Autonomy and Safety: A Quantitative Study with Control Room Operators on Affinity for Technology Interaction and Wish for Pervasive Computing Solutions

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ABSTRACT

Control rooms are central to the well-being of many people. In terms of human computer interaction (HCI), they are characterized by complex IT infrastructures providing numerous graphical user interfaces. More modern approaches have been researched for decades. However, they are rarely used. What role does the attitude of operators towards novel solutions play? In one of the first quantitative cross-domain studies in safety-related HCI research (N = 155), we gained insight into affinity for technology interaction (ATI) and wish for pervasive computing solutions of operators in three domains (emergency response, public utilities, maritime traffic). Results show that ATI values were rather high, with broader range only in maritime traffic operators. Furthermore, the assessment of autonomy is more strongly related to the desire for novel solutions than perceived added safety value. These findings can provide guidance for the design of pervasive computing solutions, not only but especially for users in safety-critical contexts.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *Interaction paradigms.*

KEYWORDS

Control Room, Affinity for Technology Interaction, Autonomy, Safety, Pervasive Computing

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1 INTRODUCTION

If the electric light comes on when you flip the switch and water flows in the shower in the morning, when you encounter an ambulance and a fire brigade on your way to work, and the supermarket is well stocked in the evening, then the control room operators in various domains worked in the background to ensure all this.

To operate successfully in such "location[s] designed for an entity to be in control of a process" [18], means to handle a variety of alarms and messages, solve demanding problems and make short-term decisions with the help of colleagues and complex IT infrastructures. While pervasive technologies (e.g., wearables, smart home solutions) are increasingly becoming part of private and professional life, where "people and devices are mobile and use various wireless networking technologies to discover and access services and devices in their vicinity" [38], state of the art control rooms are characterized by numerous screens and graphical user interfaces operated by mouse and keyboard. Cooperation between operators is rarely proactively supported by technology. Approaches that go beyond these established solutions have been researched for decades. Although their benefits have been demonstrated, as illustrated in section 2, that has hardly had any impact on practice so far. The question is, why?

It can be assumed that there is no single answer and that various factors contribute (financial, legal, etc.). One of them could be that operators don't want to engage with new solutions because they prefer proven ones due to their high-responsibility job. Answers are becoming more urgent as demands on control rooms increase in many areas (e.g., private photo-voltaic systems influence energy grids, the number of emergencies increases due to demographic and climate change).

In any case, "it is crucial that HCI researchers [...] contribute to next-generation control room technologies" [6]. In the following, we take a quantitative approach to shed light on and compare operators' perspectives from three domains (emergency response, maritime traffic, and public utilities). First, their affinity for technology interaction (ATI) is considered. Whether a person approaches or avoids interaction with technology [13] is considered an important component of operator skills [7]. Instead of relying on common self-assessments [33], a validated ATI scale was used (see section 3).

Second, we have provided specific suggestions for pervasive computing in control rooms and asked operators to assess influences on autonomy, safety, and their wish to use them. Specifically, we focus on the following three research questions:

- **RQ1:** What is the distribution of affinity for technology interaction in control room operators?
- **RQ2:** What is control room operators' assessment of different pervasive technology scenarios regarding safety, autonomy and their wish to use such a solution?
- **RQ3:** What is the relationship between affinity for technology interaction and wish for pervasive technology?

The remainder of this paper is structured as follows: In section 2, we summarize previous research on control rooms. The subsequent section 3 provides details on study design. Results (see section 4) are presented, focusing on affinity for technology perspectives and feedback on pervasive computing approaches, followed by a discussion of results in section 5. Finally, goals and main outcomes of this study are summarized (see section 6).

2 RELATED WORK

Subsequently, characteristics and HCI-related research of control rooms relevant for further understanding are described.

2.1 Characteristics of Control Room Environment

Multi-screen single-user workstations, larger wall-mounted screens, graphical user interfaces operated with a mouse, keyboard, and other haptic controls (e.g., knobs), as well as shift work can be considered characteristic for the state of the art control rooms fitting the generic definition in section 1 [21, 40, 41, 47]. Mobile devices, wearables, and sensors have rarely been used so far [17, 20, 27]. In general, a rather conservative attitude to novel technology can be identified [32, 37].

In addition to these, there are domain-specific characteristics. A possible differentiation is provided by the taxonomy of Mentler et al. [36] focusing on location and number of operators acting in parallel (see Figure 1). It mentions a key difference between control rooms at "fixed" locations (e.g., emergency response, public utilities) and "mobile" control rooms that are often part of the managed infrastructure and processes (e.g., ship bridges, aircraft cockpits).

This difference concerns means and way of work. In control rooms with fixed locations, there are often input and output devices comparable to office environments - only in larger numbers (more private and public screens, more than one keyboard and mouse at a single workstation, headsets connected to a telephone system that routes multiple calls in parallel to one operator) [37]. In "mobile" control rooms, operators work with more customized solutions because rooms are usually narrower, in motion (e.g., swaying) and can be exposed to extreme weather conditions [29, 30, 42]. In addition, many tasks (e.g., "manoeuvring close to a towering oil rig" [30]) require a look outside the windows.

While operators working in control rooms with fixed locations can return home after their shifts, operators working in mobile settings often can't. For example, many maritime traffic operators are on the move for several days to months on different ships with changing sizes, bridges, and international crews in a wide variety of locations [30, 31].

2.2 HCI-related Research on Control Rooms

Control rooms have been studied by HCI researchers for more than 30 years with respect to automation, alarms, collaboration, safety culture, situation awareness, training, interaction design, and workload [6, 41, 47]. Apart from conceptual or model-based approaches [3, 5], the majority of research involving operators is characterized by qualitative approaches, e.g., contextual inquiries [50], ethnographies [4, 16], expert evaluations [25], interviews [12, 28], participatory observations [19], and usability inspections [1]. Valuable insights have been gained on control rooms as contexts of use. Quantitative approaches that complement these findings and facilitate transferability have been rarer. They are often characterized by studies with smaller sample sizes that complicate the interpretation of results [22, 48]. With a few exceptions (e.g., [34, 46]), research is devoted to a specific control room domain (e.g., simulator studies [15, 24], questionnaires [8]).

Current research on user interface and interaction design for control rooms is devoted to multi-modal interaction, extended reality applications, and enhanced collaboration (e.g., touch control for surfaces, gesture and voice control at workstations, [2, 23, 25, 44]). Findings have often been promising, but "there still exists a gap between the interaction technologies being employed in pervasive displays used in other settings and those used in control rooms" [17].

Less related to individual applications, but to control rooms as a whole, approaches of "smart control rooms" [23, 37] or "control rooms as human-centered pervasive computing environments" [12] have been developed. They break with traditional interaction paradigms as there are no single desktop workstations any more, and users are able to interact in the moment when the need arises, regardless of what they were doing in the first place. These control rooms might include solutions that proactively execute identified tasks, filter messages by priority or route them to other operators if one is busy or stressed, ensure messages reach operators, or suggest actions to maintain the operators' health [35].

Operators have often been involved in participatory design processes and as participants in usability tests (e.g., [9, 10, 23]). While performance and well-being have already been addressed, to the authors' knowledge, there has not been any assessment of technology affinity or related concepts yet. However, it cannot be assumed that operators, due to their technology-influenced work environment, are generally positive about new forms of technology. In summary, HCI-related quantitative research involving operators of different control room types is largely absent.

3 METHOD

Within the framework of the research project PervaSafe Computing, which is dedicated to the topic of human-centered pervasive computing environments [12], an online survey was conducted via LimeSurvey to investigate **RQ1**-**RQ3**. Invitations were sent out in germany via email to 112 fire and rescue services (emergency control rooms), 263 public utility companies (energy and water

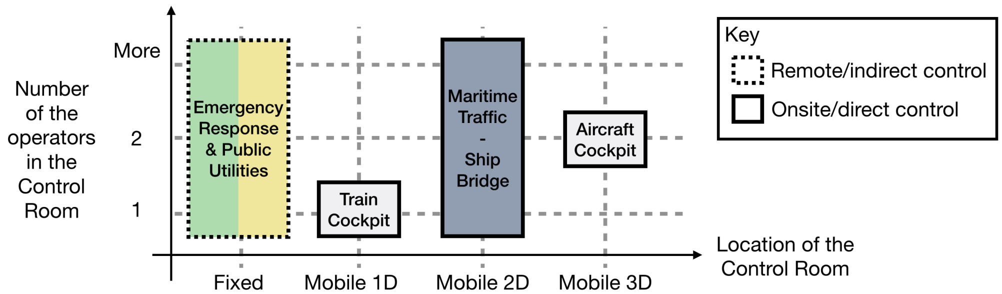

Figure 1: Types of control rooms according to location and number of operators (Illustration based on [36]. Highlighted areas (green, yellow, dark grey) indicate the 3 domains considered in this study and are reflected in the statistical analyses).

control rooms) and 9 associations of captains and ship officers (maritime traffic control rooms). They represent control room contexts that are both different enough to gain insight into the transferability of findings and comparable with respect to the taxonomy shown in Figure 1. Among others, the Professional Association of Control Centers in germany invited their members to participate. Links were distributed in the forum of the web-based control room simulation LstSim (https://lstsim.de/).

Survey questions assessed demographic variables (including age group, job domain, work experience), current state of workplace digitization (including use of tablets, smartphones, IoT, etc.), evaluation of pervasive technology use cases, and affinity for technology interaction.

Scenarios (see Table 2 and appendix Table 3) were selected in collaboration with domain experts during interview and workshop activities within the project to cover a variety of use cases relevant in all three domains: to adapt tasks and task load to current demands (A-D), to improve communication (B, E), and to help dealing with high stress levels and maintaining the operators' health (F-H). Respondents rated on a six-point Likert scale (completely disagree to completely agree) whether the pervasive technology used in the scenario would improve safety, maintains the operators' autonomy, and whether they would like to have it available (wish). To control for acquiescence bias, for half of the participants, the agreement to the scenarios (whether it would improve safety or autonomy) was reverse coded (e.g., "does not increase autonomy").

To assess affinity for technology interaction (ATI) in a structured manner, the scale by Franke et al. was used (ATI-scale, [13], see appendix Table 4). It is grounded in the psychological construct need for cognition and assesses a person's tendency to actively engage in intensive technology interaction as a uni-dimensional construct with a short (9 items) and reliable scale. Answers are given on a six-point Likert scale (from 1 = completely disagree to 6 = completely agree). Validity has been demonstrated with more than 1500 participants, and independently by other researchers [26].

Participants opened the link to the survey, were informed about study details, asked for consent to participate, and if they did, filled in their answers. Finally, they were thanked and asked if they would be available for further research requests. If yes, they were able to provide a contact email address independently of survey responses.

4 RESULTS

In total, 161 participants finished the survey. 59 of them agreed to be contacted for further research purposes. Data were manually checked for inconsistencies, such as people claiming a longer work experience than possible in their age group. This resulted in 155 usable answers with a fully completed ATI scale.

Demographic variables: 151 of 155 participants (97.4%) were male, three female (1.9%), one gave no answer (0.6%). Regarding age, 7 participants were between 18-29 years, 38 between 30-39 years, 49 between 40-49 years, 48 between 50-59 years, and 13 were 60 years or older. Work domain was unbalanced. 106 participants work in emergency services and 20 work in public utilities control rooms. All of the 29 answers in work domain "other" were related to maritime traffic, which is used as label for this group. Average work experience was 14.74 years (SD = 9.88), ranging from 0 to 44 years (see appendix, Figure 2). Maritime traffic operators had a significantly higher work experience (ANOVA, $F(2, 152) = 13.93$, $p < .001$, $\eta^2 = .15$), though care should be taken when interpreting results due to unequal group sizes.

Workplace and digitization: Number of coworkers (see appendix, Figure 3) and state of digitization (see appendix, Figure 4) support previous research (see section 2). Looking at mobile devices and private work spaces, maritime traffic operators are descriptively more mobile than emergency response operators, while public utilities control room operators frequently work with common workplace screens. Wearables and IoT are rarely used by any group.

Affinity for technology interaction: As Cronbach's alpha was .9 (excellent), items were combined into one mean ATI value (reverse-coding items 3, 6, and 8). Average ATI was 4.66 (SD = 0.84), ranging from 1.89 to 6.00 (see Table 1 and appendix, Figures 5 and 6). ATI was statistically significantly different between the three work domains (ANOVA, $F(2, 152) = 17.51$, $p < .001$, $\eta^2 = .19$), with maritime traffic operators having a lower ATI score than the other two groups, using Bonferroni-corrected post-hoc tests. Using the data from [13] as a comparison, emergency response operators and public utilities control operators have statistically significantly higher ATI values than the German quota sample (M = 3.61, SD = 1.08). For maritime traffic operators, no statistically significant differences could be found (see Table 1, two-sample t-tests were used as the raw data was available through the authors, one-sample t-tests using the German quota sample mean of 3.61

Table 1: ATI overall and in the three work domains

Domain	*M*	*SD*	Range	comparison with quota sample
Overall	4.66	0.84	1.89 — 6.00	$t(376.69) = 10.68$, $p < .001$
Emergency Services	4.84	0.71	2.67 — 6.00	$t(295.96) = 12.45$, $p < .001$
Public Utilities	4.77	0.50	4.00 — 5.56	$t(37.34) = 8.76$, $p < .001$
Maritime Traffic	3.91	1.05	1.89 — 5.67	$t(259) = 1.38$, $p = .17$

Table 2: Correlations between ATI and autonomy, safety and wish. The scenario refers to a digital assistance system for control rooms that detects (and) ...

Scenario	Correlation		*r*	*p*	effect size
A) execute tasks that were identified in the communication of the operators	**autonomy**	**wish**	**.55**	**< .001**	**large**
	ATI	**wish**	**.27**	**.001**	**small**
	safety	**autonomy**	**.26**	**.001**	**small**
	safety	**wish**	**.23**	**.003**	**small**
	ATI	autonomy	.13	.111	small
	ATI	safety	.05	.519	
B) whether an operator is on the phone and if so presents messages not via sound but using other modalities	**autonomy**	**wish**	**.63**	**< .001**	**large**
	ATI	**wish**	**.42**	**< .001**	**medium**
	safety	**wish**	**.30**	**< .001**	**small**
	ATI	**autonomy**	**.21**	**.009**	**small**
	safety	autonomy	.16	.051	small
	ATI	safety	.11	.187	small
C) an unusual work situation or system state and offers to log all activities in the control room automatically	**autonomy**	**wish**	**.52**	**< .001**	**large**
	safety	**wish**	**.38**	**< .001**	**medium**
	ATI	**wish**	**.24**	**.003**	**small**
	safety	**autonomy**	**.23**	**.005**	**small**
	ATI	safety	.10	.228	
	ATI	autonomy	.08	.319	
D) whether team briefings are currently being conducted, in which case the system offers to withhold low priority messages during that time	**autonomy**	**wish**	**.42**	**< .001**	**medium**
	safety	**wish**	**.37**	**< .001**	**medium**
	ATI	**wish**	**.23**	**.004**	**small**
	safety	**autonomy**	**.20**	**.014**	**small**
	ATI	autonomy	.14	.085	small
	ATI	safety	.12	.122	small
E) whether an operator is in his personal work space, if not the messages are presented where the person is at the moment	**autonomy**	**wish**	**.57**	**< .001**	**large**
	safety	**wish**	**.39**	**< .001**	**medium**
	safety	**autonomy**	**.32**	**< .001**	**medium**
	ATI	**wish**	**.21**	**.008**	**small**
	ATI	**safety**	**.16**	**.047**	**small**
	ATI	autonomy	.09	.267	
F) whether the operator is eating or drinking and gives the operator the instruction to do so if necessary	**autonomy**	**wish**	**.51**	**< .001**	**large**
	safety	**autonomy**	**.42**	**< .001**	**medium**
	safety	**wish**	**.39**	**< .001**	**medium**
	ATI	wish	.12	.142	small
	ATI	safety	-.05	.548	
	ATI	autonomy	-.07	.384	
G) by monitoring the respiratory frequency how stressed the operator is and if necessary distributes incoming tasks to other operators	**autonomy**	**wish**	**.40**	**< .001**	**medium**
	safety	**wish**	**.34**	**< .001**	**medium**
	safety	**autonomy**	**.22**	**.006**	**small**
	ATI	**wish**	**.19**	**.016**	**small**
	ATI	autonomy	.12	.135	small
	ATI	safety	.06	.439	
H) whether the operator needs physical exercise and gives movement recommendations	**autonomy**	**wish**	**.55**	**< .001**	**large**
	safety	**wish**	**.27**	**.001**	**small**
	ATI	**wish**	**.21**	**.008**	**small**
	safety	**autonomy**	**.20**	**.013**	**small**
	ATI	autonomy	.12	.130	small
	ATI	safety	-.02	.827	

as comparison leads to similar results). As the gender distribution is highly skewed (97.4% male) and [13] report gender differences, another comparison was done using only male participants, which leads to similar results.

Evaluation of the pervasive technology scenarios: Looking exploratively at the correlations between autonomy, safety and wish in the eight scenarios (see Table 2), we find large to medium positive correlations between autonomy and wish (ranging from .63 to .40), and medium to small positive correlations between safety and wish (ranging from .39 to .23) as well as safety and autonomy (ranging from .42 to .16).

Descriptively, maritime traffic operators are much more reluctant to use the suggested pervasive technology, while — in some cases — seeing that it preserves autonomy and contributes to safety. They are also the only group for whom with some scenarios, no member wants to use the technology (see appendix, Figure 7).

Possible relationships between affinity for technology interaction and pervasive technology scenarios: Looking at the correlations between ATI and autonomy, safety and wish (see Table 2), they ranged from medium ($r = .42$, wish for scenario B) to small or not even small (all correlations positive). Strongest ATI related correlations were between ATI and wish ($r = .42$ to .12, see Table 2).

5 DISCUSSION

Subsequently, results are discussed with respect to the aforementioned research questions and limitations of the study.

5.1 Distribution of Affinity for Technology Interaction (ATI; RQ1)

Looking at the ATI distribution, control room operators in emergency response and public utilities are open to technology and like to interact with it. Maritime traffic operators have lower ATI values. This might be partly explained by more frequent changes of work environments ("mariners move from ship to ship and from company to company" [39]), operators' expectations for the robustness ("durability") of technology in "mobile" control rooms [42], and higher average age. To some extent, these values reflect the taxonomy by [36] and domain similarities outlined in section 2.

While a selection bias cannot be excluded with an online survey about the use of technology, given that low ATI values were present in one group (maritime traffic operators), this effect would have to be group specific (occurring for emergency services and public utilities operators, but not for maritime traffic operators). In combination with the (for some scenarios) critical assessment of the pervasive technology scenarios, this bias seems unlikely. Given that all but four participants were male and there are indications for gender differences in ATI in the general population (with males having higher ATI on average, see [13]), the high ATI values might also be partly explained this way. However, again this does not explain the lower values in maritime traffic operators. While sampling all operators in a control room (e.g., cluster sampling) might provide more reliable answers, ATI values indicate that at least emergency and public utilities control room operators like to interact with technology more than the general population.

5.2 Assessment of Different Pervasive Technology Solutions Regarding Safety, Autonomy and Wish (RQ2)

The assessment of the pervasive technology scenarios (**RQ2**, cf. Table 2 and appendix, Figure 7) regarding safety, autonomy and whether operators want to use this technology, differs descriptively between scenarios and work domains. Pervasive technology with a high chance of acceptance are those that many operators want to have (wish). If they are technically feasible, they are "easy wins", esp. if the perceived consequences on safety are also seen as highly positive. These implementations could be used as a way to introduce pervasive technology to these contexts. Note that these scenarios can differ between groups. For emergency services, it would be logging unusual work situations, or having messages presented where the operator is at the moment. For public utilities control room operators, it would likely be indicating physical exercises. Finding a suitable scenario for maritime traffic operators is more difficult. It is much easier to identify scenarios that have little chance of succeeding, at least if their self-assessment is taken at face value. For example, indicating when to eat or drink, or monitoring stress, and even executing tasks automatically based on the communication, is not desired by the maritime traffic operators despite its descriptively higher safety evaluation.

The rejection of certain pervasive technology scenarios seems to be strongly related to its negative effect on operators' autonomy. In general, autonomy, not safety, seems to be more strongly positively correlated with wishing to have the pervasive technology (although autonomy and safety are also correlated. While these are correlations and no causal inferences can be drawn, it seems prudent to pay close attention to preserving users' autonomy when implementing pervasive technology in control rooms. A possible explanation could be the role of acting autonomously (incl. not being constrained by a system) in order to deal with exceptional circumstances. Further studies could examine by differentiating between autonomy in general as a human need (cf. self-determination theory, e.g., [43]) and autonomy in specific work situations, in which being constrained by the rules would have detrimental effects, including on safety.

Scenarios that operators do not desire do not necessarily imply that realization should not be attempted, especially if their utility for safety is seen. Further studies can use these results to delve deeper into the concrete concerns and try to find ways to ameliorate them. One likely concern is the perceived limiting of personal autonomy if such a system is used. However, there may be other variables that might be discovered during human-centered design processes. Cross-domain research can help to identify similar challenges [45] and transfer solutions [36].

5.3 Relationships Between Affinity for Technology Interaction and Wish for Pervasive Technology (RQ3)

As for possible relationships between ATI and pervasive technology scenarios (**RQ3**), ATI seems to be (weakly) related to whether a person wants to use a pervasive technology. Other variables, e.g., whether the solution preserves autonomy, seem to be more important. However, overall ATI values of the samples were rather high (with a broader range only in maritime traffic operators), which makes assessing honest correlations difficult [49]. Additionally, a high correlation between ATI and scenario evaluations could be constrained by the highly responsible work context. For example, a person might want to interact with technology, but not when doing so might put others at risk. Similar to the research on effects of attitudes on behavior, measuring closer to the actual situation leads to better predictions. Instead of using the ATI scale speaking about "a technical system" in general, it could be adapted to the systems used in the work context. Comparing these two variants would allow the detection of effects of the workplace on interaction with technology.

ATI was measured after evaluating the scenarios, in order to avoid having a person's conscious self-assessment on how much they like to interact with technology influence their evaluation of the scenarios. However, as a consequence, participants could have thought specifically about technology in control rooms and not about technology in general when answering the ATI scale. Even though the ATI scale was introduced by asking about and defining "technical systems" in general, pervasive technology was primed. In this case, the correlations between the assessment of the technology and ATI might already reflect the specific technology in question and asking specifically about pervasive technology and not about "a technical system" would make little difference. Thus, further research, asking specifically for "pervasive systems", would shed some light on whether the correlations are already at their upper bounds. However, the caveat is that a more specific use of ATI (e.g., regarding interaction with pervasive technology) reduces the usefulness (in terms of applicability to different kinds of technology) compared to a general "technical systems" assessment of ATI.

5.4 Limitations

There are some limitations to this study. The sample is self-selected, so self-selection biases cannot be ruled out. As a general interest in technology would likely have to be present to participate in such a survey, the results might reflect the best case when it comes to ATI and evaluation of these scenarios. However, even if such a bias occurred, there are operators – at least in emergency services and critical infrastructure control rooms – that are likely willing to use pervasive technology. They might serve as early adopters and multipliers in change processes.

Although the gender ratio is highly skewed, it is not untypical for studies with control room operators (e.g., 95 all-male participants in [14], 15 all-male participants in [51] or 12 all-male participants in [11]). As control rooms were contacted via publicly available contact addresses and asked to forward the request to all operators, it can be assumed that the discernible imbalance approximately reflects work reality. However, sampling whole control rooms (cluster sampling) would allow for a more accurate assessment, especially as information about the non-responders could be assessed.

The ATI scale was deliberately used in very broad and abstract technical context. Further investigations in the context of concrete realizations of assistance systems and pervasive computing environments are necessary.

While the focus on emergency services, public utilities, and maritime traffic cover different kinds of control rooms facing increasing complexity, other contexts should be examined as well, e.g., air traffic control or power plants. Furthermore, the differences between the groups presented must also be further examined for other relevant factors.

The present study examines the wishes of the operators regarding the scenarios. When it comes to actually introducing technology to these safety-critical and highly regulated work places, other factors must be taken into account. Beyond the difference between imagination and reality, this includes regulations and laws, finances, but also cyber-security. After all, if the work environment becomes less static and more pro-active, a compromised (hacked) pervasive environment has many options to actively work against the operators. While these are serious concerns, given that promising scenarios can be identified, at least the operators themselves will likely not be part of the barriers.

6 CONCLUSION

Our study shows that, in general, control room operators in three different domains have a rather high affinity for technology interaction (ATI) and are not outright rejecting pervasive technology. According to a cautious assessment, users' attitude to technology does not represent a striking reason why innovative system and interaction concepts have hardly found their way into control room practice so far. ATI scores are even higher for emergency and public utilities control room operators, while maritime traffic operations have a lower ATI score with a broader range. The later are also more critical on proposed pervasive computing solutions, especially if their autonomy would be restricted. But even in this work domain, some operators are open to certain scenarios (e.g., a system that detects unusual work situations, and offers to log all activities in the control room). Results suggest that findings from one control room domain should be transferred to another only after thorough evaluation. This seems to be especially true between "fixed" and "mobile" control rooms. Given the correlations between wish for a system and autonomy (which was even higher than with ATI), care should be taken to preserve the autonomy of the operators (although causal inferences cannot be drawn). In principle, ATI and autonomy considerations can provide valuable guidance for the design of interactive systems, not only but especially for professional users in safety-critical contexts. The quantitative cross-domain approach allowed for a better understanding of the relationships between (perceived) autonomy, (perceived) safety gain and wish for novel technologies.

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A METHODS DETAILS AND STATISTICAL ANALYSIS

Table 3: Scenarios for pervasive technology in control rooms

ID	A digital assistance system for control rooms that detects ...
A	... and executes tasks that were identified in the communication of the operators.
B	... whether an operator is on the phone and if so presents messages not via sound but using other modalities (e.g., text, graphics).
C	... unusual work situations and offers to log all activities in the control room automatically.
D	... whether team briefings are currently being conducted, in which case the system offers to withhold low-priority messages during that time.
E	... whether an operator is in his personal work space, if not, the messages are presented where the person is at the moment (e.g., via wall projection, other screens).
F	... whether the operator is eating or drinking and giving instruction to do so if necessary.
G	... by monitoring the respiratory frequency how stressed the operator is and if necessary distributes incoming tasks to other operators.
H	... whether the operator needs physical exercise and gives movement recommendations.

Table 4: Items of the ATI-scale by [13]

No	Item
1	I like to occupy myself in greater detail with technical systems.
2	I like testing the functions of new technical systems.
3	I predominantly deal with technical systems because I have to. *(reversed)*
4	When I have a new technical system in front of me, I try it out intensively.
5	I enjoy spending time becoming acquainted with a new technical system.
6	It is enough for me that a technical system works; I don't care how or why. *(reversed)*
7	I try to understand how a technical system exactly works.
8	It is enough for me to know the basic functions of a technical system. *(reversed)*
9	I try to make full use of the capabilities of a technical system.

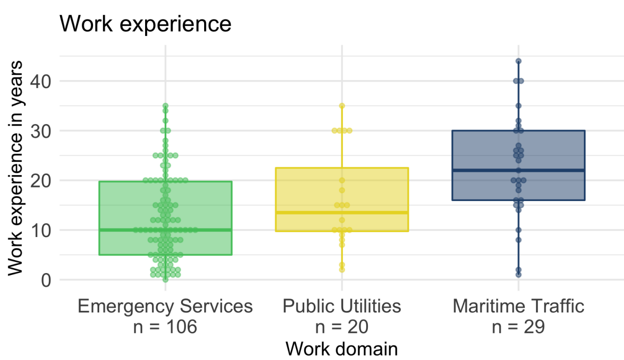

Figure 2: Reported Work Experience in Years, shown for the three different control room work domains.

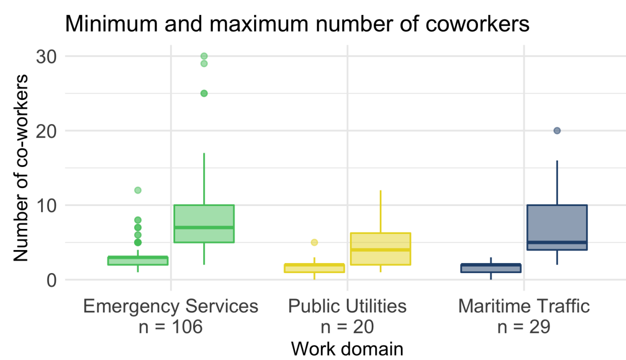

Figure 3: Minimum and maximum number of coworkers reported for the three different control room work domains.

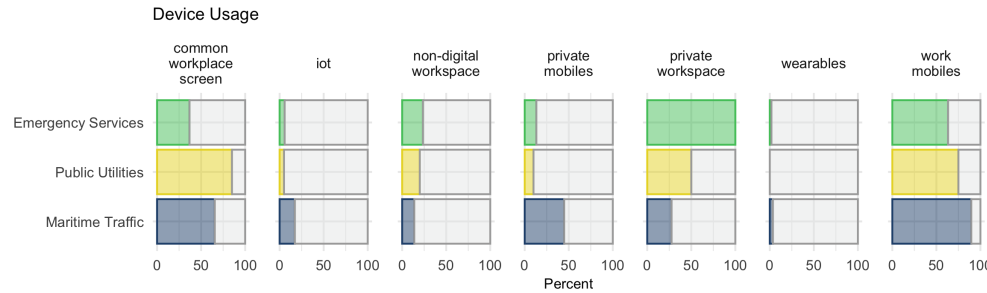

Figure 4: Respondents' feedback on technology usage in the three control room domains (colored bars = percentage of yes answers)

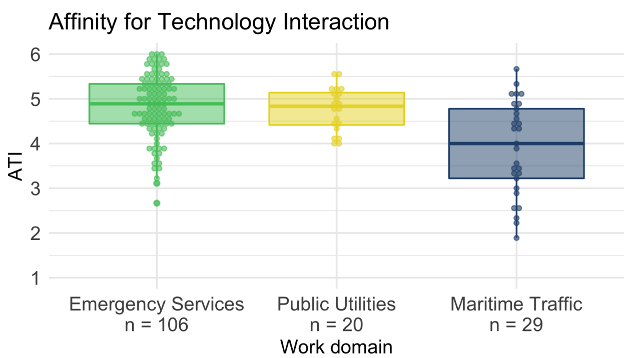

Figure 5: ATI values for the three different control room work domains investigated in this work.

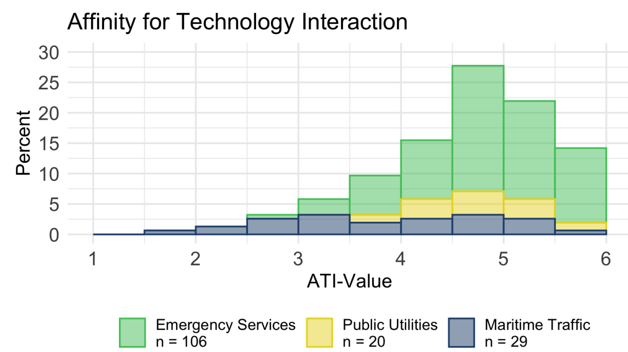

Figure 6: Stacked histogram of ATI values in the three different control room work domains.

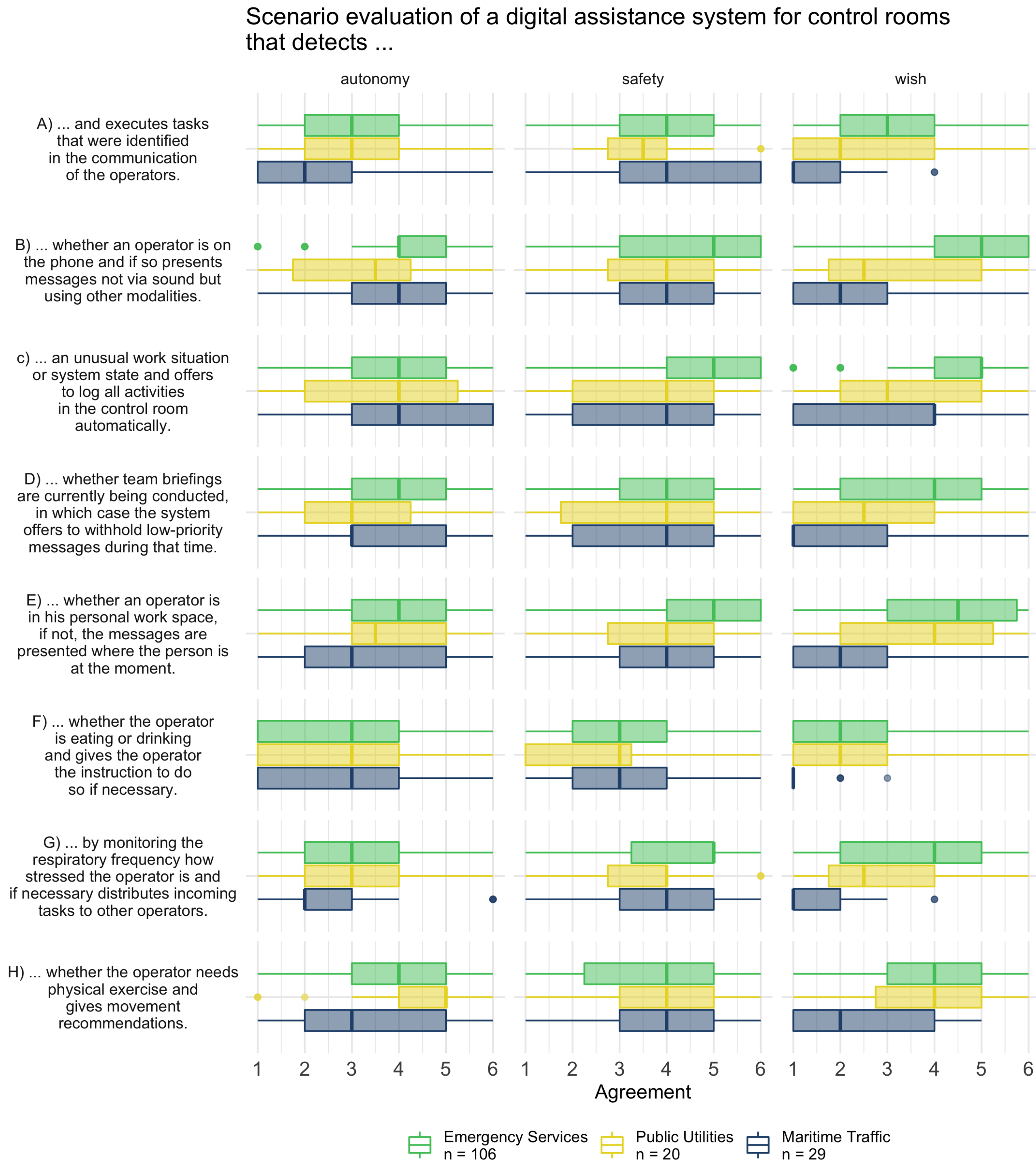

Figure 7: Evaluation of the pervasive technology scenarios for the three different control room work domains, according to whether it preserves the operators' *autonomy*, is seen as contributing to *safety*, and whether the operators would *wish* to have this technology available. The higher the number, the higher the agreement.