https://doi.org/10.17648/rea.v13i2.41.en

ASSOCIAÇÃO BRASILEIRA DE ERGONOMIA
ABERGO
Revista Ação Ergonômica
www.abergo.org.br
Ação Ergonômica
Revista da Associação Brasileira de Ergonomia - ISSN 1519-7859

CROSS-DEVICE DESIGN PROCESS FOCUSED ON USER EXPERIENCE QUALITY.

Genilda Oliveira de Araujo: genilda@gmail.com; UFSC
Lizandra Garcia Lupi Vergara: l.vergara@ufsc.br; UFSC

ABSTRACT

The combined use of devices has become commonplace with the popularization of desktops, notebooks, tablets, smartphones and wearables. Despite this, cross-device use cases are rarely supported by software and users often need to act as a bridge to connect devices. Considering this context, the present paper aims to identify the specific aspects that need to be part of analysis and decision making in cross-device projects in order to guarantee their ergonomics and the quality of user experience. For this purpose, a systematic literature review was carried out. As a result, a descriptive model of the cross-device design process was synthesized. This model is based on activity analysis and presents the main aspects involved in the qualityassessment of the system.

KEYWORDS: interaction design; ergonomics; user experience; cross-device.

1. INTRODUCTION

The number of computing devices that people use is growing. In addition to traditional desktops, other devices such as laptops, tablets, smartphones, and wearables are now part of people's daily lives, bringing new possibilities for applications. One of these possibilities is cross-device interaction (SKOV et al., 2015), in which the completion of an activity is supported by the combined use of multiple devices.

This combined use can occur in two types of arrangements: sequential or parallel (JOKELA; OJALA; OLSSON, 2015). In the sequential case, the user switches devices during the task. For example, they may start writing a document on a tablet and finish it on a laptop. In the parallel case, the user simultaneously performs different aspects of a task on at least two devices. For instance, a smartphone can serve as a control for a presentation displayed on a desktop.

According to Zagermann et al. (2017), this new scenario expands the scope of Human-Computer Interaction (HCI), which no longer only addresses the isolated use of devices but also deals with the use of device ecologies. However, as highlighted by Dong et al. (2016), cross-device use cases are rarely supported by application software, and users commonly need to act as a bridge to connect devices. Thus, users often bear the burden of transferring data between devices or repeating actions on one device that were already performed on another. As a consequence, the physical and cognitive load increases, as well as the difficulty of performing even relatively simple tasks.

This scenario, characterized by the contrast between the availability of technical resources for building cross-device systems and the scarcity of high-quality experiences, implies, according to Dong et al. (2016), the existence of design challenges that have not yet been fully understood.

2. OBJECTIVE

This article aims to identify the main specificities that need to be part of the analysis and decision-making process during the cross-device project, in order to promote its ergonomics and the quality of the user experience.

3. METHODOLOGY

The adopted procedure was a systematic literature review. For this, the methodology proposed by Kitchenham and Charters (2007) was followed, which suggests five steps: (a) definition of the research question; (b) definition of the search strategy; (c) search; (d) selection of primary results; (e) data extraction. The defined research question was: 'What aspects need to be addressed in cross-device design to ensure ergonomics and the quality of the user experience?'

As a search strategy, the following keywords were selected: ("usability" or "user experience" or "ergonomics" or "human factors") AND ("cross-device" or "multi-device" or "cross-platform" or "multi-platform" or "multiple user interfaces" or "distributed user interfaces"). In addition to the keywords present in the research question, terms used as synonyms or found to be relevant in search string testing were added.

The search was conducted in the SCOPUS, ACM Digital Library, and Web of Science databases. The research included articles from journals and conferences, as well as book chapters. The decision was made not to limit the publication period. In the selection of primary results, studies were included that:

I1: Address design issues that influence ergonomics, usability, and/or user experience;
Studies were excluded if:
E1: Keywords were only briefly mentioned;
E2: There is a focus only on technical issues for cross-device development.

Table 1 provides a quantitative overview of the review. These data show a significant number of articles being discarded. The reason for this is the prevalence of studies focused on technical development issues.

Table 1. Quantitative overview of the systematic review.

Data Base	Results	Not Duplicates	Select
SCOPUS	378	374	31
ACM Digital	63	28	3
Web of Science	91	60	2
Total	**532**	**462**	**36**

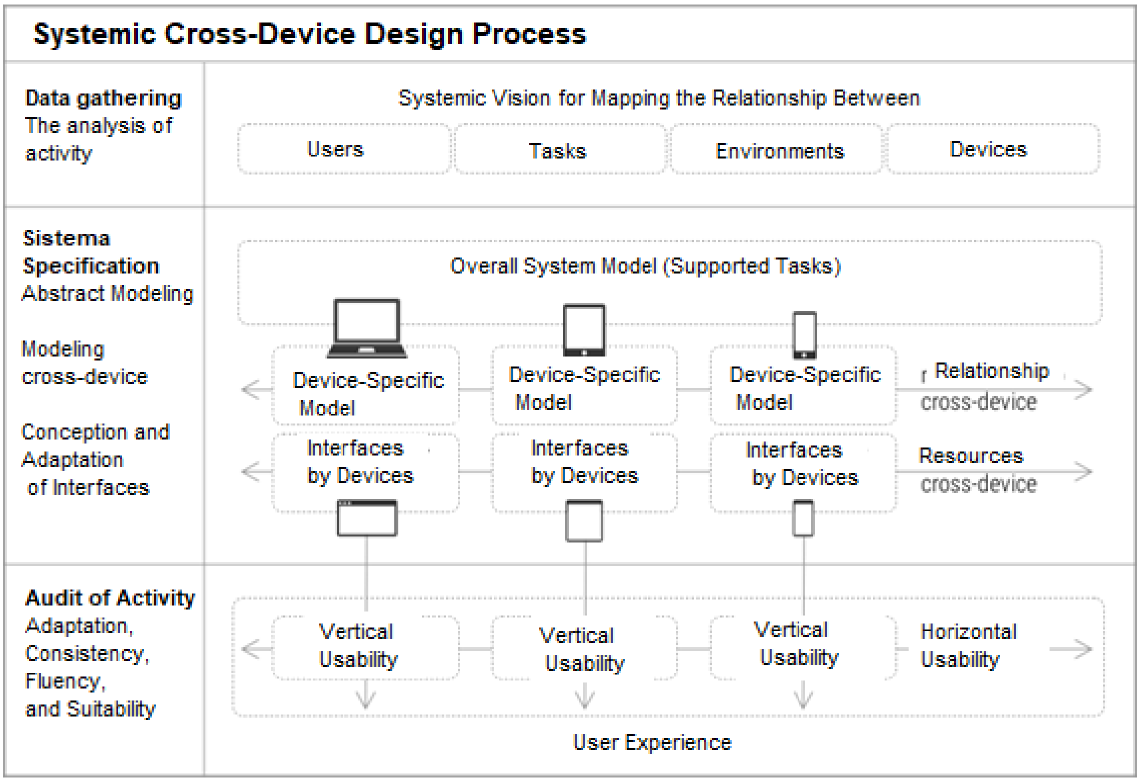
4. RESULTS

As a result of the analysis of the selected articles, the main specificities mentioned for the cross-device design process were identified. These items were synthesized to generate the proposed design model in this section of the article.

As a starting point for the model, it was identified that an essential aspect to be addressed in cross-device design is heterogeneity (SEGERSTÅHL, 2008). Devices vary in terms of storage capacity, resources, modalities for data input and output (e.g., visual, auditory, haptic, etc.), interaction styles, and procedures (DENIS; KARSENTY, 2003). As a consequence, interfaces need to be different to accommodate the variation in characteristics among devices such as desktops, tablets, and smartphones. Thus, there is a need for an integrative vision to govern the design. According to Oliveira and Rocha (2007), in the absence of a systemic conceptualization, interfaces developed for one device often break the conceptual model created for another. As a result, the system becomes inconsistent, and elements of the user's cognitive process, such as memory, learning, and reasoning, are disregarded.

As a path to a unified system conception, the use of model-based design processes was identified in several of the selected articles in the review. The purpose of this approach, according to Paternò (2005), is to identify high-level models that allow specifying and analyzing systems at a conceptual level, rather than immediately dealing with interaction and implementation aspects, which may vary across devices. Since a systemic view is an essential feature of ergonomics (WILSON, 2014), we chose to adopt this approach. The proposed design structure consists of three stages: (a) data gathering; (b) system specification; (c) quality evaluation. These stages are shown in Figure 1 and detailed below.

Figure 1 - Cross-device design process.



The data gathering stage serves as the basis for model development. In this context, an approach based on activity analysis is suggested. According to Segerståhl (2008), information technology, including multiple devices, should be used if, and only if, the functions provided are suitable for users' activities. It is essential to precisely identify the activity to be supported by the system to be designed, including its decomposition into a set of goal-directed actions formalized as tasks. This aligns with Work Ergonomic Analysis (DARCES; FALZON; MUNDUTEGUY, 2007), which also adopts the concept of activity as the unit of analysis.

Segerståhl and Oinas-Kukkonen (2007) state that the identification of activity can occur in various social, physical, and chronological contexts. These contexts are connected with technology and allow establishing the distribution of devices concerning the activity. Thus, an essential aspect of cross-device design is understanding the relationship between users, tasks, environments, and devices. Adopting an integrative view ensures that, despite the multiplicity of devices, tasks, and environments, the system is perceived by users as a single interface designed to support a specific activity.

Regarding the system specification stage in the cross-device case, modeling the solution at different levels of abstraction is suggested. The first level, designated by Seffah et al. (2004) as a general task model for software support, involves the classification, prioritization, and temporal relationship between tasks to be supported by the system, establishing an abstract operational structure. Meixner et al. (2011) highlight that the necessary information to perform each task is also defined at this stage.

The second level of abstraction corresponds to cross-device design itself and includes the distribution of tasks among devices (SEFFAH; FORBRIG; JAVAHERY, 2004). At this level, according to Celentando and Dubois (2017), two layers of the interactive process must be considered. The first, called interaction in the small (ItS), addresses the design of interaction with each device, defining sequences of operations that the user performs on each of them in a short, uninterrupted timeframe to achieve a specific goal. The second layer, called interaction in the large (ItL), includes the design of a more global view that establishes relationships between tasks and devices. In this layer, more complex task sequences involving different devices and perhaps different contexts are designed. The term "trajectory" is used to describe this sequence. Similarly, Majrashi et al. (2016) refer to horizontal tasks as those involving more than one device and containing subtasks distributed among them.

In this horizontal design process, it is essential to plan how the system will support joint use. According to Tungare and Pérez-Quinones (2009), the lack of support leads to a decrease in user experience quality due to mental demand, workload, and consequent frustration. In extreme cases, a task disconnection may occur, described by Pyla et al. (2009) as a temporal rupture due to the user's need to perform actions external to the focused task to enable the use of multiple devices. Thus, defining the relationship between devices for task execution is essential.

The third level of abstraction involves the design of interfaces for each device. In this part of the process, the execution of tasks assigned to a device must be adapted to its characteristics. For example, to respond to a WhatsApp message on the Apple Watch, which does not have a keyboard, interfaces are offered that allow the use of predefined responses, sending an audio message, or using the dictation feature. According to Paterno and Santoro (2012), interfaces can vary in four aspects: presentation, components, content, and navigation. When variation occurs in terms of presentation, there are more superficial adjustments, involving resizing and repositioning interface elements. Component variations occur to accommodate differences between operating system standards (e.g., iOS and Android) or their interactive modalities (e.g., use of gestures, mouse, or voice commands). Content adaptations express the need to remove, add, or modify information and/or parts of the task to ensure usability according to the device's resources. Finally, navigation variations organize access to interfaces according to the characteristics of each device.

In the quality evaluation stage, the scope of analysis expands to involve vertical usability, horizontal usability, and user experience. Vertical usability (SEFFAH; FORBRIG; JAVAHERY, 2004) refers to traditional usability requirements specific to each device. At this level, it is important to evaluate the quality of task adaptation to the device. Horizontal usability (SEFFAH; FORBRIG; JAVAHERY, 2004) is focused on promoting easy transitions between devices. According to Majrashi et al. (2018), the two main aspects to be verified in the transition are consistency and fluency. Consistency promotes continuity of knowledge (DENIS; KARSENTY, 2003) and aims to facilitate the recovery, reuse, and adaptation of knowledge built by the user from interaction with one or more devices. According to Zeng et al. (2014), the consistent use of components serves as a reference to facilitate the extraction of the essence of the application. Fluency is linked to task continuity (DENIS; KARSENTY, 2003) and is based on resources for sharing between devices the memory of the user's last operations, ensuring synchronization. Thus, the system removes from the user the cognitive effort to recover data status and activity context. Additionally, another factor that affects horizontal usability is the spatial distribution of devices, which can generate physical interactive problems (ZAGERMANN et al., 2017).

Finally, user experience is considered a broader quality aspect. As highlighted by Shin (2016), the main goal in a cross-device system is to ensure responsiveness to the user, not the devices. This means that promoting a good experience does not only consist of allowing tasks to be performed on multiple devices. The result of this process has to be meaningful for the user and linked to meeting the needs that motivate the activity (HASSENZAHL et al., 2013). Thus, it encompasses the adaptation of the system to users' needs, considering their capabilities, abilities, and limitations, as well as the environment and devices.

5. CONCLUSION

This work presented a model that describes a process for cross-device design based on activity analysis and modeling. As a contribution, the identification of the main specificities that need to be part of the analysis and decision-making process in different stages of cross-device design was emphasized to ensure its ergonomics and the quality of the user experience. Thus, it offers an integrative approach to activity and its distribution across devices, aligning with the systemic view of ergonomics. As highlighted by Wilson (2014), the analysis of complex systems can benefit from representations that show where and how the boundaries of a certain type of system operate, providing context for ergonomic assessments and proposals for improvements in instances of that category of problem. Specifically regarding quality evaluation, the work contributes with a three-level analysis approach: vertical usability, horizontal usability, and user experience. Finally, for future work, it is suggested to delve into the description of task modeling and cross-device modeling.

REFERENCE

CELENTANO, A.; DUBOIS, E. **Interaction-in-the-large vs interaction-in-the-small in multi-device systems**. Proceedings of the 12th Biannual Conference on Italian SIGCHIChapter. **Anais**...ACM, 18 Set. 2017.

DARCES, F.; FALZON, P.; MUNDUTEGUY, C. Paradigmas e modelos para a análise cognitiva das atividades finalizadas. Em: FALZON, P. (Ed.). **Ergonomia**. São Paulo: Edgard Blucher, 2007. p. 155–173.

DENIS, C.; KARSENTY, L. Inter-Usability of Multi-Device Systems – A Conceptual Framework. Em: **Multiple User Interfaces**. [s.l.] John Wiley & Sons,

2003. p. 373–385.

DONG, T.; CHURCHILL, E. F.; NICHOLS, J. **Understanding the Challenges of Designing and Developing Multi-Device Experiences**. Proceedings of the 2016 ACM Conference on Designing Interactive Systems. **Anais**...ACM, 2016.

HASSENZAHL, M. et al. Designing Moments of Meaning and Pleasure. Experience Design and Happiness. **International Journal of Design**, v. 7, n. 3, p. 21–31, 2013.

JOKELA, T.; OJALA, J.; OLSSON, T. **A Diary Study on Combining Multiple Information Devices in Everyday Activities and Tasks**. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. **Anais**...: CHI '15.New York, NY, USA: ACM, 2015.

KITCHENHAM, B.; CHARTERS, S. **Guidelines for performing Syst Software Engineeri**. [s.l.] Keele University and Durham University Joint Report, 2007.

MAJRASHI, K.; HAMILTON, M.; L. UITDENBOGERD, A. **Cross-Platform Cross-Cultural User Experience**. : Electronic Workshops in Computing. Em: BCS HUMAN COMPUTER INTERACTION CONFERENCE 2016. BCS Learning & Development, 2016.

MAJRASHI, K.; HAMILTON, M.; UITDENBOGERD, A. L. **Task Continuity and Mobile User Interfaces**. Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia. **Anais**...ACM, 25 Nov. 2018.

MARTINIE, C.; NAVARRE, D.; PALANQUE, P. A multi-formalism approach for model-based dynamic distribution of user interfaces of critical interactive systems. **International journal of human-computer studies**, v. 72, n. 1, p. 77–99, 1 Jan. 2014.

MEIXNER, G.; SEISSLER, M.; BREINER, K. Model-Driven Useware Engineering. Em: HUSSMANN, H.; MEIXNER, G.; ZUEHLKE, D. (Eds.). . **Model-Driven Development of Advanced User Interfaces**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011. p. 1–26.

OLIVEIRA, R.; ROCHA, H. V. **Conceptual Multi-Device Design on the**

Transition between e-learning and m-learning. Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007). **Anais**...2007.

PATERNÒ, F. Model-based tools for pervasive usability. **Interacting with computers**, v. 17,n. 3, p. 291–315, 2005.

PATERNÒ, F.; SANTORO, C. **A Logical Framework for Multi-device User Interfaces**. Proceedings of the 4th ACM SIGCHI Symposium on Engineering Interactive Computing Systems. **Anais**...: EICS '12.New York, NY, USA: ACM, 2012.

PYLA, P. S. et al. **Continuous User Interfaces for Seamless Task Migration**. Human-Computer Interaction. Ambient, Ubiquitous and Intelligent Interaction. **Anais**...Springer Berlin Heidelberg, 2009.

SEFFAH, A.; FORBRIG, P.; JAVAHERY, H. Multi-devices «Multiple» user interfaces: development models and research opportunities. **The Journal of systems and software**, v.73, n. 2, p. 287–300, 2004.

SEGERSTÅHL, K. **Utilization of Pervasive IT Compromised?: Understanding the Adoption and Use of a Cross Media System**. Proceedings of the 7th International Conference on Mobile and Ubiquitous Multimedia. **Anais**...: MUM '08.New York, NY, USA:ACM, 2008

SEGERSTÅHL, K.; OINAS-KUKKONEN, H. **Distributed User Experience in Persuasive Technology Environments**. (Y. de Kort et al., Eds.)Persuasive Technology. **Anais**...: Lecture Notes in Computer Science. Em: INTERNATIONAL CONFERENCE ON PERSUASIVE TECHNOLOGY. Springer Berlin Heidelberg, 2007.

SHIN, D.-H. Cross-Platform Users' Experiences Toward Designing Interusable Systems. **International Journal of Human–Computer Interaction**, v. 32, n. 7, p. 503–514, 2 Jul. 2016.

SKOV, M. B. et al. **Investigating Cross-Device Interaction Techniques: A Case of Card Playing on Handhelds and Tablets**. Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction. **Anais**...: OzCHI ’15.New York, NY,USA: ACM, 2015.

TUNGARE, M.; PÉREZ-QUINONES, M. A. **Mental Workload at Transitions between Multiple Devices in Personal Information Management**. Personal Information Management Workshop, ASIST Vancouver. **Anais**..., 2009.

WILSON, J. R. Fundamentals of systems ergonomics/human factors. **Applied ergonomics**, v.45, n. 1, p. 5–13, 2014.

ZAGERMANN, J. et al. **Studying the Benefits and Challenges of Spatial Distribution and Physical Affordances in a Multi-device Workspace**. Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia. **Anais**...: MUM ’17.New York, NY, USA:ACM, 2017.

ZENG, Y.; GAO, J.; WU, C. **Responsive Web Design and Its Use by an E-Commerce Website**. (P. L. Patrick Rau, Ed.)Cross-Cultural Design. **Anais**...: Lecture Notes in Computer Science. Em: INTERNATIONAL CONFERENCE ON CROSS-CULTURAL DESIGN.
Springer International Publishing, 22 Jun. 2014.