Establishing Guidelines for User Quality of Experience in Ubiquitous Systems

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Abstract. Interaction Technologies are designed to provide continuous, shared and user-friendly access in the current computerized world. Ubiquitous computing includes several features, such as invisibility, continuous interaction and various modes of interaction, which are not present in the paradigm of traditional computing. A relevant issue is that existing recommendations for quality user experience in traditional computing may not prove to be sufficient for the field of ubiquitous computing. In this research a systematic review method was chosen to develop a theoretical basis of the literature about the research theme "investigate user experience in ubiquitous systems", followed by a qualitative analysis of the selected papers. One result of this work is the guidelines establishment which aims to assist the ubiquitous system design favoring the user experience quality. A case study of the Waze application was carried out to analyze the applicability of the proposed guidelines.

Keywords: Ubiquitous systems · User experience · Guidelines

1 Introduction

Ubiquitous computing is transforming how user interaction gets along with technology, moving away from the traditional way afforded by desktops. Sensors, mobile devices and the improvement of mobile networks are some factors that allowed the diffusion of technology and its use in our daily activities. Weiser, creator of the concept of ubiquitous computing, said in the late 80s that "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" [2]. Ubiquitous computing is a relatively recent area and involves many factors in its production, so new issues emerge, both related to hardware, such as processing power, as related to software, such as security, privacy and user experience [18].

User experience is defined by ISO 9241-210 [10] as a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". In addition to that, user experience (UX) "includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments that occur before, during and after use".

Likewise, Tullis and Albert [25] have the vision that some people distinguish the terms of usability and UX, "Usability is usually considered the ability of the user to use

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a thing to carry out a task successfully, whereas UX takes a broader view, looking at the individual's entire interaction with the things, as well as the thoughts, feelings, and perceptions that result from that interaction". In the same way, for Hassenzahl and Tractinsky [6], UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality etc.) and the context (or the environment) within which the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use etc.).

The paradigm of traditional human-computer interaction, systems and UX was designed thinking in static interactions with the keyboard and mouse inputs. The recommendations for design and usability evaluation in these systems considered this nature. In ubiquitous computing, the devices are omnipresent and the interaction forms are natural to the user. According to Ranganathan *et al.* [21], "in designing usable pervasive environments developers must consider both old and new usability challenges". The standards and recommendations that exist in the field of 'traditional' human-computer interaction (HCI), although relevant, they are not enough to the research and development of systems in this area. Due to the nature of ubiquitous computing, some parts of the project and evaluation are not covered. Efforts have been made to extend the existent techniques and/or establish new techniques, recommendations and normative for the project and evaluation on HCI [23, 25].

Given the above, this research produced a literature review with the purpose of seeking the existence of recommendations and reviews techniques for UX quality in ubiquitous systems. For this purpose, the methodology adopted was the systematic review, followed by a qualitative analysis of selected papers. One result of this study was the formulation of (11) eleven guidelines that aim at assisting the design of ubiquitous systems that favor the UX quality. The guidelines was applied in Waze application.

2 Systematic Review Protocol

The methodology used to search the theoretical basis was the systematic review (SR) [14]. In this study, we defined three research questions: (1) are there guidelines or specifics normatives to ensure a UX quality in ubiquitous systems?; (2) What are the HCI characteristics required for ubiquitous systems? and (3) What are the criteria to be observed in ubiquitous systems, to evaluate the UX quality? The first question's aim was to discover whether there are any guidelines or normatives as ISO [10], about UX quality in ubiquitous systems. If there were any, they would be evaluated, checking their scope and possible updates. In the second question, attempts were made to find articles that discuss the HCI features and requirements needed for ubiquitous systems. By the third question, the focus was on the evaluation processes of the UX quality.

Some systematic review keywords were proposed from the research questions: "human-computer interaction", "ubiquitous computing", "context-aware systems", "usability", "quality of interaction", "user experience quality". The search strings are composed of the keywords along with logical operators (see Fig. 1). The search strings were executed in the digital libraries: journals CAPES/MEC, IEE Xplore Digital Library, Scholar Google, ACM Digital Library, Springer e Citeseer Library. The studies inclusion criteria adopted were: (1) period: starting from January 2000; (2) language: english and portuguese; (3) availability on the Internet; and (4) if it appears duplicate papers, only the most complete works would be included.

The selection criteria would filter papers for the final selection that must have only the relevant articles to the research topic: Exclusion Criteria 1 (The study presents characteristics or evaluation of HCI or usability); Exclusion Criteria 2 (The publication presents characteristics, criteria and/or guidelines to be followed when evaluating or designing ubiquitous systems to ensure the UX quality?). After defining the SR protocol, searches strings were executed in the selected digital libraries, through November/2014 to April/ 2015. The returned papers were selected and stored based on the title and abstract. Later, the papers were read thus selecting only those that are relevant to the research, paying attention to the inclusion and exclusion criteria and the research questions.

Figure 1 shows the phases and results of systematic review based on PRISMA diagram [26]. In the 1st stage 1419 studies were returned. In the next step we selected 104 articles, among which 26 papers were included in the final selection of this SR. With the reading and study of the 26 articles was possible to see that there are no guidelines or standards for the UX quality in ubiquitous systems.

Some articles discussed such initiatives as Somervell *et al.* [24], which proposed a set of guidelines for exposure to Ubiquitous information displays. Santos *et al.* [23] developed a model of quality named TRUU (Trustability, Resource-limitedness, Usability and Ubiquity) to support the assessment of HCI in ubiquitous systems. Hong *et al.* [8] proposed a method for elicitation of context-aware applications requirements. Jensen and Larsen [13] proposed a framework that includes a subset of data to automate the capture and analysis of UX data field in large scale studies. However, the framework deals only with quantitative data, and lack of qualitative data. Ranganathan *et al.* [21] presented several metrics to assess pervasive computing environments. They are divided into security, programmability and usability metrics. These initiatives still require further checks, as validation applications in future studies.

The systematic review also made a clear differentiation between usability and usability in ubiquitous computing and the need for the creation or expansion of usability evaluation methods in ubiquitous computing [21]. For Santos *et al.* [23] the nature of ubiquitous systems suggests that new quality characteristics should be taken into account. Kray *et al.* [16] also says that a fundamental problem in the evaluation of ubiquitous systems with users is the lack of clear guidelines for the selection of valuation methods adapted to ubiquitous computing.

Given the need that ubiquitous computing brought in defining new recommendations, some features considered important for ubiquitous computing for use of quality are already under discussion in some of the papers returned by the SR.

For Boca *et al.* [3], one of the most important variable in pervasive systems is represented by the cognitive load. Related to minimization of cognitive load, for Santos *et al.* [23] "it is necessary to assure that ubiquitous systems support user activities in a transparent way with little or no need for attention or input from the user". Likewise, for Iqbal *et al.* [11], ubiquitous computing paradigm, with computers being everywhere, calls for new technology that prevents humans from feeling overwhelmed by information. Finally, for

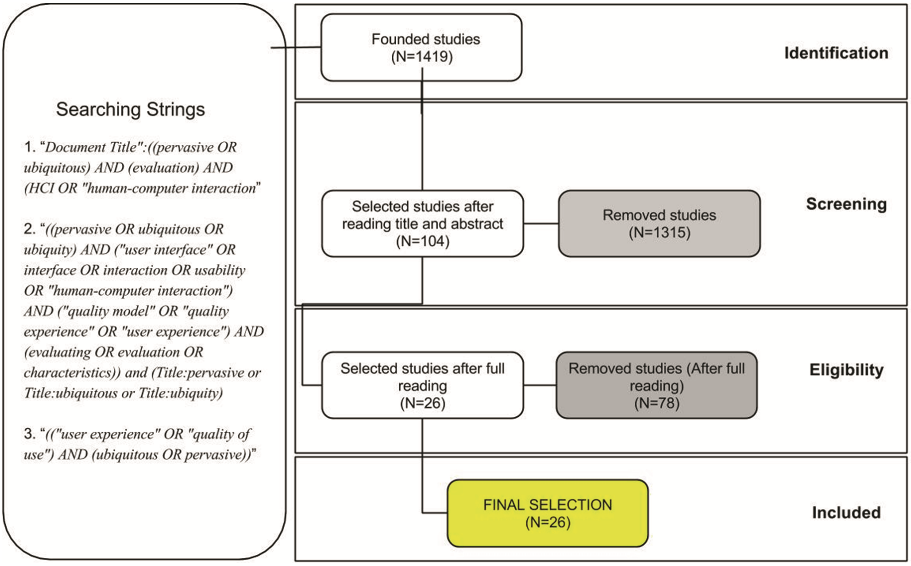

Fig. 1. Systematic review process [26]

Jensen and Larsen [13], the cognitive load in most usage situations is significantly higher than average for desktop applications.

Likewise, properly exploit the characteristic of high availability of devices and interaction modes is a significant concern. Islam and Fayad [9] propose to do the appropriate task on the appropriate device. "Different input techniques make sense on different devices". Other papers discussed the importance of multimodal interaction [1, 21, 23] that should provide the user flexibility of choice in the interaction.

Context-awareness is also seen as an important factor in the design of ubiquitous systems, and discussed in the work of [1, 8]. For Hong *et al.* [8], "context makes the communication between humans and computing devices much more efficient".

Further characteristics were mentioned in the articles, such as personalization [7] - the systems becoming increasingly customized to reflect the desires and personality of the user, and natural interfaces [1], allowing ease of use of the system. For Hong *et al.* [8] by using a natural interface, a user does not need to change the current interaction behavior; According to [1, 8, 21], systems should provide access to the user at any time since the interaction is no longer static. And finally in line with the papers, equally important factors for the quality of user experience are the concern for accessibility in the design of ubiquitous systems [8], and cultural aspects [12]. These characteristics should be explored in ubiquitous computing projects, promoting a quality user experience.

The discussions and results presented in the papers were important to make up the state of the art about characteristics, criteria and recommendations for the UX quality in HCI. Just as formed the conceptual basis for the establishment of new recommendations to assist designers in evaluation and design phases of ubiquitous systems with regard to UX.

The next section presents the eleven guidelines for the UX quality built on the theoretical basis acquired in the systematic review. The guidelines are standardized with the same format: definition, an example and reference the work that discussed issues directly related to the concept established in the guideline.

3 Guidelines

With the systematic review was possible to observe general concerns of researchers about the UX quality in ubiquitous systems. Many of these concerns were referenced in several articles. So these guidelines are based mostly in literature studies. In this research, 11 (eleven) guidelines are presented below.

1. **Make use of multimodal interaction:** The system should allow the user to benefit functionalities available in applications by interacting in different ways with the device such as touch, gesture, voice etc. Multimodality increases the ease of use giving flexibility in user interaction with applications. For example, a user can benefit from using the voice command while adjusting the seat belt in your car [1, 5, 12, 21].
2. **Introduce an integrated system of interactions:** Ubiquitous environments feature various functionalities and interactions forms. These interactions forms allow the user to communicate in a more comfortable and natural way, because they use natural inputs, as gestures, voice, image capture etc. The ideal, to provide user experience quality, is to present an integrated interaction system, where the device offers to the user all these interaction options with the system and the user could choose the best option in a specific context. For example, a user who uses an agenda, can enter appointments by voice while alone, or typing in a location where he does not feel comfortable to interact by voice [8, 21]
3. **Designing continuous interaction in ubiquitous services:** The services and features of a ubiquitous system must be continuous between different devices and platforms. The user must switch between these different devices without feeling the changes. For example, a user is in a meeting in his company and creates a reminder for an event for later evening on his computer. Through the phone, he adds location to the event. Later, when he get into the car to leave, the car warns him about his commitment, saying the time and place. Also asks if the user wants to connect the GPS to address to the location [1, 5, 8, 21].
4. **Project to explore the characteristics of each system:** The ubiquitous system could present several functionalities to the user, and run in various devices, however, it should explore positive points in each device (cellphone, tablet, desktop) aiming to offer a suitable group of interactions. For example, a app can suggest to the user purchase options, while he gets around a mall with a mobile device, but this functionality wouldn't apply to a laptop or desktop [9].
5. **Know how to explore the characteristic of invisibility:** The ubiquitous systems should not require explicit user interaction at the time. They must act in the context from the collection of environment information, not just the interaction with the user, with the appropriate level of intrusion. For example, in an application which

assists a physician in monitoring their patients should be calibrated to notify the doctor only in situations where he wish, for example in more severe situations. In other situations the application would notify a nurse or just record information for any reports. The user could access the App any time to check the status of patients [1, 20, 22, 23].

6. **Design interfaces that minimize the effort of attention:** The interface should present the information in a simple way for the user, so that the attention of effort is minimized. Since generally in a ubiquitous and context aware environment, there is no focal point for the user to fully concentrate because the attention is usually shared with other devices and also affected by external factors such as noise, movement etc. For example, imagine a situation where a user is making a run and want to see the application that monitors your heart rate if the information is not presented simply, without requiring much of attention for viewing, the user may not be able to observe information while moving [3, 8, 23].
7. **Make use of affordances and mental models:** The interface and system behavior must be intuitive for the user, i.e., the system should make use of affordances and support mental models to be more understandable thereby increasing ease of use. For example, an application that controls a multimedia room could use in interface world universal knowledge artifacts such as control room light is a light bulb icon [4, 20, 21].
8. **Designing for the user control:** The system shall allow users to take control of the application and its features. Thus, the application will best meet the preferences and needs of the user. For example, in a streaming and music sharing application, if the user wishes, the application must allow users deactivates some features such as recommendations and share music [7, 19].
9. **Designing interfaces for trust:** The interface should be designed to raise user trust exploring features like transparency. The interface should provide the user clear understanding of what and why something happens in the system. The information must be clear and easy to access, in order to increase user confidence in the application. For example, applications that check-in places such as restaurants, nightclubs, should allow the user to control the sharing options leaving you free to activate and deactivate the check in whenever you want [17]
10. **Designing for error management:** The system should allow the user to recover from an error, or give a workaround for the error. When the error happens, the system should help the user with clear explanations of what is happening, avoiding obscure messages with error codes without explaining them, and offer an alternative solution. For example, in a ubiquitous application an interaction mode failure, such as the touch input, the system must offer another form of interaction for the user to continue to use the system, such as voice input, explaining clearly how the application works in this form of interaction. The system can also, when recognize that an error occurred, indicate other device that the user can use to continue the task performed [1, 20].
11. **Design for accessibility:** Take advantage of the context awareness characteristic to draw a user profile and assist the user in making decisions and daily activities. Likewise, use the multimodal interaction feature to assist the user interaction with

the application. For example, a user with physical disabilities should not be directed to the stairs when requesting the path to certain room of the building. It should be directed only by the paths it can go, such as ramp or lift. In the field of interaction, the user with visual impairment can interact with an application through gestures or speech [8].

All in all, the guidelines 1 to 3 deal on the new interaction nature of the ubiquitous systems, i.e. about their multiplicity and rapid transition between modes of interaction. The guidelines 4 to 7 recommend important characteristics based on the amount of different available devices and characteristic of devices invisibility. The guidelines from 5 to 7 have focused on the importance of UX quality seeking to minimize the cognitive effort. The guidelines 8 to 10 also deals with the quality of the UX, but in the basic aspects of the application to ensure trust and user acceptance. Finally, the guideline 11 raises concerns in the design for accessibility for all users without distinction be able to use the application or the ubiquitous system. We believe that these guidelines can contribute to research and development of new projects guiding researchers to make these systems easier to use.

4 Case Study - Analysis of the Guidelines Applicability

To analyze the applicability and the need for guidelines refinement, an inspection process with ubiquitous applications was conducted. This section will present how the study was conducted with the Waze application from the category “Travel & Local” as well as the results.

Waze Operation: Waze is a GPS navigation application, who maps routes to reach a destination using real-time information from a collaborative network of users. The application informs traffic data such as police traps, accidents and other events. The system guides the navigation to the user informing direction and path. In the map are informed route details like place address and phone number. The user also can interact with the application through voice and gestures. Furthermore, the system has the functionality to view and update information about fuel and share routes with friends.

Inspection Methodology: It consists of selecting applications and analysis of the guidelines applicability in selected applications. In the application selection process, some criteria have been met: 1 - technical and general criteria (a - Android applications; b - were highly rated in Google Play; c - were popular on Google Play.); and 2 - criteria on the nature of the application (a- be ubiquitous or; b - have ubiquitous characteristics). Were adopted the Android operating system for its range of users. The popularity and good evaluation criteria are important because through them ensures the selection of applications that users have interaction with regularity. The criteria 1-b was adopted as highly rated applications with an average reviews score above 4 stars; in the criterion 1-c were considered applications with at least 10 million downloads. Lastly, the criteria on the nature of the application ensures that evaluate in fact applications of ubiquitous nature.

After the selection of applications, the methodology for evaluating the guidelines consisted of two steps: (1) selection functionalities - were selected functionalities relevant to the ubiquity and UX, and (2) analysis of the functionalities in the light of the guidelines - for each guideline, we examined its applicability in the functionalities of the applications by looking if the guidelines were adopted and its range of adoption. At the end of the two stages was made an analysis of the process as well about their guidelines adoption on the project application, pondering requirements and factors that affect the quality of UX.

Analysis of Guidelines Applicability: The functionalities available in the Waze application are accessible through natural interactions to users, i.e. the set of interactions available to the user goes beyond the interaction through smartphone buttons and touch-based interaction. User can interact through voice, gestures; make alerts by voice command and attach photos. In this way, the guidelines "1. Make use of multimodal interaction" and "2. Present an integrated system of interactions" are observed in the application.

The guideline "3. Design continuous interaction in ubiquitous systems" does not apply because the mobile and desktop applications have different purposes. On desktop, you can edit the map; see big disasters or unforeseen events that may affect navigation. In the smartphone, the purpose is navigation and real-time information sharing that update map data. The app runs on Android, iOS and Windows Phone, and some users use the application on cars through smartphones and mirror link. On the other hand, in desktops the user can access maps and edit them in the application site (waze.com). Therefore the guideline "4. Design to explore the characteristics of each device", that says to exploit the strengths of each device aiming to providing an appropriate set of interactions is contemplated. It makes sense to use functionalities alerts, navigation and local sharing by mobile devices, while walking or driving. Thus the option of editing maps is best used by computers, with a larger screen.

Context-awareness is very well explored in the application. Through the GPS user can be located on the map, see different types of nearest shops and gas stations - all these features help the user in making decisions and it minimizes the work that would have without using the application. As a result, the context sensitivity in the application identifies the map alerts and show them to the user. Also with these data, the application uses the alerts to calculate alternative routes to the destination. So the guideline "5. Know explore the invisibility characteristic" is well observed.

The buttons of the application's functions are accompanied by consistent icons with artifacts from the real world, contributing to the intuitiveness of the system. Therefore, the guidelines "6. Design interfaces that minimize the effort of attention" and "7. Make use of affordances and mental models" are included in this application.

In the setup menu, user can change various application functions such as fuel preferences, types of streets among others. The user also has control over how the map will be displayed, their Wazer icons etc., can drive as invisible, i.e., appears as disconnected for friends. Therefore, as the major features in total are controlled by users and they are intuitive, it is considered that the guidelines "8. Design for user control" and "9. Design interfaces to trust" are also contemplated.

The multimodal interaction and context-awareness help the user interaction with the system and improve the overall UX, including for the disabled. However, the guideline

"11. Design for accessibility" could only be assessed by testing with users with special needs, which was not possible yet.

At the end of the inspection tests with the use scenarios, no problems were found as the guideline "10. Design for error management." However, it should be considered the need for more extensive testing, including seeking to ascertain the compliance with the guideline 11, only then to say that the guideline 10 was fully met.

Discussion: The Waze app proved to have many of the features that benefit the quality of UX. Good use of existing technologies in the devices by application designers, such as sensors, microphone, camera etc., show the concern to provide a more dynamic and natural user interaction. It was also noted the interface simplicity, for capturing the information that exists on the device screen in a more ease way. This increases the scope of use because they are more affordable options for users who have difficulty typing or viewing due to screen size. The chosen application met most of the proposed guidelines. Sensitivity to context is a key feature in the application, as well as the collaboration of users. For Korkea-aho [15], "a system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use". Design system intelligence from the context requires optimized collection because smartphones does not have the same ability to persist information as computers. In addition, the data processing can not take for themselves all the resources available on your smartphone. Thus, with the advancement of mobile computing power, sensitivity context may find a path to be used in all applications.

At the analysis end, some guidelines were restructured: guidelines "1. Make use of multimodal interaction" and "2. Introduce an integrated system of interactions" have similarities. When using multimodal interaction, should be given flexibility to the user in choosing the mode of interaction, selecting the best option given specific context. So present an integrated system of interactions is a good practice in the use of multimodal interaction for the quality of UX. Thus the guideline "1" came to include in your description the guideline recommendation "2" with the wording:

1. **Make use of multimodal interaction:** Attention should be paid to a good multimodality design, featuring an integrated system of interactions, allowing the user to take advantage of their functions by interacting in different ways with the device such as touch, gesture, voice etc. And the user could choose the best way for interacting in a specific context of use. This increases the ease of use giving flexibility in user interaction with your application. For example, a user can benefit from using the voice command while adjusting the seat belt in your car [1, 5, 8, 12, 21].

Use affordances, representative symbols and clear mental models, based on previous experience of the user in both the real world and virtual, are ways to minimize the user's attention effort. Thus the guidelines "6. Design interfaces that minimize the effort of attention" include in its description the guideline recommendation "7. Make use of affordances and mental models" with the wording:

6. **Design interfaces that minimize the effort of attention**: The interface should present simply information to the user, to minimize the effort of attention. Once, in a context-awareness environment, usually there is no focus point for the user to fully

concentrate because the attention is usually shared with other devices and also affected by external factors. Use affordances and support mental models are good practice for the system to be comprehensible without much effort. For example, imagine a situation where a user is making a run and want to see the application that monitors your heart rate. If the information is not presented simply, without requiring too much attention for viewing, the user may not be able to observe the information while moving [3, 4, 8, 20, 21, 23].

At the end of the evaluation and discussion process, the 11 (eleven) proposed guidelines were synthesized in 9 (nine).

5 Conclusion

The conception of ubiquitous applications has been a constant in the development of new systems. In this sense, this article visits the literature of this research area, especially the user experience quality in ubiquitous systems gather by the systematic review method. With the problematic identified, we brought to discussion the challenges and initiatives in this area. From the gathered literature were made eleven guidelines to assist designers from the area to develop ubiquitous applications, focusing on the area of user experience quality. The guidelines went through an analysis process of applicability and refining, with ubiquitous application, being summarized in 9 (nine) guidelines.

After the analysis process, it was possible to verify that most of guidelines were addressed on Waze application. In this sense, the guidelines could assist designers to develop applications that give support to the user with useful functionalities that are pleasant to use.

Therefore, the guidelines depart from questions related to usability until late computing techniques, in order that user experience with the system is better developed. The guidelines, as seen, are recommendations that can be important to the user experience and are feasible to execute. They are useful to designers on the development of solutions by the fact that they assist providing a survey of important questions to be addressed in a given application.

It can be noted that the guidelines are applicable into systems and, in future steps, metrics can be developed to address the recommendations. For example, this analysis, does not know the interaction errors impacts, frequent or occasional, regarding the user experience quality. As multimodal technology is always advancing, voice and gesture recognition techniques are prone to errors. The environment of ubiquitous computing is diffuse and surrounded by noises, which hinder interaction. The system still cannot verify the urgency that a user may want to utilize a functionality, to optimize it to interaction in a time period. If an error occurs in a urgency situation, it may be more serious than frequent errors in ordinary situations.

Context sensibility and system intelligence also were not measured on the application analysis. The effects of automatic actions from the system can cause on user experience are unknown. As stated on guideline 8, the system should not do what the user have not requested, i.e., the user must have control over available functionalities on the application, and can change them as needed. Therefore, context sensibility impacts some human's feelings, proper form user experience with the system, as confidence, privacy, deception etc.

Lastly, user experience is affected by the idea that the user has by the system, in other words, what it hopes from the application. Ubiquitous systems must be attractive, involve the users so the interaction has a more natural character, benefiting the task which supports. A path to user experience quality is the personalization and control combined with context sensibility. If applications are more similar with user profile – personalization -, similar with what the user expects – context analysis – and not hinder user's autonomy – control -, user experience may indeed be experienced with quality.

As the applicability of the guidelines is already verified, the next phases must be the implementation of ubiquitous application with the guidelines. Henceforth, execution of test with field users using the available technologies, to data collection and analysis that will aid on creation of possible metrics, validations and extension of guidelines.

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