Safe and Secure? Visions of Military Human-Computer Interaction

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ABSTRACT

Safety-critical human-computer interaction has focused on technology use in life-critical situations, including military operations. Due to the practical relevance of HCI and disciplinary debates about human-centered design, this literature review studies HCI scholarships' visions of military human-computer interaction. Through text analysis and categorization of publications, it is found that interaction is envisioned to take place in the context of both mission-oriented operational (e.g., target detection) as well as organizational tasks (e.g., military training). While artificial intelligence, virtual/augmented reality, and robots are most frequently defined as technological environments, goals, such as situation awareness, enjoyment, and trust are predominantly associated with them. Considering scholarly references to application contexts and different factors of the context of use allows to systematically approach how military human-computer interaction is imagined. Offering insight into research trends in HCI, this first overview of research endeavors also contributes to interdisciplinary debates, such as *Security Studies* and technology assessment.

KEYWORDS

Safety-critical HCI, context of use, military, vision assessment

1 INTRODUCTION

Safety-critical human computer interaction (HCI) has focused on human interaction with technologies in environments that are "uncertain, unstable and time-critical" [73]. This includes, for example, mass injuries, fires, or other time-critical crisis situations [73, 83]. Military operations are another important context that requires quick, accurate response and have been identified as such alongside disaster scenarios [23]. In HCI, there has been an ongoing discussion about technologies' purposes for society, with scholars noting the discipline's contributions to military usage [75, 107]. More recently, paying special attention to AI, political actors have stressed

> "the emerging need for more human-AI interaction research (...) to ensure an appropriate and cohesive integration strategy of AI in warfighting and defense sectors" [105].

Fields such as *Security Studies* or vision assessment have investigated governmental interests in technological innovations [11, 37, 62]. At the same time, HCI scholars have showed the effort to generate an understanding of explainable and trustworthy AI [60, 61]. Such ethical approaches have been debated within the AI and science and engineering community as well [102].

Considering the disciplinary focus on safety-critical systems as well as dynamic debates about human-centric or societal computing and political stakeholders' interests, it is necessary to gain an overview of how HCI scholarship envisions military human-computer interaction. While visions may not be formulated explicitly or comprehensively across publications, scholarly perceptions of the context of use of technologies may indicate understandings and anticipations of military human-computer interaction. The impact of HCI on real-world interactions is apparent when respective knowledge is translated into industries, for example, in the course of patenting [16].

Thus, I pose the main research question of how HCI scholarship envisions military human-computer interaction. This is answered by focusing on the following sub-questions:

(1) What tasks are envisioned to be completed in interaction with technologies?
(2) In which technological environments are these conducted?
(3) What main goals can be identified to contribute to usability?

To answer the main question, a first exploratory text analysis (see Section 4.1) is conducted. This is followed up by a categorization of selected publications (see Section 4.2.2) which proposes that interaction is envisioned with regard to different operational and organizational military tasks. Further, a systematic analysis of the literature is possible considering references to the broader context of application (see Section 4.2.1) as well as specific context of use. In this regard, the work presents insights into how the physical, organizational (see Section 4.2.1) as well as technological environments (see Section 4.2.3) and important goals (see Section 4.2.4) of military human-computer interaction are envisioned.

The analysis reveals that most publications present technological artifacts as general-purpose technologies instead of focusing exclusively on military settings. This is associated with diverse depictions of organizational and physical environments, ranging from hierarchic institutional settings to less formalized, individual use at home. In contrast, studies on safety-critical, including military, scenarios characterize environments with regard to the surrounding nature, wider areas and uncertainty. Further, it is possible to differentiate visions of military human-computer interaction based on envisaged tasks. These tasks also reflect different points in the chronology of military operations, while works refer most frequently to the *operational* activity of situation awareness (SA) as

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well as the *organizational* task of training personnel. With regard to the former, robots are identified as an important technology whereas virtual reality/augmented reality (VR/AR) is seen as useful to the latter task. The prevalence of artificial intelligence (AI) systems is already indicated in the text analysis as is the importance of goals, such as trust, accuracy, or explainability.

Building on these results, the work contributes to an assessment of visions of safety-critical human-computer interaction, in particular regarding the military application context. While both practitioners [33] and scholarship [34] have noted the context-specificity of military human-computer interaction, the findings indicate that tasks and goals may be translated from everyday and safety-critical contexts. Accompanying studies with a specific focus on military visions may not only connect to this research endeavor but also be able to pay special attention to conceptualizations of usable security.

After a presentation of related work (see Section 2, I illustrate the methodological approach (see Section 3) as well as the findings of both the text analysis (see Section 4.1) and the categorization of selected publications (see Section 4.2). This is followed by a discussion (see Section 5) as well as conclusion (see Section 6).

2 RELATED WORK

2.1 Human-computer Interaction in Safety-critical Environments

Works focusing on usable security and safety have included studies on human-computer interaction in safety-critical situations. This implies contexts, such as disasters, emergencies as well as police use of technology in disruptive situations [80, 82]. With respect to usable security and safety, military scenarios have been touched upon. For example, Mentler et al. [68] study design, engineering and evaluation issues with regard to control rooms in safety-critical contexts and refer to multimodal interactions in military aircraft cockpits. Others [93] have more generally focused on time-critical situations. Further, Chen [19] offers insights into various (military-funded) research on human-autonomy teaming in military settings and Stanney et al. [98] present a military use case of "eXtended reality" (XR). In Ergonomics, behavior of military pilots has been studied with regard to deviating procedures [28]. Insights on trust in conversational agents in military missions are illustrated alongside other application contexts [84], with Shneiderman [95] generally referring to "life-critical systems". Alongside resilience engineering, which has focused on system safety based on adaptivity to complex, continuously changing conditions and has contributed to a multidisciplinary, practice-oriented discourse on safety and risk management [41], these problem-solving approaches have generated insights into human interaction with technologies in safety-critical situations.

Additionally, scholarship of "Critical HCI" has reflected upon hegemonic use of technologies [57, 100], but, with a few exceptions [32], rarely considered oppressive state usage of technology. Accompanying emancipatory endeavors of decolonizing HCI [2, 56], Nocera et al. [75] emphasize that, when considering the geopoliticized nature of HCI as a science and practice "HCI has several roots deep in military needs from the world wars of the 20th century." Reflecting on HCI's "legitimacy trap", Dourish [30] also notes the discipline's origins (and subsequent departure) in "human factors analysis for military pilots". However, while HCI has noted the importance to connect to the AI community in dedication to issues such as human-centered AI [60, 61] and critics of unethical or AI-enhanced weapons are prominent, there is no established knowledge on the HCI discourse's standpoint(s) on military usage of technology. Inkpen et al. [45] note that other disciplines, such as science and technology studies (STS), communication and media studies, have been committed to such critical perspectives and ask how they can "be brought into a meaningful, productive dialog with design and implementation-oriented work".

Further, looking at developers involved in the design of AI systems, Sanderson et al. [89] as well as Mäntymäki et al. [65] note the need to bridge the gap between political debates on design principles and requirements and practical techniques.

2.2 Security Studies and Technology Assessment

Security Studies have studied the broader international and societal dynamics related to technological developments, including autonomous weapon systems. In this regard, scholars have emphasized the importance of (meaningful) human control or the assurance of International Humanitarian Law (IHL) in the application of such weapon systems [86, 88]. More recently, it has been noted that respective debates have framed the issue as a technical one [44]. While legal and political discourses have repeatedly been integrated into works of *Security Studies*, contributions that focus on military human-machine interaction have largely stayed isolated [49].

Apart from academic debates, innovation policies have emphasized the importance of responsible research and innovation. In this respect, ELSI frameworks are proposed to introduce ethically-aligned systems through the consideration of ethical, social, and legal implications [39]. Technology assessment has been another venue of dialogue, comprising works offering both scientific and practice-oriented approaches to foster responsible design of so-called "dual-use technologies", which can be used in both military and civilian contexts [85]. More recently, approaches of technology assessment have concentrated on actors' visions of technological application, at times inspired by critical studies on the strategic nature of governmental policies [11, 37]. Considering these different discursive arenas indicates that the study of human-computer interaction in military contexts has primarily been dealt within institutionally-separated channels. Both HCI and *Security Studies* only touch marginally upon military contexts and interactional frameworks *vice-versa*.

Following others [40] in their effort to capture (future) developers' awareness of dual-use potentials, this contribution offers a first overview of tendencies of HCI scholarship's envisioned military human-computer interaction. As it allows to look at references to broader application contexts as well as specific contexts of use, this work bridges disciplinary debates due to the interdisciplinary nature of the research subject.

3 METHOD

3.1 Literature Search, Study Selection, Data Retrieval

Interested in how HCI scholarship views human-computer interaction with reference to military environments, I conducted a systematic literature review [53]. Thereby, publications are seen as codified expert knowledge, which can be transferred via accessing, funding, or citing these works[1] [67]. For the literature analysis, a search in the encompassing collection of the ACM Digital Library was conducted. Inclusion criteria were the keywords "human-computer interaction" AND "military". Further, the search was limited to publications between 2018 and April 2023 and research papers, meaning that other content types were excluded. This resulted in the retrieval of 601 publication entries. As the study is interested in human-computer interaction in military environments, publications which focus on social media discourses about experiences in the military instead of military contexts itself were excluded. Further, secondary studies were excluded as well as works that dealt with psychological trauma and had relied on military personnel in interviews in the study of civilian technologies such as social media. Exclusionary keywords were:

- "social media", "Facebook", "Twitter", "online platform", "self-disclosure", "fake news"
- "systematic literature review", "systematic review", "taxonomy"
- "memorial", "veteran", "ptsd", "prison", "sexual"

Searches through textual data were made possible by the organization of references and PDFs in Zotero[2]. Publications which were to be excluded were searched by "military" to make sure the decision was legitimate. This resulted in a total of 508 publications.

3.2 Text Analysis

For the analysis of the literature, publications were converted into text files and imported to R 4.0.0[3]. This allowed coding phrases by keyword search with RQDA [42] to gain more insight into publications' content. Codes were developed deductively based on literature on usable security [81] and trustworthy or ethical AI [92] as well as works on military discourses [86]. Codes were categorized either as *quality characteristics* for usable security or value-based human-computer interaction (such as "Transparency", "Accuary" or "Efficiency") or as representing the *contexts of application and use* (such as "military", "Teaming", or "Virtual Reality"). This resulted in 50,372 codings. Based on the text corpus, I conducted text mining (using the tm package [35]) to check for most frequent terms and co-occurrences of words. Combined with the content analysis in RQDA, the study reveals a first, broad overview of tendencies in the HCI discourse referring to military contexts.

3.3 Categorization

To gain more detailed insight into how military HCI is envisioned in the academic discourse, I selected publications from the sample for further categorization based on the occurrence of the term "military" in either the title or abstract of the publication, as these works put an emphasis on military technological usage. Due to the limited number of publications (N=36), the pool was further accompanied by more visible publications that were cited at least 20 times according to Zotero's citation numbers plug-in (referring to CrossRef). Ultimately, 57 publications were studied more closely with regard to indications of the broader application context as well as context of use (for an overview see https://github.com/PEASEC/vision-military-hci.git).

The context of use is an important factor to human-computer interaction and can be characterized by the (1) technological environment, (2) goals (i.e., important quality characteristics), (3) tasks, the (4) physical as well as (5) organizational and cultural environment [18, 46]. An analysis of the studies based on these criteria allowed to approach the question of how military human-computer interaction is envisioned. Because political debates and security studies have been interested in the different functions technology can fulfill, the categorization was based on a differentiation by tasks. The suggested types of operational and organizational human-computer interaction should be seen as a first overview that aims to take into consideration that there is a prevalent focus on human-computer interaction in the course of concrete military *operations* [44], while other (long-term) *organizational* tasks are conducted in the field of logistics or training as well [25].

4 RESULTS

The text mining analysis supports the idea that the sample of publications represents HCI scholarship, as the most frequent terms refer to human-computer interaction (see Table 1). Generally, the choice of codes proved plausible as many codes were among the most frequent terms, occurring at least 500 times.

4.1 Text Analysis of HCI Publications

Table 1: Most frequent word stems across text documents.

Word stems	Occurrences
system	14,824
design	13,590
particip	12,921
user	12,235
interact	12,202
comput	11,234

4.1.1 Contexts of Application and Use. Interested in indications of envisioned contexts of application and use, the analysis reveals a range of interesting findings. Firstly, it is evident that distinction between contexts labeled as "military" vs. "civilian" (or "dual-use") was

[1]This plausibilizes the inclusion of papers that referred to literature or the existence of military applications but did not focus on military applications themselves. It is important to note that these publications do not share an exclusive emphasis on military human-computer interaction. However, references to military applications indicate awareness of such works and might play into the general reception of contexts of use. While some of the selected publications do indeed look specifically at military contexts or are funded by defense bodies, this work is interested in the vision that can be abstracted from the academic discourse and does not presume that individual actors have deliberately formulated a holistic vision.
[2]https://www.zotero.org/download
[3]https://cran.r-project.org/bin/windows/base

relatively modest. While the term "military" was present in all 508 publications, the overall frequency of its occurrence (N=828) was higher, though it does not imply dominance within the publications. Rather, military settings are introduced among other application contexts:

> *"Target tracking integrates target recognition, image processing, artificial intelligence, modern control and many other fields. Its main research content is target tracking in image, which is widely used in intelligent monitoring, electronic police, human-computer interaction, medical diagnosis and military weapons, etc."* [114]

Indeed, there is only one publication (*"On the Application of Computer War Chess Technology in the Support of Military Supplies"* [110]) which explicitly tackles the military application of technology in its title. Further, 24 publications refer to military environments in their abstracts, such as that *"[a]utonomous vehicles and robots are increasingly being deployed to remote, dangerous environments in the energy sector, search and rescue and the military."* [87]. However, it should also be considered that some publications name the defense sector as a relevant setting in which human-machine interaction takes place: *"Furthermore, the use of robotics is among the top government strategies in different domains such as manufacturing, defence, and nuclear for the near future"*[5]. Notably, there is only one reference to "dual-use", i.e., military and civilian [92], application:

> *"China constantly adjusts defense procurement and research production structure layout, develops dual-use technologies, and has made breakthrough progress in the field of guidance and control, detection and identification, modeling and simulation, network communication and satellite application."*[112]

This again supports the view that understandings of technology as dual-use, in contrast to their general-purpose applicability, are marginal in more design-oriented HCI discourses. Instead, the term is situated in economic and political discourses, referring to different industries, i.e., application contexts, and R&D on a larger scale. Further, references to ethical, social, and legal implications (ELSI) were only made 4 times, while the term "ethical" was used considerably more frequently (N=907).

Second, these publications support the view that robotics, AI, virtual reality, vision and speech technology are technologies with which military application is associated (see Table 2). While explicit co-occurrences are absent, these technologies are heavily referenced across publications that relate to military settings both implicitly and explicitly.

Third, regarding instances which specifically deal with military environments, the specificity of this context is mostly reflected by references to policies, legislature, regulation and human dignity. It is further referred to the operating "pilot", streets, the municipal level and hostility. Looking at these terms that co-occur by 50% there are no references to security or safety-related quality characteristics.

4.1.2 Quality Characteristics. Interested in the occurrence of quality characteristics associated with usable security and value-aligned human-computer interaction, the analysis shows that "trustworthy" is the most occurring quality characteristic, followed by well-known features such as accuracy, security, or effectiveness (see Figure 1). This raises two issues: First, "trustworthy" is not a clear requirement in itself but has been filled with meaning through associating trustworthiness with values such as reliability, predictability, robustness, explainability, and security. This has been politically pushed by the European Union [1]. Looking into associations of "trust", i.e., terms co-occurring by at least 50%, there are several references to reliability ("relianc", "reliabil", "reliabl") as well as references to compliance, benevolence, trust as an issue or "checkingbehavior" and notions on "expos[ing]ourselv[es]". This indicates increased awareness of trustworthiness as an issue in HCI, in particular with regard to automation ("autom", "automationai"). Second, while prominent requirements associated with usable security are regularly referred to, and explainability has been introduced into HCI debates referring to military environments and AI, other relevant requirements were less focused upon. For example, integrity is comparably less frequently named. Further, resiliency or predictability were on the lower end of occurrences, addressing specifically safety-critical scenarios. Focusing on human-swarm interaction (HSI) in forest fire fighting, scholars state: *"We argue that an important challenge for the HSI community is to understand how to design for effective, efficient, and resilient human-swarm interaction with this in consideration."*[12] Further, adaptability or flexibility appear more often across publications and imply awareness of ever-changing socio-technical contexts:

> *"Some scenarios were tested during the flexibility analysis, however a more extensive analysis on the fabrication process for flexible scenarios is required in order to find a solution that preserve the sound sensitivity and adaptability to different shapes."*[9]

Table 2: Frequencies of codings regarding applications and references to different contexts.

Codings	Frequencies
Robotics	8,761
Teaming	5,425
AI	4,933
Environment	4,285
Vision	2,322
Speech	1,606
Virtual reality	1,175
Military	828
Machine learning	508
Neural network	377
Deep learning	211
Civilian	93
ELSI	4
Dual-use	1

4.2 Categorization of Envisioned Military Human-Computer Interaction

Following the exploratory text analysis, 57 selected publications were analyzed regarding the context of application and, to get a

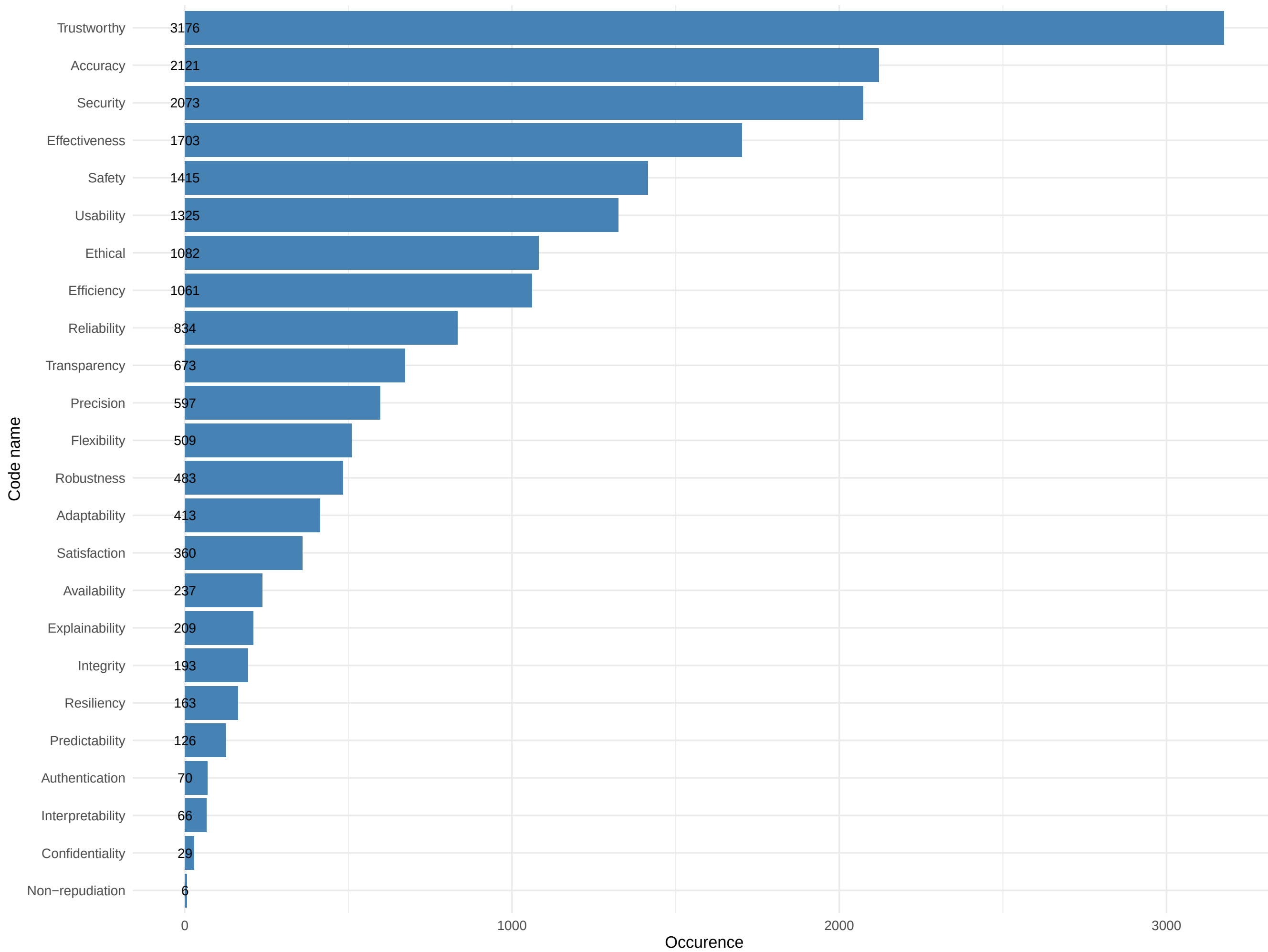

Figure 1: Frequencies of references to quality characteristics in publications.

closer, more immediate view, by organizational and physical environments (see Section 4.2.1). Summarizing different tasks that were identified as important to human-computer interaction in the military allowed to group HCI contributions systematically (see Section 4.2.2). With respect to the identified types of military human-computer interaction, the technological environment (see Section 4.2.3) as well as important goals (see Section 4.2.4) were analyzed.

4.2.1 Context of Application, Organizational and Physical Environments. Looking at the application context, most publications (N=38) were categorized as sharing an understanding of the envisaged technology as **general-purpose**. Thus, references to application contexts ranged broadly from medicine, manufacturing to education [27]. While these publications also referred to the military as an application context and were at times relying on respective data or funding [4, 79], they did not distinguish in the design between safety- or time-critical scenarios and other everyday situations. Thus, they refer to both the hierarchical institutional context of the military and civilian authorities as well as less formalized use by individuals. This also implied different visions of the physical environment, including references to different noises [111] or movements [15, 20]. There is also awareness to different contexts across the globe:

> *"A world of ubiquitous AR will require a network infrastructure that supports low-latency, personalized computing. Our vision is that fog servers would provide local computing resources to different geographical regions."* [4]

About one third of publications (N=16) related mostly to **safety-critical** application contexts and named military operations alongside disaster or emergency responses as well as medicine. For example, Zhou et al.[113] referred to the application of drones for both *"civilian rescue and military surveillance realms"* while research on emotion recognition [48] or teleoperated surgeries [78] was associated with both medical and military settings. Time-critical situations were characterized by a physical context that could be shaped by disruptions in large areas and uncertainty caused by, for example, fire [23], a limited view at the sky [26] or underwater [87]. Others illustrated work among team members with different levels of expertise and who contribute to any *"remote physical collaboration that requires a high-degree of fidelity and accuracy (down to the centimeter scale)"* [38]. Thus, contributions in this category excluded human-computer interaction for leisure or one that is less determinant with respect to human safety.

Further, I could only identify few publications (N=3) which did not reflect broad application of technology but instead focused specifically on the **military** context. Thereby, the multi-level nature of military organizations [94] as well as the organization's strategic aims, implying battlefield preparation [66] or game theoretical training [110], served as contextual characteristics. Neither of these publications referred to the physical context but focused on software security or interface design.

4.2.2 Computer-supported Tasks in the Military. Focusing on envisioned tasks that are to be completed in human-computer interaction, it is possible to subsume activities under the broader categories of operational and organizational tasks. While the former captures any directed actions that are executed in the course of a specific military field mission and include steps of the mission cycle [70], the latter refers to any task that is conducted more routinely within a military organization.

Considering the broadest categories, it is more frequently referred to **operational** tasks (N=38) while human-computer interaction is also envisioned more generally in the military organization in other instances (N=19). Note that some works do not exclusively focus on one broader set of tasks but envision technology to be useful in the context of different tasks. Some publications (N=9) focused more generally on design theory and were thus not associated with any specific task(s).

Most frequently in the category of operational tasks (N=9), works referred to **situation awareness** (SA). This broad task, comprising the act of understanding the situation, including your surroundings, builds on observation and anticipation. As it is a broader, almost "catch-all" term, it is not surprising that many tasks defining military human-computer interaction, could be subsumed under it. However, situation awareness can be understood as military activities that are conducted prior to the steps of decision and execution and thus also reflects that different sets of tasks take place at different points in time or with different time frames.

As defined by Jones et al. [50] SA encompasses various steps:

> *"(...) operators must both cultivate and maintain a posture of awareness, and work together to qualify any of the wide variety of phenomena they are observing as 'situations'; then package their observations and actions to support the work of other entities."*

For their case of a local transportation management center, this includes incident reporting in the data base as well as social media analytics. Relating to other studies, SA is characterized by a gaining a focus and understanding of the environment, approaching it through different channels, for example, sensing sound [10], content filtering for Augmented Reality [4], or visualization interfaces that allow operators to gain a better overview.

As indicated, situation awareness is practiced in team work, to which **communication** (N=8) is crucial. Independent from different perspectives on technology, either as a non-human team member or rather a tool enabling team work among human agents, mostly conversational agents or explainable AI were introduced [31, 71].

Further, ***surveillance***, implying the observation and monitoring of activities, environments or people is a relevant field (N=6). This includes object tracking through UAV swarms or datasets of aerial objects [26, 97]. While most publications envision surveillance technology to also conduct object ***detection*** (N=6), these are two different tasks. For example, with teleoperated UAVs it is also possible to detect objects in a search and rescue operation, while these UAVs are also able to observe the environment in general [113].

Object recognition (N=3) is also closely related to SA as it allows to gain an overview through the identification of pre-defined objects. Computer vision has been found useful to this task [17], while scholarship has focused on biases of relevant data sets [91].

Constituting the final step in SA, one work focused on ***target selection*** in human-swarm collective teaming. In this case, target selection was tested based on two different models and was depicted as a collaborative activity by *"a single human operator supervising four simulated collectives"* [23]. In this process, identified objects in the environment are assessed and help to evaluate different options for decision-making.

After SA has evolved, **delivery** of items or people to a (safe) destination is another task that can be translated to military operations. While several contributions have focused on SA and relied on UAVs, there is only one work that mentions collection and delivery as tasks to robots, while referring to both search and rescue scenarios and the military application context [17].

In **close-by assistance** (N=3), human interaction with technology is envisioned in the context of team work and characterized by at least one human team members being in nearer proximity to the technological artefact. Besides one VR/AR system, which includes a *"smartwatch to interact with an eyewear device"* and *"mid-air hand gestures"* [15], other contributions focus on human-robot interaction. In this regard, zoomorphic or anthropomorphic looks are envisioned to foster collaboration [63, 72]. Instead, interaction in the context of ***battlefield care*** (N=2) is imagined to be possible with human team members situated in different locations [38, 78].

The second category of organizational tasks starts with **training**, which was most frequently (N=11) focused upon compared to other mid- and long-term institutional tasks. Various VR/AR technologies were presented as useful for training sessions due to the possibility to immerse into different scenarios and train behavior without related physical consequences [20, 59]. Game interfaces also played a relevant role and were emphasized as offering the possibility to test game theoretical thinking or perceptive behavior [7, 74]. While most publications did not focus specifically on safety-critical scenarios in their experiments but pointed out the utility of VR/AR applications to military training, An et al. [8] focused specifically on a time-critical situation and developed a VR-integrated *"Chemical Incident Response Training Program"*.

Further, **intelligence** (N=2), a typical task for security agencies, can be conducted with the help of machine learning for speaker recognition, also taking into consideration the occurrence of severe noise [79].

Choosing the case of a military headquarter environment, which is characterized by segregated networks, Shield et al. [94] tackle the issue of secure **information processing** (N=2) in the multi-level organization. **Supply chain management** (N=1) was also envisioned to be supported by data mining and a wargame system, predicting the consumption of military supplies in (non-) war time [110]. Ad-hoc **reviews** (N=3), taking place after human-computer interaction, were also proposed with regard to AI systems and constitute the last organizational task that could be identified as a contextual factor envisioned regarding military human-computer interaction.

4.2.3 Technological Environment. Considering the technological environment, in which military human-computer interaction is envisioned, different technologies are targeted.

Most frequently (N=20) humans are understood to interact with **artificial intelligence (AI)**. This includes NLP [24], reinforcement learning [4, 64], neural networks [22, 31, 43, 47], machine [79] and deep learning models [111]. Conversational agents may play an important role in the successful communication in teams. For example, Xiao et al. [108] evaluate INDIGO and find that it not only helps in the task of team formation but also *"could be potentially used as a team companion to accompany teams longitudinally"*. With regard to communication, explainable AI has been identified as an important technology [71, 90].

Robots (N=11) were also identified as crucial for operational tasks, such as object recognition, delivery, or detection. This particularly applied to unmanned aerial vehicles (UAVs, N=5), such as *"an early visionary prototype of UAV deployment for River Search-and-Rescue"* [3] or controlling *"a fleet of flying robots"* [97]. As indicated above, humanoid or stationary robots are envisioned as useful for team assistance [38, 63].

Further, **virtual reality/augmented reality (VR/AR)** is comparatively frequently focused upon (N=10). Thereby, it is almost exclusively presented as an interactive technology in the context of training. For example, Cheng et al. [21], pose the scenario of a

> *"a group of flying droids that physically attack the user. Our approach conveys a sense of a living, animate world, when in reality the user is the only animate entity present in the system, complemented with only one or two physical props."*

The possibility of immersion into a virtual or mixed reality is identified as one of the main benefits for training as it resembles potential real-life incidents. Referring to leakages or explosions in chemical factories, An et al. [8] offer different training levels with varying virtual environments and state that *"there is a growing demand for education and training of response personnel to reduce damage from such incidents."*

While some works focused on **games** [110], others paid special attention to **data sets** [26] or (heat) **map interfaces** [74, 104]. Other technology such as a *"Self-powered Audio Triboelectric Ultra-thin Rollable Nanogenerator (SATURN) microphone"* [10], social media [50], or information security architecture [94] was only targeted in individual contributions and played into interactions in the context of both operational and organizational tasks.

4.2.4 Goals. Goals play an important role to the context of use. Across publications, a good user experience, i.e., **enjoyment** (N=9) was identified as crucial. This applies to human interaction with robots as well as VR/AR. With regard to the former, **trust** (N=7) was also an important goal, while an enjoyable interaction with the latter was associated with the goal of **immersion** (N=6) into a virtual or mixed reality. VR/AR artifacts aim at an *"increased level of immersion"*, for example, through *"passive haptics"* [21] or the creation of a *"Simulated Reality"* which *"involves a fully immersive experience"* [103]

A good user experience is also important in the interaction with robots, in particular, when they aim at generating trust. An enjoyable user experience is, for example, indicated by the *"willingness to work with a robot"* [109] that may be influenced by (deep-level) human-robot similarity [109]. In this regard, reflecting vulnerabilities, robots benefit from *"Ripple Effects"* of self-disclosure to other team members in times of tension [99]. In the context of trust, **explainability** (N=6) has found to be an important goal with regard to AI [71]. Publications relating to this goal focused on AI and the communication within decision-making [31]. For example, Schaffer et al. [90] note: *"Explanation interfaces (...) are thought by many to be the solution for instilling trust (...)"*. However, they find that this depends on users' personal expertise and explanations might also lead to automation bias. This issue points out the goal of human **autonomy** (N=5) which has been focused upon on a fundamental level [6, 52] as well as in the context of reviewing AI [29, 64]. Considering robotic agents, different levels of autonomy or control are also envisioned [17].

Further, technologies are envisioned to be usable, and thus effective, with regard to performing **situation awareness** (SA) (N=9). Conceptualized in this work as the activity of observing and understanding, the effective use of technologies to achieve SA is a goal in itself. This applies especially to shared SA in team work [50]. Associated with SA, robustness (N=4) is another identifiable goal [79, 97] as is information quality (N=2). Conducting a user study, Kunze et al. [54] emphasize the importance of communicating uncertainties regarding displayed information in automated driving and relate to different attention levels and foci. Additionally, **accuracy** (N=9) was noted as an important goal, which was quantitatively tested. For example, Cheng et al. [22] focus on the accuracy of a proposed *"Co-Attention Network for Self-Supervised Audio-Visual Representation Learning"* used for the synchronization of video and audio material.

Several works, focusing on more abstract and critical design approaches, envisioned **fairness** in technology. For example, Scheuerman et al. [91] studied biases in computer vision data sets while Kaptelinin's [51] existential inquiry framework considers the importance of authentic human life (and death) experiences.

Security is focused upon comparatively less (N=3) and envisaged regarding information processing [94] or VR/AR use in different geographical locations [4]. Other goals, such as **transparency** (N=2), **adaptivity** (N=1), or **predictability** (N=1), were rarely emphasized, yet contribute to SA and usable security.

5 DISCUSSION

In political arenas [1, 105], HCI has been accredited the role of a practice-oriented science. In *Security Studies*, human-computer interaction has predominantly been analyzed in the context of the

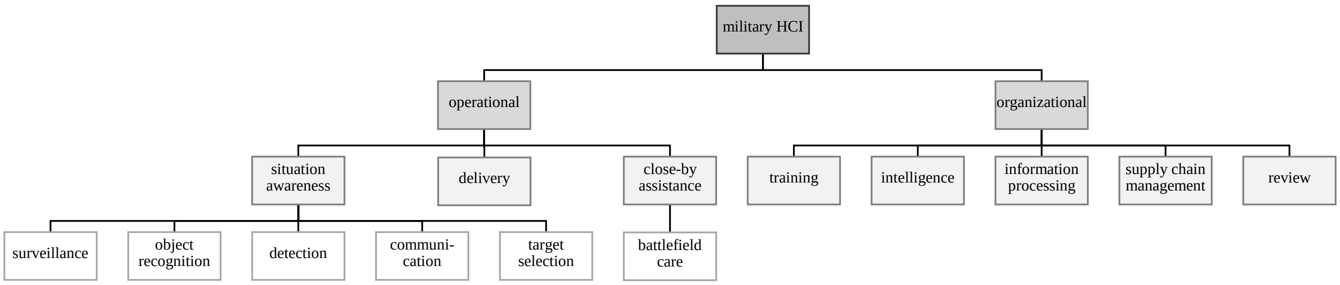

Figure 2: Hierarchical categorization of military human-computer interaction according to different tasks.

Table 3: Categorization of envisioned military human-computer interaction differentiated by tasks.

Category	Definition	Examples	Publications
Operational	Tasks take place during military operations.		
Situation Awareness	Active understanding which is achieved through observation and anticipation.	incident reporting and social media, AR display for communicating uncertainties	[50], [66], [4], [10], [43], [54], [76], [104]
Communication	Any verbal or textual transfer of information among team members	conversational agent collaborating with auton. underwater vehicle	[24], [87], [31], [47], [71], [90], [99], [108]
Detection	Noticing an object that has not been pre-identified and searched for	UAVs and enhanced tele-operation control interface	[17], [26], [97], [113], [3], [109]
Surveillance	Any activity that aims at observing & monitoring activities, environments, or people	data set of aerial object image sequences for target tracking	[23], [26], [97], [113], [22]
Object recognition	Identification of pre-defined objects	computer vision	[17], [47], [91]
Target selection	Process in which the appropriate target is selected before execution.	teaming with swarm collective (best-of-n decision-making model)	[23]
Delivery	Taking and moving objects to a destination.	robot for object collection, delivery	[17], [109]
Close-by assis-tance	Assistance within the closer physical space of the human agent	Collaboration in close distance with humanoid robot	[15], [63], [72]
Battlefield care	Medical care, surgeries due to battlefield injuries	AR-VR collaboration system for military emergency scenarios	[38], [78]
Organizational	Tasks take place within the military institution.		
Training	Education, preparing military personnel for future real-life incidents	VR considering haptics in physical attack by drones	[7], [8], [20], [27], [48], [59], [103], [21], [74], [106], [90]
Intelligence	Strategic information gathering	ML based on DARPA RATS data with severe noise	[79], [111]
Information processing	Reception, conversion, or transfer of information within the organization	security architecture for mil. HQ	[94], [101]
Supply chain management	Management of military material	Prediction of supplies based on wargame system and data mining	[110]
Review	Ad-hoc assessment of actions	After-Action Review of AI	[29], [64], [69]
Broad (Undefined)	Focus on design approaches and theory	technology use embedded into socio-political context	[6], [13], [36], [51], [52], [55], [77], [91], [96]

development of autonomous weapon systems [44, 58]. Literature on usable safety [68] has considered contexts of use in which situation awareness is important due to high-stake decision-making and complements other HCI studies in their agnostic approach of implementing technology and optimizing human-machine teaming in such critical settings. Further, critical HCI [75] has contributed with theoretical perspectives that consider socio-political contexts but largely omit to focus on state use of technology, including military human-computer interaction. Connecting to these debates, I pose the question of how HCI scholarship envisions military human-computer interaction.

Thereby, I focus on both the context of application – which reflects an understanding of socioeconomic adoption of technology – and on the specific notions of the context of use. Interested in related attributes, such as tasks (see Section 4.2.2), organizational and physical (see Section 4.2.1), as well as technological environments (see Section 4.2.3), and goals (see Section 4.2.4), it is possible to gain a first overview of the relevant points of reference HCI in research.

5.1 Limitations & Outlook

While the keyword search for literature based on "military" and "human-computer interaction" included works that did not specifically pay attention to a military application context, some of them referred to military funding in the acknowledgement [4, 22] or illustrated user studies with military personnel [87]. Future works may select such studies for gaining a more accurate picture of how military human-computer interaction is envisioned, as these publications represent accessible expert knowledge [67] in the context of confidential research and patents.

As military tasks in the context of concrete operations, such as situation awareness, including surveillance and detection, as well as organizational activities, for example, training or information processing, are similar to those of other safety-critical situations such as disaster or emergency response, future studies dedicated to technology and vision assessment [37, 39] might focus on respective understandings of the context of use.

5.2 An Evolving Vision

At the same time, different technology readiness levels (TRL) [14] may be reflected by the emphasis on civilian technologies in safety-critical scenarios or context-independent artifacts. While the findings of the text analysis (see Section 4.1) and systematic analysis of selected publications (see Section 4.2) indicate that goals such as trust and accuracy are generally relevant to both civilian and military human-computer interaction, one needs to consider that, for example, civilian AI technologies show a higher level of maturity. Associated risks reflect that functionality in military contexts, in particular regarding weapon systems, is not assured [33, 34]. This matches with political actors' identification of challenges regarding "acquiring, sorting, and interpreting relevant data, questions surrounding the reliability of ML algorithms" that make "applying this technology in a complex operational environment" [34] difficult.

Considering the context-specificity, the need for future study becomes again clear when contrasting the results of the different analyses: While security was labeled very frequently as a quality characteristic across the total sample of documents (N=508), the analysis of selected papers indicates only little focus on security as a main goal. In light of repeated quotes on the risks of cyber attacks [33] as well as the political side of safety-critical situations, usable security is also relevant issue regarding military human-computer interaction.

Connecting to the various strands of literature that are summarized under the banner of HCI, it is relevant to note that they share their legitimacy of fostering "human dignity and flourishing" [30] in human-computer interaction. Reflecting on this common ground of research, it is valuable to capture visions of human-computer interaction that are situated in safety-critical settings. To date, the vision of military human-computer interaction does not appear to be concrete but – apart from some notions on the physical environment and an emphasis on situation awareness – rather general and context-independent. Considering different innovation policies and the more recent interest in the strategic implementation of advantageous and value-aligned human-computer interaction into the military sphere [1, 11, 62, 105], it is crucial to understand to what degree HCI views technology as adaptable to different contexts and which goals and contextual reference points influence the perspective on military human-computer interaction.

This study proposes a systematization of visions of military human-computer interaction based on contextual attributes. Differentiating types based on envisaged collaborative tasks proves a first step that should be complemented by a comprehensive taxonomy which identifies different (ideal) types of military human-computer interaction. Building on further analysis of data, it could be useful to formulate categories building on configurations of multiple attributes, thereby integrating technologies and goals as defining characteristics.

6 CONCLUSION

This work studies the underlying, often implicit vision of military human-computer interaction that is notable in HCI's scholarly discourse. While contributions regularly appear to perceive technologies as context-independent for general purpose, references to the military application context are also made in works on safety-critical HCI. Connecting to HCI's self-positioning as a practice-oriented discipline and interdisciplinary interest in military human-computer interaction, I analyze publications according to different attributes of the context of use. While depictions of the organizational and physical environments vary greatly in their explicitness, AI, robots, and VR/AR can be identified as the trending visions of technological environments. Further, goals, such as accuracy, trust and explainability as well as effective situation awareness are envisioned, with the latter reflecting context-specific design. Focusing on tasks as a relevant contextual attribute, visions of military human-computer interaction do not only refer to operational activities in the course of missions but also to organizational tasks. In this regard, the findings connect to more recent works that have focused on predictive maintenance in the military [25] and HCI's input to technology development [16] as well as to interdisciplinary debates on technology governance [39, 65].

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