clear assignment was possible. Processing time varied noticeably, from sorting several terms in a few seconds to longer considerations (< 1 minute), which according to the comments have a lot to do with the interpretation of the respective terms. Basically, the Interaction Vocabulary used was considered interesting as in "I haven't been asked that before".

Some limitations need to be addressed. While most of the participants have years to decades of experience with control room activities, results must be evaluated cautiously due to the small sample size and different work domains. Exact interpretation of the order of assignments should be avoided. Furthermore, the understanding or interpretation of the individual terms was not explicitly queried. It was partially communicated by the participants, but nevertheless it cannot be ruled out that the same assessments are based on very different understandings. Similarly, the freely expressed comments were only recorded, but not decidedly discussed in terms of individual elements of the control room. With regard to the acceptance of the methodology, reference should also be made to the small sample size. However, it can at least be ruled out that only people who had assessed the Interaction Vocabulary as interesting in advance participated. As already mentioned, it was used without prior notice in the context of workshops and interviews. Thus, there was a basic interest among participants in supporting research, but no method-specific preference.

Future work will focus on expanding the number of participants. For this purpose, the Interaction Vocabulary could be made available as a web-based solution, which could be used independently of researchers' presence. In addition, the question of how the desired properties can be reflected in the concrete design of control rooms is pursued. How does a "gentle control room" behave and look like? In an overarching sense, it will be necessary to examine how the UX perspective is compatible with requirements for safety and security. This means investigating the extent to which common measurements for UX, which are often focused on the consumer realm, fit or need to be adapted.

5 CONCLUSION

Though the importance of considering user experience in addition or extension to usability in safety-critical working environments has already been outlined, there is a lack of UX-specific methods

applied to these contexts. The use of an interaction vocabulary focused on pragmatic and hedonic qualities (PQ/HQ) by 9 control room operators, presented here, provides initial insights. While these safety professionals want their working environment and interaction experience to be fast (PQ), precise (PQ) and stable (PQ) in a first place, "feel good factors" should not be neglected. The methodical approach was positively received by the participants, even if some individual terms were associated with a smirk or longer musings. More generally, approaches developed for leisure and entertainment or not explicitly for safety-critical contexts need to be critically evaluated. For example, questions about the enjoyment or fun of using a control room system in the context of rescue operations could certainly seem misleading. In any case, the rule is: safety first.

ACKNOWLEDGMENTS

This project is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 425868829 and is part of Priority Program SPP2199 Scalable Interaction Paradigms for Pervasive Computing Environments.

REFERENCES

[1] Sarah Diefenbach and Marc Hassenzahl. 2017. *Psychologie in der nutzerzentrierten Produktgestaltung*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-53026-9

[2] Sarah Diefenbach, Marc Hassenzahl, Kerstin Klöckner, Claudia Nass, and Andreas Maier. 2010. Ein Interaktionsvokabular: Dimensionen zur Beschreibung der Ästhetik von Interaktionen. In *Tagungsband UP10*, Henning Brau, Sarah Diefenbach, Katharina Göring, Matthias Peissner, and Kostanija Petrovic (Eds.). Fraunhofer Verlag, Stuttgart, 27–32.

[3] Sarah Diefenbach, Eva Lenz, and Marc Hassenzahl. 2013. An Interaction Vocabulary. Describing the How of Interaction.. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (Paris, France) *(CHI EA '13)*. Association for Computing Machinery, New York, NY, USA, 607–612. https://doi.org/10.1145/2468356.2468463

[4] Sarah Diefenbach, Eva Lenz, and Marc Hassenzahl. 2013. An Interaction Vocabulary. Describing the How of Interaction.. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (Paris, France) *(CHI EA '13)*. Association for Computing Machinery, New York, NY, USA, 607–612. https://doi.org/10.1145/2468356.2468463

[5] DIN EN ISO 9241-11. 2018. DIN EN ISO 9241-11:2018-11, Ergonomie der Mensch-System-Interaktion - Teil 11: Gebrauchstauglichkeit: Begriffe und Konzepte (ISO 9241-11:2018); Deutsche Fassung EN ISO 9241-11:2018.

[6] Nadine Flegel, Jonas Poehler, Kristof Van Laerhoven, and Tilo Mentler. 2022. Towards Control Rooms as Human-Centered Pervasive Computing Environments. In *Sense, Feel, Design*, Carmelo Ardito, Rosa Lanzilotti, Alessio Malizia, Marta Larusdottir, Lucio Davide Spano, José Campos, Morten Hertzum, Tilo Mentler, José Abdelnour Nocera, Lara Piccolo, Stefan Sauer, and Gerrit van der Veer (Eds.). Springer International, Cham, 329–344. https://doi.org/10.1007/978-3-030-98388-8_29

[7] Tobias Grundgeiger, Jörn Hurtienne, and Oliver Happel. 2021. Why and How to Approach User Experience in Safety-Critical Domains: The Example of Health Care. *Human Factors* 63, 5 (2021), 821–832. https://doi.org/10.1177/0018720819887575

[8] Mare Hassenzahl, Axel Platz, Michael Burmester, and Katrin Lehner. 2000. Hedonic and Ergonomic Quality Aspects Determine a Software's Appeal. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (The Hague, The Netherlands) *(CHI '00)*. Association for Computing Machinery, New York, NY, USA, 201–208. https://doi.org/10.1145/332040.332432

[9] Erik Hollnagel and David D. Woods. 2006. *Joint cognitive systems: Patterns in cognitive systems engineering*. Taylor & Francis, Boca Raton, FL. https://doi.org/10.1201/9781420005684

[10] Hannu Karvonen, Hanna Koskinen, Helena Tokkonen, and Jaakko Hakulinen. 2014. Evaluation of User Experience Goal Fulfillment: Case Remote Operator Station. In *Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality*, Randall Shumaker and Stephanie Lackey (Eds.). Springer International Publishing, Cham, 366–377. https://doi.org/10.1007/978-3-319-07464-1_34

[11] Tilo Mentler. 2021. Usability Engineering und User Experience Design sicherheitskritischer Systeme. In *Sicherheitskritische Mensch-Computer-Interaktion: Interaktive Technologien und Soziale Medien im Krisen- und Sicherheitsmanagement*, Christian Reuter (Ed.). Springer Fachmedien, Wiesbaden, 47–66. https://doi.org/10.1007/978-3-658-32795-8_3

[12] Tilo Mentler and Michael Herczeg. 2016. On the Role of User Experience in Mission- or Safety-Critical Systems. In *Mensch und Computer 2016 – Workshopband*, Benjamin Weyers and Anke Dittmar (Eds.). Gesellschaft für Informatik e.V., Aachen. https://doi.org/10.18420/muc2016-ws01-0001

[13] Tilo Mentler, Philippe Palanque, Michael D. Harrison, Kristof Van Laerhoven, and Paolo Masci. 2022. Control Rooms from a Human-Computer Interaction Perspective. In *Sense, Feel, Design*, Carmelo Ardito, Rosa Lanzilotti, Alessio Malizia, Marta Larusdottir, Lucio Davide Spano, José Campos, Morten Hertzum, Tilo Mentler, José Abdelnour Nocera, Lara Piccolo, Stefan Sauer, and Gerrit van der Veer (Eds.). Springer International, Cham, 281–289. https://doi.org/10.1007/978-3-030-98388-8_25

[14] Tilo Mentler, Tim Rasim, Marcel Müßiggang, and Michael Herczeg. 2018. Ensuring usability of future smart energy control room systems. *Energy Informatics* 1, 1 (2018), 167–182. https://doi.org/10.1186/s42162-018-0029-z

[15] Philippe Palanque, Andy Cockburn, and Carl Gutwin. 2020. A Classification of Faults Covering the Human-Computer Interaction Loop. In *Computer Safety, Reliability, and Security*, António Casimiro, Frank Ortmeier, Friedemann Bitsch, and Pedro Ferreira (Eds.). Springer International Publishing, Cham, 434–448. https://doi.org/10.1007/978-3-030-54549-9_29

[16] Rohn J. Petersen, William W. Banks, and David I. Gertman. 1982. Performance-Based Evaluation of Graphic Displays for Nuclear Power Plant Control Rooms. In *Proceedings of the 1982 Conference on Human Factors in Computing Systems* (Gaithersburg, Maryland, USA) *(CHI '82)*. Association for Computing Machinery, New York, NY, USA, 182–189. https://doi.org/10.1145/800049.801778

[17] Daniel Reich, Felix Putze, Dominic Heger, Joris Ijsselmuiden, Rainer Stiefelhagen, and Tanja Schultz. 2011. A real-time speech command detector for a smart control room. In *Twelfth Annual Conference of the International Speech Communication Association*. ISCA, Florence, Italy, 2641–2644. https://doi.org/10.21437/Interspeech.2011-675

[18] Paula Savioja, Iina Aaltonen, Hannu Karvonen, Hanna Koskinen, Jari Laarni, Leena Norros, and L. Salo. 2012. Systems usability concerns in hybrid control rooms. In *Proceedings*, Vol. 1. American Nuclear Society (ANS), United States, 476–487. Project code: 73575 (Safir Hacas); 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies, NPIC & HMIT 2012, NPIC & HMIT 2012 ; Conference date: 22-07-2012 Through 26-07-2012.

[19] Paula Savioja, Marja Liinasuo, and Hanna Koskinen. 2014. User experience: does it matter in complex systems? *Cognition, Technology & Work* 16, 4 (2014), 429–449. https://doi.org/10.1007/s10111-013-0271-x

[20] Thomas A. Ulrich, Ronald L. Boring, and Roger Lew. 2018. Qualitative or Quantitative Data for Nuclear Control Room Usability Studies? A Pragmatic Approach to Data Collection and Presentation. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 62, 1 (2018), 1674–1678. https://doi.org/10.1177/1541931218621380