

On the Role of User Experience in Mission- or Safety-Critical Systems

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Abstract

Mission- or safety-critical domains (e.g. crisis management, healthcare, transportation) are increasingly characterized by interactive and multimedia systems. Therefore, safe and efficient human-computer interaction and cooperation more and more becomes a crucial factor for overall performance, satisfied users and satisfying outcomes. For more than 30 years, usability has been the major criterion for evaluating interactive systems in this regard. However, latest consumer and entertainment products are often assessed and marketed emphasizing on user experience (UX) rather than usability. We will discuss three different perspectives on UX in application domains putting high requirements on humans, machines and their interaction.

1 Introduction

Human-machine systems can be characterized as mission- or safety-critical “*if the[ir] failure [...] could lead to consequences that are determined to be unacceptable*” (Knight, 2002, p. 547) and if they entail substantial risks due to mass, energy or information associated with them (Herczeg, 2014, p. 10). In domains like aviation, automotive, crisis management or healthcare, wearable, mobile and stationary interactive systems supporting different kinds of interaction modalities (e.g. touch, gestures, speech) and offering enriched multimedia capabilities gain in importance. These systems increasingly replace paper-based cognitive artifacts (Mentler & Herczeg, 2015) or complement computer systems with “*graphical user interfaces based on windows, icons, menus, and a pointing device, typically a mouse*” (van Dam, 1997, p. 63).

While technical reliability and safety of hardware and software in safety-critical domains are of utmost importance, safe and efficient human-computer interaction has to be ensured in order to achieve successful outcomes or at least prevent incidents and accidents. Redmill and Rajan (1997) state concisely: “*When the user interaction with a safety-critical system goes wrong, the result can be catastrophic*”.

For more than 30 years *usability* as “*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*” (ISO 9241-11:1998) has been the major criterion for evaluating interactive systems with respect to human-computer interaction. Systematic approaches to addressing it throughout the design process have been developed under the name of *usability engineering* (Good et al., 1986; Butler, 1996; Benyon, 2010).

However, latest consumer and entertainment products are often developed and marketed rather with respect to *user experience (UX)* as “*a person's perceptions and responses that result from the use or anticipated use of a product, system or service*” (ISO 9241-210:2010) than in terms of *usability*. Law (2011) noted a growing interest in UX in general and UX measures as scientific methods in particular. She showed that it “*is an emerging research area with a range of issues to be resolved*”. One of them is the question whether and how UX concepts for entertainment products should and could be applied in mission- or safety-critical domains.

In the following section, usability and UX will be compared and distinguished. Subsequently, conduction and results of a brainwriting approach during the workshop on human-computer interaction and social computing in safety-critical systems at the largest European conference on human-computer interaction, user experience, computer-supported cooperative work and usability (“Mensch & Computer”) in 2015 are described. Based on them and literature review three possible perspectives on the role of UX in mission- or safety-critical systems are outlined in section 4.

2 Usability vs. UX

Although there are some occasionally used definitions for UX (see section 1), dealing with it and distinguishing it from usability aspects is difficult in theory as well as in practice for several reasons:

1. According to Law (2011) there is a “*set of proposed relationships between usability and UX (e.g. identical, autonomous or exclusive, hierarchical or subsumptive, symbiotic with distinct characteristics)*”.
2. The definition of UX in ISO 9241-210 and further remarks on this topic within the standard like “*all aspects of the user's experience*” or the term *desirability* “*may produce rather questions than answers*” (Hassenzahl, 2008).
3. A study of Alves et al. (2014) “*paints a picture of the 'UX jungle' in what concerns UX evaluations, as well as the distinct definitions and interpretations it encompasses*”. Times and modes of UX evaluations vary strongly.

Hassenzahl (2008) summarizes the common denominator of all UX approaches as follows: “*They focus on well-being and not performance as an outcome of human-product interaction*”. Pragmatic and more usability-related attributes of products can be distinguished from hedonistic and more UX-related qualities like “*impressiveness*” (Hassenzahl, 2005).

3 Brainwriting and Discussion on UX and Safety

After a short introduction to the topic UX and the challenges mentioned in the previous section, 14 researchers from academia and industry were invited to participate in a brainwriting session during the final part of the one-day workshop “Human-Computer Interaction and Social Computing in Safety-Critical Systems” at the “Mensch & Computer 2015” conference.

“Brainwriting refers to a variant of brainstorming in which people write down their ideas instead of talking about them” (Rollett, 2003). Participants were asked to remember a (positive) UX within a safety-critical context and write down the major characteristics of the situation respectively human-computer interaction. Following this, they had to discuss their records in groups of three or four and derive collective terms. Finally, all groups were asked to put their results onto a wall (see Figure 1) and discuss the overall outcome.



Figure 1: Work results after brainwriting and group discussions sorted by general terms

Some clusters of characteristics and general terms could be identified:

- look and feel / design;
- pleasure / positive reinforcement;
- goal achievement / reliability / assisted-as-needed;
- positively surprising / proactive / context-aware / automatic adaption.

During the following discussion, different views were taken. While some of the participants argued that all of these aspects somehow belong to established approaches to usability engineering (e.g. “assisted-as-needed” interpreted as successful human-machine task

allocation), others assumed differences – at least in ways of thinking about system design. Although, interactive systems should not surprise operators in safety-critical domains, there seems to be room for improvement with respect to long-term motivation, context-aware error handling and graceful degradation of functionality in rare or unexpected circumstances.

4 Three Perspectives on UX in Safety-Critical Domains

In the following sections, three different reasonable views on the role of UX in safety-critical human-machine systems are outlined. They are based on literature review (see references in sections 4.1-4.3) and the group activities mentioned in section 3.

4.1 UX is (still) not well defined

With respect to section 2, it could be argued that UX can not be considered for developing mission- or safety-critical human-machine systems because such application contexts require precise criteria and dedicated measures for legal, regulatory and ethical reasons. In this regard, UX is (still) not well defined. While labelling and marketing consumer and entertainment products with such a term might lead to users' disappointment and could have severe consequences in domains like crisis management or healthcare. Good or positive UX can depend on certain levels of usability but it does not necessarily have to. This is not acceptable for systems entailing substantial risks.

4.2 UX should be considered irrelevant

Even if there was a shared definition of UX in the future, safe and efficient usage of an interactive system would be the most important aspect of the human-machine relationship in mission- or safety-critical domains. Focusing "*on well-being and not performance as an outcome of human-product interaction*" (Hassenzahl, 2008) can lead to design solutions addressing hedonistic more than pragmatic qualities. Goal achievement could be hampered. Therefore, UX should be considered irrelevant for systems entailing substantial risks. Usability is a sufficient criterion hard enough to reach in complex contexts of use and user's satisfaction is considered as well (ISO 9241-11:1998).

4.3 UX is worth a look

Despite the arguments in sections 4.1 and 4.2, UX might be worth a look while designing mission- or safety-critical interactive systems at least for three reasons:

1. With respect to the two-factor theory of job satisfaction of Herzberg et al. (1959), hygiene and motivating factors can be distinguished. While absence of the first ones (e.g. job security) leads to unhappiness, presence of the second ones (e.g. achievements) leads to contentment. Therefore, overall job satisfaction comprises of two different continuums (Sanjeev & Surya, 2016). In this regard, usability might

be seen as a hygiene factor and user experience as a motivating factor. As “*managers [are necessitated] to consider two sets of job attributes*”, designers of mission- or safety-critical interactive systems should pay attention to usability and UX.

2. Consumer and entertainment products providing own frameworks and guidelines for user interface and user experience design have already made their way into domains with mission- and safety-critical characteristics (Rice et al., 2016).
3. Upcoming generations of operators in mission- or safety-critical domains will be used to design solutions considering aesthetics and hedonism to a greater degree in their private life and might expect them in their professional life, too. Tractinsky et al. (2000) measured “*strong correlations between system's perceived aesthetics and perceived usability*” with respect to a cash machine and “*stress the importance of studying the aesthetic aspect of human-computer interaction (HCI) design and its relationships to other design dimensions.*”

Several researchers already aim to go “*beyond usability*” for “*evaluating emotional response as an integral part of the user experience*” (Agarwal & Meyer, 2009), for “*user satisfaction and quality management*” (Sikorski, 2000), and for designing “*safety-critical systems*” (Palanque et al., 2007). For example,

- Savage-Knepshield et al. (2014) tried to “*help [to] ensure that a positive user experience (UX) will result when soldiers and systems interact under harsh conditions on the battlefield*”;
- Kjeldskov and Stage (2003) were involved in “*designing the user experience of the Handheld Maritime Communicator [...], a mobile computer system supporting communication and coordination of safety-critical work activities on large container vessels*”; and the work of
- Eckoldt et al. (2013) is in place of several research efforts on UX in automotive.

Furthermore, addressing the “*whole user experience*” is one of the principles of human-centered design named in ISO 9241-210:2010. However, the standard states that for safety- or business-critical systems effectiveness and efficiency could be more important than fulfilling users’ preferences.

5 Conclusions

User experience (UX) can not be applied to mission- or safety-critical domains straightforwardly and might even be considered too ambiguous, irrelevant or even risky. Performance is of utmost importance because well-being of users (operators) and other human beings depends on it. Therefore, usability seems to be a sufficient criterion for assessing human-computer interaction aspects at first glance. However, taking hedonistic attributes of products and positive humans’ emotions like pleasure or pride into account – as UX approaches suggest – might lead to more profound design solutions. Future operators could even expect them in their professional life because they grow up with corresponding

consumer and entertainment products. Herzberg's two-factor theory of job satisfaction might be a helpful foundation in further research. In any case, designers of mission- or safety-critical interactive systems should strive for usability in the first place but consider the key ideas of UX design as motivating factors.

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