Guidelines' Parametrization to Assess AAL Ecosystems' Usability

Carlos Romeiro[2] and Pedro Araújo[1,2]
[1]Instituto de Telecomunicações (IT-UBI), Universidade da Beira Interior, Covilhã, Portugal
[2]Department of Computing, Beira Interior University, Covilhã, Portugal

Keywords: Usability, Ambient Assisted Living, User Interaction, Automation, Heuristics Analysis.

Abstract: With the aging of the population, healthcare services worldwide are faced with new economic, technical, and demographic challenges. Indeed, an effort has been made to develop viable alternatives capable of mitigating current services' bottlenecks and of assisting/improving end-user's life quality. Through a combination of information and communication technologies, specialized ecosystems have been developed; however, multiple challenges (ecosystems autonomy, robustness, security, integration, human-computer interactions and usability) have arisen, compromising their adoption and acceptance among the main stakeholders. Dealing with the technical related flaws has led to a shift in the focus of the development process from the end-user towards the ecosystem's technological impairments. Although many issues, namely usability, have been reported, solutions are still lacking. This article proposes a set of metrics based on the parametrization of literature guidelines, with the aim of providing a consistent and accurate way of using the heuristic methodology not only to evaluate the ecosystem's usability compliance level, but also to create the building blocks required to include automation mechanisms.

1 INTRODUCTION

The age pyramid has been shifting in both western and eastern civilizations. The decrease in birth-rates and the overall improvement of health care services, combined with higher life expectancy, have led to the current population distribution tendency on a worldwide scale (Eurostat, 2019).

This phenomenon poses new challenges and opportunities in several sectors, specially in the health sector, where there have been growing demands to ensure the elderly's wellbeing. These demands, combined with resources shortage and lack of a patient-oriented approach, compromise both the efficiency and availability of these core services. As a consequence, the scientific and industrial communities have attempted to develop an ICT based solution able to improve the user's quality of life, ensure his/her autonomy, optimize the economic sustainability of medical assistance services and address the healthcare services specific needs – the Ambient Assisted Living Ecosystems (Curran, 2014). Despite their improvement, multiple challenges should be tackled in order to make their widespread adoption feasible and secure. Challenges related with multiple topics, such as security, usability, aytonomy, data management among others (Curran, 2014; A. V. Gundlapalli, M.-C. Jaulent, 2018; Van Den Broek, G., Cavallo, F., Wehrmann, 2010; Peek et al., 2014; Greenhalgh et al., 2013; Duarte et al., 2018; Mkpa et al., 2019; Ismail & Shehab, 2019; Vimarlund & Wass, 2014).

Concerning the system's usability, multiple studies have attempted to identify the key factors compromising it, and indeed several approaches have been proposed to aid in its multiple context analysis (Macis et al., 2019; Martins & Cerqueira, 2018; Hallewell Haslwanter, Neureiter, et al., 2018; Hallewell Haslwanter, Fitzpatrick, et al., 2018; Holthe et al., 2018). To tackle this issue the author's proposition was to empower the product manufacturers and provide them a simple and feasible way of evaluating and monitoring the product's usability. From all the available methodologies, the one eligible to be executed in an enterprise setup, due to its ihnerent cost and speed of execution, was the heuristic-based. Alas, it also presents limitations that compromise its adoption, namely its results' accuracy and its restricted applicability.

Considering the challenges presented, this article provides a parametrization of the usability guidelines depicted in literature. Our aim is to: 1) optimize the

Romeiro, C. and Araújo, P.
Guidelines' Parametrization to Assess AAL Ecosystems' Usability.
DOI: 10.5220/0011043800003179
In *Proceedings of the 24th International Conference on Enterprise Information Systems (ICEIS 2022) - Volume 2*, pages 309-316
ISBN: 978-989-758-569-2; ISSN: 2184-4992

subjectivity level typically found in heuristic-based methodologies, 2) optimize their overall accuracy and results consistency, 3) extend its accessibility/ aplicability to non-usability experts and 4) minimize the effort typically related to their automation.

A thorough search in literature was conducted in order to identify what can be learned from the best practices depicted, how they can be applied in a practical scenario and how the inclusion of automation can be a feasible option in an enterprise context.

2 MULTIDIMENSIONALITY OF USABILITY

Usability is a multidimensional property that reflects the scope in which a product/service is expected to be used (Application, 2016; ISO 9241-11, 1998; Cruz et al., 2015). Typically, both User Experience and Usability are mixed during the product analysis phase, given their broad scope and definition. However, these properties have different purposes: while User Experience focuses on the analysis of how behavioural, social or environmental factors influence the user's product perception (Saeed et al., 2015; Martins et al., 2015a; Quiñones et al., 2018), Usability focuses on the efficiency, effectiveness and satisfaction in which the user is able to accomplish a certain goal during the product's interaction process (Quiñones et al., 2018). To ensure the product usability from an early stage, it is mandatory to define a set of guidelines to be adopted during the interface's implementation phase and methodologies to identify usability bottlenecks.

2.1 Guidelines

The search for a set of golden rules that could assist the team during the development cycle was explored from an early stage.

In 1990 the authors Jakob Nielsen and Rolf Molich proposed 10 heuristic principles (Molich & Nielsen, 1990). In 1996 the author Jill Gerhardt-Powals proposed 10 cognitive principles (Powalsa, 1996) focused on a holistic analysis of the usability evaluation process. In 1998 the author Ben Shneiderman proposed a set of 8 golden rules (Shneiderman, 2010). In 2000 the authors Susan Weinschenk and Dean Barker combined Jakob Nielsen's principles with vendor specific guidelines to achieve a set of 20 principles (Science, 2016) that intended to bridge the gap between the defined principles and the typical environments in which they were to be applied.

2.2 Methodologies

Regarded as an intrinsic part of the design and development lifecycle, the usability methodologies' main role is the identification and mitigation of usability bottlenecks (Martins et al., 2015b).

From the multiple methodologies available – enquiries, inspection and test-based - this article focuses on an inspection-based methodology – heuristic methodology. However, before applying any guideline breakdown, it is important to identify the main benefits and drawbacks, in order to address what motivated the selection of such methodology in the first place.

In terms of benefits, the heuristic methodology is a quick and low cost approach that provides feedback to the designers in an early development stage, without the direct intervention of end-users. This approach uses literature guidelines to evaluate the interface and this assists the designers in identifying correction measures to solve usability bottlenecks detected. Regarding drawbacks, the ones most frequently highlighted are: 1) the efficiency and viability of any approach depend on expert's know-how regarding usability guidelines and best practises; 2) inability to evaluate usability in its full extent – indeed, the approaches evaluation scope does not include user related metrics, such as user's satisfaction; 3) the uncertainty regarding the end-results reliability, which can be tackled by including a significant number of specialists with the proper know-how in the development cycle, and 4) costs/expenses (Molich & Nielsen, n.d.)(Federal Aviation Administration, n.d.).

The dependency on expert's know-how and the execution restrictions identified in the heuristic approach are challenges that the proposed parametrization intends to mitigate, so as to ensure that its execution is accessible to any non-usability expert. However, it should be noted that applying a set of well defined metrics to manually evaluate an interface in terms of guidelines compliance level is a time consuming task. Since parametrization is a first step to define business rules to be consumed by a yet to define tool, it is reasonable to explore the use of automation mechanisms to handle such procedure.

3 HEURISTIC AUTOMATION

The use of automation in the heuristic methodology is an explored topic in the literature, that brings several benefits such as: evaluation cost reductions, maximization of the interface's test coverage, provisioning of mechanism to accurately assess the gap between the actual and the expected results and to predict design changes side effects and independence from usability expert's know-how (Bakaev, Mamysheva, et al., 2017; Ivory & Hearst, 2001; Quade, 2015).

Nonetheless, the inclusion of automation neither discards the need for manual testing, nor provides mechanisms capable of evaluating usability to its full extent (Ivory & Hearst, 2001). There are user related metrics which are out of the scope of the heuristic methodology approach, namely the user's satisfaction level - unmeasurable by currently available automatic mechanisms.

Note that the advantages that automation ihnerent brings to the heuristic methodology applicability motivated the scientific community to explore and create tools to assist developers and end-users in the usability evaluation process. The direct result of such analysis was the definition of four tool categories, each one with their unique characteristics: interaction-based – focused on the use of users' interactions to evaluate the interface's usability (Bakaev, Mamysheva, et al., 2017; Bakaev, Khvorostov, et al., 2017; Type & Chapter, 2021; Limaylla Lunarejo et al., 2020; Paternò et al., 2017), metric-based – focused on the definition metrics used to quantify the interface's compliance level with usability guidelines defined in literature (Bakaev, Mamysheva, et al., 2017; Bakaev, Khvorostov, et al., 2017; Type & Chapter, 2021), model-based – focused on the definition of interaction models through the use of Artificial Intelligence mechanisms to evaluate the interface (Bakaev, Mamysheva, et al., 2017; Bakaev, Khvorostov, et al., 2017; Type & Chapter, 2021; Todi et al., 2021), and the hybrid-based (Bakaev, Mamysheva, et al., 2017; Bakaev, Khvorostov, et al., 2017).

According to the environment in which these solutions are integrated, a tendency towards the type of categories adopted can be noticed.

3.1 Enterprise Context

In an enterprise context, the available options are metric-based standalone tools that corroborate the interface's compliance level with the accessibility guidelines. The elapsed time required to manually check each individual guideline, as well as the government accessibility guidelines compliance policy (European Commission, 2010) (Pădure & Independentei, 2019), were the two reasons that further fostered the development of several tools for web and mobile applications between 2010 and 2020 (Dynomapper[1], AChecker[2], UI Automator Viewer[3], WCAG Accessibility Checklist[4] among others).

3.2 Academic Context

In an academic context, the solutions developed focused on the evaluation of the multiple features which define usability. An analysis of 96 scientific articles ranging from 1997 to 2021 provides an overview of the trends in the usability automation domain (41% interaction-based, 26% model-based, 25% metric-based and 2% hybrid-base proposals).

The approach that is explored in the article intends to follow the hybrid-based approach. We will combine a metric-based approach with a model-based approach; within the former, we have used the definition of metrics to assert the interfaces' compliance level with defined guidelines; within the latter, we have checked the compliance level of the actions executed within the interface of the interaction models created and trained. By combining the characteristics of both approaches, we have thus created a heuristic methodology capable of checking interface's components and actions with neither the external expert's direct intervention based know how, nor end-users'.

4 HEURISTICS OPTIMIZATION

4.1 Principles' Breakdown

Considering the highlighted principles and with the objective of identifying aspects in common, a parallelism between each author's specific set and the principles/definitions unique of each subset has been

[1] https://dynomapper.com/

[2] https://achecker.ca/checker/index.php

[3] https://developer.android.com/training/testing/ui-automator#ui-automator-viewer

[4] https://apps.apple.com/us/app/wcag-accessibility-checklist/id1130086539

established. The generated output provided the insights required to minimize the subjectivity in the principles analysis and consequently define the parametrization building blocks.

The considered guidelines within the parametrization scope were the following: 1) Jakob Nielsen's principles, 2) the Shneiderman's golden rules and 3) the Weinschenk and Barker's cognitive principles. Each principle was grouped according to its scope within the interface. Segmentation that took into account the interface main building blocks: the components and the actions (Galitz, 2002). As a direct result the analysis was divided into three scopes: component oriented (CO), action oriented (AO); and section oriented (SeO).

For each guideline, the respective parametrization is presented in Table 1, Table 2 and Table 3.

Table 1: Jakob Nielsen and Rolf Molich's principles parametrization (Galitz, 2002; Harley, 2018; Kaley, 2018; Nielsen, 1999; Laubheimer, 2015; Budiu, 2014; Moran, 2015; Nielsen, 2001).

Type	Parameters
CO	Visibility of system status - Providing feedback for each unique interactive state.
AO	Visibility of system status - Providing a progress bar indicator and a closure dialogue when applicable.
AO	Match between system and real world - Including an icon within the component that provides a real-world visual representation of the component's purpose; Excluding system terminology from component's text content.
CO	User control and freedom - Ensuring action reversibility.
AO	Consistency and standards - Ensuring the compliance of the components structure, look and feel properties with pre-set values.
CO	Error prevention - Restricting the user's input; Providing defaults; Disabling a control when mandatory data is missing; Presenting warning messages reporting any unconformities regarding the input provided before action closure.
AO	Error prevention - Providing a confirmation dialog; Including a resolution within the error messages presented to the user; Providing an option to cancel the action execution in any given time.
SeO	Error prevention - Including a mechanism that automatically saves the user's work when an abnormal event that prevents the interface stability occurs.
CO	Recognition rather than recall - Including hints that identify the data type required, tooltips with the description of the component's action, labels/icons that clarify the component's action purpose; Ensuring components' consistency to help the user recollect the component's purpose through its aesthetic.
CO	Flexibility and efficiency of use - Providing short keys to navigate across the interface components and interact with them accordingly.
CO	Aesthetic and minimalist design - Avoiding the use of highlights, shadows, glossy effects, and 3D effects; Including colour contrasts that consider the accessibility guidelines defined for the interface type created.
AO	Help users recognize, diagnose, and recover from errors - Providing a non-technical error message that includes the reason which led to the abnormal event and some advice on how to recover from it; Ensuring that error messages provided do not exceed the 20 words limit.
SeO	Help and documentation - Providing, in the global navigation menu, a dedicated option where the user can access the interface's official documentation.

Table 2: Shneiderman's golden rules parametrization (Mazumder & Das, 2014; Rozanski & Haake, 2017; Shneiderman et al., 2017).

Type	Parameters
AO	Offer informative feedback - Providing a task's completion rate and a progress bar for time consuming operations; Including a clear indication of the current section.
AO	Design dialog to yield closure - Providing a closure dialogue.
AO	Support internal locus of control - Providing a confirmation dialogue.
SeO	Support internal locus of control - Including a clear indication of the user's position and the interface navigation hierarchy through breadcrumbs; Providing a global navigation menu.

Table 3: Weinschenk and Barker's cognitive principles parametrization (Nayebi et al., 2013; Nielsen, 2010; Rempel, 2015; Kvasnicová et al., 2015).

Type	Parameters
AO	User Control - Ensuring action reversibility; Providing a task's completion rate and a confirmation dialogue during the actions execution.
SeO	User Control - Including a clear indication of the current section; Providing a global navigation menu.
AO	Human Limitations - Ensuring interface response time lower than 10s; Providing stateful component's capable of giving feedback to the user.

Table 3: Weinschenk and Barker's cognitive principles parametrization (Nayebi et al., 2013; Nielsen, 2010; Rempel, 2015; Kvasnicová et al., 2015) (cont.).

Type	Parameters
SeO	Human Limitations - Providing text content in a simple and direct manner; Avoiding flourished font families and redundant hyperlinks; Avoiding the use of unrelated images within the section's context.
CO	Linguistic Clarity - Including hints that identify the data type required and tooltips/labels with the description of the component's action purpose; Avoiding the use of foreign words or acronyms in the text content provided; Avoiding spelling errors.
CO	Aesthetic Integrity - Ensuring aesthetic similarity, proximity, and continuity across components from the same family or used to perform a similar action.
CO	Simplicity - Providing default in the multiple-choice fields.
SeO	Simplicity - Providing mechanisms to display in a gradual fashion the interface functionalities, from a basic to an advanced setting.
CO	Predictability - Ensuring the component's consistency.
SeO	Predictability - Including a clear indication of the user's position and the interface navigation hierarchy through breadcrumbs; Providing a global navigation menu.
SeO	Interpretation - Including mechanisms to predict the user's intents.
SeO	Technical Clarity - Presenting trustworthy information according to the domain being modelled by the interface.
SeO	Flexibility - Providing mechanisms which allow the user to change the interface look and feel.
AO	Precision - Ensuring that results/feedback provided matches user's expectations.
AO	Forgiveness - Providing mechanisms that allow for reversion/recovery from any action executed within the interface.

Note that there were principles in the Shneiderman and Weinschenk and Barker's principle subset that have not been described, since they are conceptually similar to principles whose evaluation process had already been discussed. Principles such as 1) "Strive for consistency", 2) "Seek universal usability", 3) "Prevent errors", 4) "Permit easy reversal of actions" and 5) "Reduce short-term memory load" share the same evaluation process described for their counterparts in the Jakob Nielsen and Rolf Molich's set (respectively "Consistency and standards", "Flexibility and efficiency of use", "Error prevention", "User control and freedom" and "Recognition rather than recall").

4.2 Real Environment Applicability

The parametrization defined provided a rule set to assert the interface's compliance level with the major guidelines depicted in literature. However, its applicability in a real environment is mandatory to identify challenges behind its quantification in a real use case. For this purpose, two e-health applications were used: an academic prototype and an enterprise solution available in the market.

The analysis evaluated the unique principles within the guideline subsets selected for each interface.

4.2.1 Academic Prototype

The evaluation of the academic prototype considered the 106 actions and 356 components available in the 15 screens of the entire interface, and covered the Jakob Nielsen and Rolf Molich, Shneiderman and Weinschenk and Barker guidelines. The end-results are presented in Table 4.

Table 4: Academic prototype evaluation results.

Subset	Evaluation
Jakob Nielsen	Visibility of system status – 69%; Match between system and the real world – 89%; User control and freedom – 73%; Consistency and standards – 90%; Error prevention – 35%; Recognition rather than recall – 76%; Flexibility and efficiency of use - 85%; Aesthetic and minimalist design – 84%; Help users recognize, diagnose, and recover from errors – 79%; Help and documentation – 50%.
Shneiderman	Offer informative feedback – 83%; Design dialog to yield closure – 74%; Support internal locus of control – 60%.
Weinschenk and Barker	User Control – 83%; Human Limitations – 63%; Linguistic Clarity – 100%; Aesthetic Integrity – 100%; Simplicity – 78%; Predictability – 92%; Interpretation – 0%; Technical Clarity – 83%; Flexibility – 100%; and Precision – 89%.

According to the results obtained it was detected a total amount of 1781 usability smells. From the principles evaluated the lowest scores (<70%) were related to "Error Prevention" in the Jakob Nielsen subset, "Human Limitations" and "Interpretation" for the Weinchenk and Barker subset.

For the Jakob Nielsen subset in terms of "Error Prevention" the main bottlenecks identified are related with the lack of an autocomplete mechanism in any of the components that receive an input from the user, the lack of a mechanism that automatically save the user's work, the lack of error messages providing clear indications of the type of inconformities detected in the user's input and the lack of mechanisms capable of disabling the action related controls when the view requirements are not met.

For the Weinchenk and Barker subset in terms of "Human Limitation" it should be emphasized the components' lack of capability to store their previous state, in order to make the user aware of his/her previous interactions without forcing the user of his/her memory. Regarding "Interpretation" principle context the main bottleneck detect was related with the lack of a mechanism in the system capable to predict the user's intentions or user's input when the interaction process is taking place.

4.2.2 Enterprise Application

SmartAL[5] is the name of the enterprise application selected to be part of the parameter evaluation effort.

The evaluation took into account 523 actions and 1918 components from a total of 103 screens of the entire interface. Regarding the principles covered due to its technical depth it was opted to cover the Jakob Nielsen and Rolf Molich subset, which already provided a proper overview of the interface state. The end-results are presented in Table 5.

Table 5: SmartAL evaluation results.

Subset	Evaluation
Jakob Nielsen	Visibility of system status – 52%; Match between system and the real world – 74%; User control and freedom – 59%; Error prevention – 23%; Recognition rather than recall – 73%; Flexibility and efficiency of use - 0%; Help users recognize, diagnose, and recover from errors – 30%; Help and documentation – 49%.

The analysis performed allowed the identification of a total amount of 2844 usability smells. From the principles evaluated the scores below the minimum quality threshold defined (70%) were related with the "Visibility of system status", "User control and freedom", "Error prevention", "Aesthetic and minimalist design", "Help users recognize, diagnose, and recover from errors" and "Help and documentation" " in the Jakob Nielsen subset.

5 CONCLUSIONS

The parametrization proposed compiled the knowledge depicted in the literature to provide an objective approach to interpret the usability guidelines to be applied in a heuristic evaluation process. Its main differentiating factor is related to the metrics definition process. Each guideline was explored thoroughly to identify ideal practices that enforce such principles. Practices that are typically applied to address usability bottlenecks in each guideline scope. By isolating the typical approaches used it was possible to define binary metrics that allow to check the compliance level of the interface with the guidelines parametrized in this study. Thus maximizing the evaluation's results accuracy and consistency, and the overall accessibility of the heuristic methodology to users without expert usability know-how.

6 FUTURE WORK

The next iterations will be focused over checking how the results obtained compare with the end-users feedback. Information required to assert the metrics validity and accuracy in the detection of critical usability issues. Additionally the automation of the current manual evaluation process is another topic to be tackled to ensure the process applicability and feasibility in an enterprise environment. Therefore an effort will be performed to identify which metrics defined are eligible to be automated to create a tool capable of taking an interface, run a static analysis, identify possible botlenecks and suggest optimizations based on the metrics defined.

ACKNOWLEDGEMENTS

This work was funded by FCT/MCTES through national funds and when applicable co-funded EU funds under the project UIDB/50008/2020.

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