Characteristics, Attributes, Metrics and Usability Recommendations: A Systematic Mapping

Franciela Nissola
Graduate Program in Applied Computer
UNIVALI – Universidade do Vale do Itajaí
Itajaí, Brazil
nissolainf@gmail.com

Fabiane Barreto Vavassori Benitti
Graduate Program in Applied Computer
UNIVALI – Universidade do Vale do Itajaí
Itajaí, Brazil
fabiane.benitti@univali.br

***Abstract*— The research scenario concerned about software usability addresses a wide range of characteristics, attributes and evaluation models. As result, we can observe the evaluators difficult in order to select the characteristics that best apply to the product that is being evaluated. By this way, this paper presents a systematic mapping in order to identify the main characteristics of usability evaluation related to web, desktop and mobile devices environments. As results, we selected 31 papers in order to perform data extraction and way possible to produce a list of 28 evaluation characteristics.**

Keywords-Usability Evaluation; Systematic Mapping.

I. INTRODUCTION

Usability is a characteristic of a certain product related to the ease of use, speed of learning, control and management of error, solving the tasks that proposes to carry out with efficiency, effectiveness and mainly offering a high degree of satisfaction for its users [1][2]. By relying on the type of user and the experience of this, as well as the tasks performed and the execution environment of the system, usability is a system property that is not constant [3]. Usability is a quality of use, measured for a given context in which software is operated. Thus, the same software can provide a good usability for an experienced user, but bad usability for a beginner, or vice versa, or it can also be easy to operate if the system is only used sporadically, but difficult when used frequently [4].

Despite all these concepts for usability, yet there is no consensus among the researches for a model that clearly describes all its features. This knowledge gap is one reason why the majority of usability studies are either simplified or specific (studies that are performed in certain contexts) [5]. Along with the various concepts related to usability and addressed in the researches, it is clear that usability is treated as a determinant of success or failure of any software product, because it allows to generate greater efficiency by the users performing their tasks, helps in reducing training costs and allows that the integration of software system in the work environment of the users can be made in a more positive and less traumatic way [6].

Another relevant aspect of usability is perceived by the vast amount of research found in this area. It has an extensive set of features, attributes and models of usability evaluation available [7][8][9]. Each of these valuation models presents its specific set of characteristics, and the same feature may have been addressed in several models or be disregarded. Another situation found in these publications are characteristics or attributes of usability presented with different nomenclatures, but with the same concept and similar concepts between models.

Note that the evaluation models are often refined and developed to a level where specific execution environments are considered for the evaluation of the usability [10]. However, even with this refinement of the models and attributes per execution environment, yet are different attributes of usability evaluation addressed to the same specific execution environment. The use of specific attributes of usability according to the execution environment makes the evaluation of the usability more consistent, provides a greater investment guarantee and also the professionals involved in the production of software for this environment can use these attributes as drivers for creating software with better quality [11].

All these different ways of evaluation emerged as a contribution to the evolution of usability evaluation, providing to the software development organizations a varied set of criteria that can be applied to specific project types [12]. Although it became evident through research that the introduction of usability practices in software development processes are beneficial, many companies oriented to development face difficulties to actually apply these practices, because it is a complex issue, which has evaluation methods underutilized and difficult to understand for development teams. This difficulty is manly in the definition of the model and attributes that should be applied in the evaluation process, due to the large amount of existing research [12][13].

In the research, the models have some limitations when compared with each other and still there is relatively little information to support the selection of a set of attributes to evaluate the usability by the evaluators. Moreover, it is not always clear how the usability attributes presented in the various models are more or less advantageous than others [8]. Based on this scenario, this article presents a systematic mapping on the characteristics and attributes of usability evaluation proposed in primary studies between the years 2005 and 2012 for the execution environments Web, Desktop and Mobile Devices, consisting an important step to meet, broadly, the dismembering of the usability concept,

 ISBN: 978-1-61208-325-4

considered by many researches under different environments, being an important step in the reach for a model that integrates all aspects identified.

The terms: characteristic, attribute, and recommendation metric, cited in this article, are used to classify the various aspects, quality and information related to usability, obtained through this systematic mapping. It was chosen to use a hierarchical structure for the presentation of issues related to usability found in the articles evaluated, considering that other models in the literature also use hierarchical structure to present information related to usability (Model QUIM, [8]).

It´s assumed in this systematic mapping of the literature that the features are on top of the hierarchical structure mentioned, representing a more comprehensive view of the quality related to usability. The attributes are below the features and represent the information in a more granular form. In this systematic mapping a feature may or may not be related to one or more attributes and the same attribute may be related to more than one feature. Finally, on the basis of the hierarchical structure, are the metrics that represent the information used for the evaluation of the attribute more objectively, and the recommendations, which aims to guide the development/evaluation of interfaces through good practices, for example, layout and menu structure, pattern of presentation for links, font color for text, etc.

This article aims at presenting the results of a systematic survey of the literature involving characteristics, attributes and usability found recommendations, aiming to know, in an impartial manner, the state of the art concerning these aspects of usability, in relation to different platforms. Therefore, the protocol for a systematic mapping of the literature used in this paper is presented in Section II, along with the implementation procedures and discussion of the results. Finally, the last section summarizes the findings and presents some possible future work.

II. SYSTEMATIC MAPPING OF THE LITERATURE

The main reason to perform a systematic mapping of the literature is to increase the quality of material used about the subject of interest, increasing the success of the investigation, avoiding unnecessary duplication of effort and errors.

A systematic mapping follows a defined sequence of methodological steps, which in turn provide a high scientific value to the results. In execution of a systematic mapping, there is the establishment of criteria, search strategies and a description of all the elements previously required to hold the methodological conduction of the activities [14]. Thus, the following sections detail each step performed.

A. Planning

In order to map the attributes of usability evaluation in execution environments Web, Desktop and Mobile Devices, the following question was established: Which attributes are related to the usability of software products when considering different execution environments (among those contemplated in this research: web, desktop and mobile devices)?

To answer the research question there were four research bases; quote: (i) ACM Digital Library, (ii) IEEExplore Digital Library, (iii) ScienceDirect, and (iv) SpringerLink. At each base, the following search string was executed: (usability) AND (attribute OR factor OR criteria OR metric OR measurement OR method OR evaluation OR requirement) AND (web OR internet OR www OR desktop OR 'mobile device').

The language adopted in the survey was English, being the predominant language in the study area. Regarding the reliability of the content on those studies, it is considered that the works have already gone through preliminary review and assessment that allowed their inclusion in searchable databases. The process will be through search of primary studies published in proceedings, journals and periodicals available in international databases. After obtaining the references of the studies obtained in this four bases, some selection and exclusion criteria that would help to limit the items that could help to answer the research question were adopted (see Table I).

TABLE I. SELECTION CRITERIA AND EXCLUSION

Selection Criteria
SC1. Studies available on some web source (among the sources cited in this article);
SC2. Studies that meet at some level, the research question. Studies that show usability attributes, applied to a software product, related to at least one of the execution environments covered by the survey;
SC3. Studies that show evidence of implementation of the proposed attributes;
SC4. Studies that show the conceptualization of the proposed attributes (the concept can be in the primary study itself or pointed location/directed by the authors);
SC5. Complete studies published in proceedings and journals since 2005;
Exclusion Criteria
EC1. Studies that do not show attributes of usability in at least one of the execution environments covered by the survey or don´t make clear the execution environment;
EC2. Studies that do not conceptualize the attributes used;
EC3. Studies that show a specific application domain, such as e-government, e-commerce, or focus on a specific user profile, for example, elderly, impaired vision, etc.;
EC4. Summaries of studies will not be selected;
EC5. Studies that don´t show the evidence of application;
CE6. When a study has multiple publications in journals or proceedings, the most complete version of the study will be used;

B. Conduction and Extraction

The conduction of the systematic mapping was done from September 2012 until March 2013, consisting of the execution of the search protocol. The conduction process observed the steps shown in Figure 1, from 345 potential studies, 65 studies were selected. The conduction of the studies was done in three steps:

- Selection and cataloging preliminary studies collected: a preliminary selection of publications made from the application of the search string in the search sources selected.

- Selection of relevant documents: a preliminary selection using the search string does not guarantee that all the material that was collected is used in the research context. Thus, after the identification of publications obtained through the search engines, the studies were analyzed according to the criteria established for inclusion and exclusion.
- Extraction of information of relevant documents: after setting the final list of relevant documents, the necessary information related to the research objective is extracted.

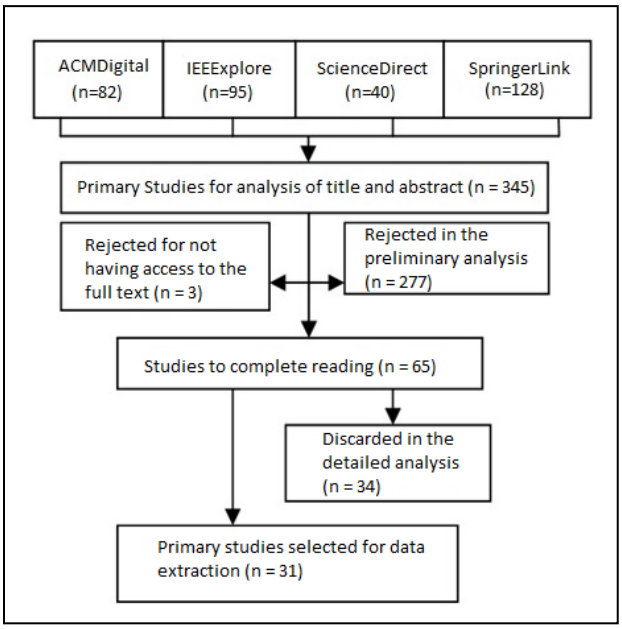

Figure 1. Process of selecting primary studies.

Among the 65 studies selected for full reading, we have the following scenario of events in each of the evaluated databases: IEEExplore Digital Library: 45,16%, ACM Digital Library: 22,58%, ScienceDirect: 19,35%, and SpringerLink: 12,91%.

From the set of primary studies selected to perform data extraction, the following information was extracted for analysis:

- Title: identifies the selected study.
- Year: provides a temporal view of the attributes of usability evaluation.
- Database: identifies the origin of the selected study.
- Execution Environment: identifies the execution environment for the attributes shown in the study evaluated. In this topic, the studies were classified as: (I) web, (II) desktop and (III) mobile device.
- Reference type: identifies the sources used to support the model of usability evaluation presented in the study.
- Structure addressed in the model: identifies the structure presented by the study evaluated, related to the presentation of the attributes of usability.
- List of attributes: compilation of the attributes of usability evaluation cited in the studies analyzed.
- Metric or recommendations: identifies whether the study has evaluate metrics or recommendations to guide the evaluation of usability.
- Assessment technique: identifies the technique used to evaluate the model or usability attributes addressed in each study rated. It was used the classification of evaluation techniques proposed by [4], as shown in Figure 2.

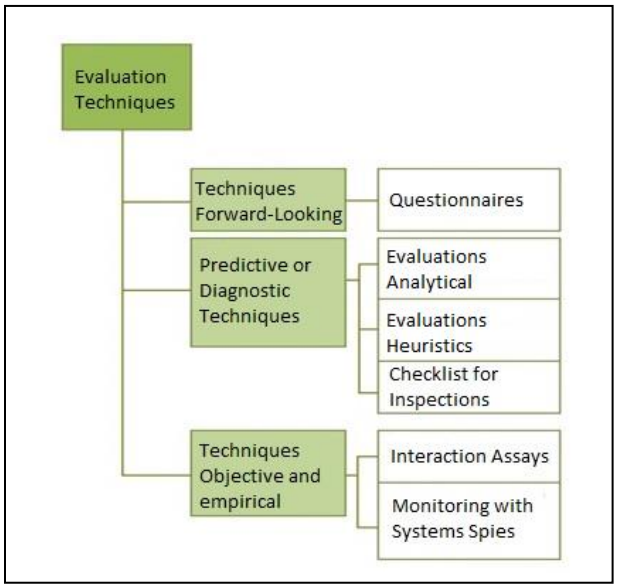

Figure 2. Usability evaluation techniques.

- Context: identifies the application context of the usability study. In this topic, the studies were classified as: (I)non-explicit,(II)academic/university and (III) business.
- Participants: identifies the number of respondents who rated the attributes or usability model presented.

In the process of selection of studies, the snowball technique [15] was applied. The application of this type of technique is to add in the research being conducted, studies referenced by the selected primary studies that may contribute to the research. Thus, when a primary study (among 31 selected) referenced another study that contains models, metrics and recommendations that could contribute to the research, this study referenced was also included. Appendix I is a listing of all studies, employing the technique of snowball nine studies were included (#35, #36, #37, #38, #39, #40, #41, #42, #43).

C. Results and Discussions

This section presents the main results obtained from 31 primary studies selected. Figure 3 shows the number of studies that were selected for data extraction in each year of the time interval considered in this systematic mapping (2005-2012). Over the years, it is observed that continuous studies have been published in this area and the research

 ISBN: 978-1-61208-325-4

output remained, highlighting the importance of this area of research forward.

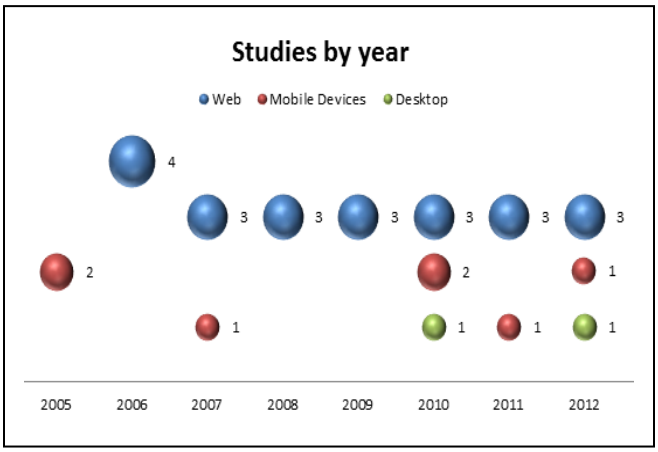

Figure 3. Number of evaluated annually.

In Figure 3, it can be seen that the occurrence of studies related to web runtime environment remained almost constant during the time period evaluated. This amount of studies related to web routine environment can be attributed, among other factors, to the grown of the Web, its popularization and its importance as a means of global communication.

In contrast, the execution environment desktop has the lowest incidence of studies to define a set of attributes to evaluate the usability. Among other factors, the rise of the Web previously mentioned, contributes to the unpopularity of the desktop environment and, therefore, to decrease research on this. In relation to mobile devices, it´s expected a growth of studies related to this execution environment, considering the growth of these environments (a report from Cisco predicts that mobile devices will exceed the number of people in 2013 and by 2017 there will be about 1.4 devices per capita) [16].

Regarding execution environments addressed in 31 studies evaluated, there´s the following scenario: 71% of the studies are related to the web environment, the mobile devices 23% and 6% related to the desktop environment.

As for the reference of the valuation models or list of attributes of usability evaluation presented in the studies evaluated, there´s the following scenario:

a) No reference model: 41,93% of the studies evaluated showed a list of attributes that were evaluated, using one of the techniques discussed in Figure 2, in a software product.

b) Adapted: 32.26% of the evaluated studies adapted a valuation model or list of attributes. In this group there is the use of ISO9241, ISO25000, and Nielsen heuristics[2].

c) Existence: 25.81% of the assessed studies used an existing model in the literature. In this group, it is important to highlight the use of ISO9241, heuristics and Nielsen Microsoft Usability Guidelines (MUG).

The scenario found as the reference of models or attributes of evaluation presented by this mapping, further enhances the already mentioned problem regarding the large amount of studies presented in which each author addresses their specific list of attributes and evaluates them not relating this list with models already existent, adapting or improving them.

It was also found that these 31 studies evaluated do not address a specific structure, for example, a framework model or categorization, to the listed attributes. The structure found in these studies, as the presentation attributes of usability evaluation is in the form of a simple list of attributes.

Regarding the application context of the studies evaluated, it´s observed that most of the selected studies did not indicate the context in which the attributes have been applied. Among the studies evaluated in this systematic mapping 74.19% do not make it clear which is the application context of the attributes addressed.

The context of business application was not used in any of the studies selected for this mapping. This scenario refers to the need to extend research regarding the evaluation of characteristics and attributes of usability in business contexts, facilitating the application, in a practical way, of the researches conducted.

During the evaluation of the articles selected for data extraction, it was checked for the presence of objective recommendations, to assist the evaluation of characteristics and attributes presented. However, the present scenario is not favorable regarding obtaining such advice. Of the 31 articles evaluated, 83.87% of them do not show metrics/objective recommendations for usability. Only 16.13% of the evaluated studies have some kind of metric/recommendation for usability. Table II presents the recommendations and metrics found in the studies evaluated in this systematic mapping. The objective recommendations found in the analyzed studies still have certain subjectivity (according to the evaluation of the authors of this article). It was observed that not all recommendations were related to some characteristic or attribute of usability, in this case it was chosen to categorize as “General Properties”.

TABLE II. RECOMMENDATIONS AND METRICS OF USABILITY

Characteristics/Attributes	Recommendations/Metrics
Prevention of errors	6 Recommendations [#3]
Integration of Communication	3 Recommendations [#22]
Attractiveness	3 Recommendations [#22]
From User Control	2 Recommendations [#22] 22 Recommendations [#43]
Security	4 Recommendations [#22]
Flexibility	2 Recommendations [#40] 2 Metrics [#5]
Effectiveness	6 Metrics [#5]
Efficiency	6 Metrics [#5]
Navigation/guidance	12 Metrics [#5]
Satisfaction	2 Metrics [#5]

 ISBN: 978-1-61208-325-4

Characteristics/Attributes	Recommendations/Metrics
Aesthetic design	52 Recommendations [#43]
Commands	40 Recommendations [#43]
Textual information	23 Recommendations [#43]
Message	34 Recommendations [#43]
Consistency interaction	33 Recommendations [#43]
Window	62 Recommendations [#43]
Interface/Layout	8 Recommendations [#43]
Font	2 Recommendations [#43]
Colors	4 Recommendations [#43]
Ícons	8 Recommendations [#43]
Animation and Transition	7 Recommendations [#43]
Graphic elements	7 Recommendations [#43]
Sound	8 Recommendations [#43]
User Experience	29 Recommendations [#43]
Components	65 Recommendations [#43]
General Properties	5 Recommendations[#22] 15 Metrics [#5] 6 Metrics [#3]

Among the 31 studies evaluated, 28 distinct characteristics of usability evaluation were found. Of these, one has the following scenario of events for execution environment:

a) Web: 28 characteristics;

b) Desktop: 5 characteristics;

c) Mobile Devices: 11 characteristics.

Appendix II has a full list of features and attributes per runtime environment, obtained through systematic mapping. In this appendix are presented the characteristics and attributes of usability evaluation which were obtained from the mapping studies conducted. One of the criteria for selection of studies was presenting the conceptualization of the attributes used to evaluate the usability. Based on this concept, we observed attributes with the same concept, but with different nomenclatures in different studies and group these attributes into a single information structure.

It was also observed that some studies had a more comprehensive view of the quality of information related to usability, for these cases, we used the characteristics structure, which, in turn, is a sort of aggregator of information. The characteristics of the structure in Appendix II were present in at least one study evaluated, or when a more comprehensive study presented information structure composed of more granular information (attributes), this structure was maintained.

In this table, using a mark with the letter "x", the possible relationships between features and attributes discussed by several authors in the studies evaluated are also presented. A nomenclature of the characteristics and attributes discussed in studies with some minor adjustments when the same characteristic or attribute was discussed in more than one study in which a different nomenclature was showed, but with the same concept presented, was used.

In Appendix II, along with the naming of features and attributes, there is also the presentation of information from references that cited such characteristics or attributes (references are identified with the hash (#) concatenated with the numbering of the bibliographic reference used) facilitating the reader find an indication of which study addressed what characteristic and attributes, and you can also check the amount of referrals every feature or attribute has. The reference for the primary study selected in which the feature or attribute was found is also mapped in this table.

There are several ways to evaluate the usability of an application and, in the context of this article, the 31 studies evaluated were classified in Figure 2. The result, illustrated in Figure 4, shows the number of studies related to the use of the techniques of usability evaluation in each execution environment evaluated. The application of the questionnaire assessment technique was the most used among the studies evaluated. This type of technique is based on questionnaires to evaluate the user satisfaction or dissatisfaction with the system and its operation. It is a technique quite relevant, considering that the user is the person who knows more the software, and because of that, nothing is more befitting than to seek their opinions to guide project reviews [4].

Trials of interaction were also widely used, the second among the most widely used techniques for the assessment of the selected studies. It has been in the execution environment web site for greater application of techniques for usability evaluation cited. A test of interaction consists of a trial use of the system which involved subjects representative of the target population to evaluate the technique. In tests of interaction, participants perform typical tasks involved in their activities with a version of the desired system [4].

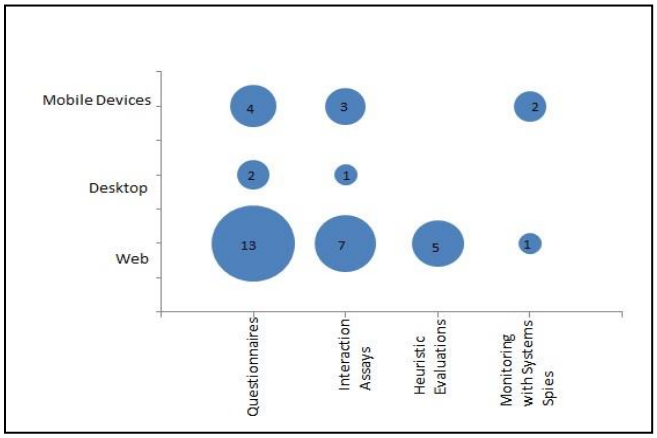

Figure 4. Evaluation Techniques for Runtime Enviroment.

Along with the information extraction of the usability evaluation techniques used in the selected studies, it was verified the number of people involved in these evaluations. It was found that such evaluations occurred either on a list of

attributes or on a model (consisting of features and attributes) of usability evaluation and the number of people involved in these evaluations did not follow a pattern in relation to the quantity displayed. For the group of studies that evaluated a list of attributes, there are since evaluations with groups of four people to evaluations with groups consisting of 215 people. The same is true for the group of studies that evaluated a model of usability, working with groups with 7 people to groups with 179 people involved in the usability evaluation proposed.

In both cases (List of Attributes or Model), the evaluation technique most used was the prospective technique of evaluation by using questionnaires, as already mentioned. This technique is based on questionnaires to those involved in the evaluation and is facilitated with a view that those involved respond to a questionnaire on a specific web address and may be performing this evaluation activity anytime. However, it´s necessary to emphasize that satisfaction questionnaires have a low return rate of responses, which indicates the need to develop/use a small number of questions, as well as using succinct questions and a space for the user to insert free comments and suggestions [4].

III. CONCLUSION AND FUTURE WORK

The systematic mapping of the literature described in this article has covered features, attributes and metric/usability recommendations found in each of the execution environments evaluated in studies found between 2005 and 2012 in four databases of the area.

This systematic mapping of the literature has shown the large amount of features and attributes discussed by several authors in various studies related to usability, considering that it was verified a total of 28 features and 76 different attributes that can be used by those involved with a usability evaluation in one of the environments mentioned.

The great quantity of features and attributes of usability evaluation is also diverse when studies for the same execution environment are being verified. Among the studies reviewed, it wasn´t found a pattern or a set of characteristics and unique attributes of evaluation among the authors that check specific execution environments. In addition, different terms to refer to the same usability attribute are found, and the construction of an ontology is a perspective for future work.

Few studies have metrics or objective recommendations to assist in the evaluation of usability. Among the studies evaluated (31 selected and 9 added by snowball), only about 12.5% have metrics or recommendations to assist, through good practices, the development of interfaces.

Thus, the choice of features and attributes that best apply to a particular evaluation, among this diverse group found, is not a trivial task, given that often the people involved with the evaluation do not have necessary expertise in the area of usability that can assist and facilitate the evaluation work and, therefore, the make the best choice.

Still, when the people involved with the evaluation of usability have a set of characteristics and attributes to evaluate, sometimes it is not clear what and how the interface should be evaluated or even how the interface should be constructed to meet certain characteristics and attributes.

Given this scenario of complexity in the choice of features and attributes of usability, companies often do not apply methods of usability evaluation in their software projects/products for not having specialized team to select the best form of evaluation, as well as the best attributes for evaluation, producing sometimes software with low usability.

The results of this systematic mapping clarify even more the need for a model of usability evaluation to guide those involved in the assessment, to provide objective guidelines for the evaluation of interfaces and indicate the execution environment for which those guidelines are valid. Another perceived need is related to the application of usability evaluation in business contexts, favoring the practical application of the researches.

It is necessary a model or tool that assists in the process of evaluation and selection of evaluation attributes, facilitating the application of usability evaluations of projects/software products.

Finally, it is important to analyze the threats inherent to the process adopted in this research, which mainly consists in the disposal of three studies for not having access to the full text. Another threat is about the mapping conduction, which was performed by a single investigator, but the planning stages and discussion involved two researches. To mitigate this threat, it was performed, after the conducting conclusion, an analysis of the disposed titles, and in specific cases, an abstract by a second researcher (as a way of review) was made. It´s also necessary to consider that the result presented is restricted to a specific search string in a set of four data sources limited to search for terms in English. The expansion of the terms, language and databases can reveal new features, attributes, metrics, and recommendations.

REFERENCES

[1] International Organization for Standardization. ISO 9241-11:1998, “Ergonomic requirements for office work with visual display terminals (VDTs), Part 11: Guidance on usability. Geneva, Switzerland: 1998.

[2] J. Nielsen, Usability Engineering, London, UK: Academic Press, 1993.

[3] B. Shackel and S. Richardson, Human factors for informatics usability-background and overview, 1rd ed., vol. 1. Cambridge University Press: New York, 1991, pp. 1–19.

[4] W. de Abreu Cybis, Usability Engineering: An ergonomic approach, LabUtil: Laboratorio de Utilizabilidade de Informatica, 2003.

[5] E. Mosqueira-Rey, D. Alonso-Ríos, and V. Moret-Bonillo, “Usability taxonomy and context-of-use taxonomy for usability analysis,” Proc. IEEE Symp. Conference on Systems, Man and Cybernetics (SMC'09), IEEE Press, Oct. 2009, pp. 812-817, doi: 10.1109/ICSMC.2009.5346929.

[6] A. M. S. Filho, “Human Perception in Human-Computer Interaction,” in Revista Espaço Acadêmico, vol. 25, 2003.

[7] S. Winter, S. Wagner, and F. Deissenboeck, Engineering Interactive Systems: A Comprehensive Model of Usability, vol. 4940. Springer-Verlag: Berlin, Dec. 2008, pp. 106–122.

 ISBN: 978-1-61208-325-4

[8] A. Seffah, M. Donyaee, R.B. Kline, and H. K. Padda, “Usability measurement and metrics: A consolidated model,” Kluwer Academic, vol. 14,Jun. 2006, pp. 159-178, doi: 10.1007/s11219-006-7600-8.

[9] O. Signore, “A comprehensive model for Web sites quality,” Proc. IEEE Symp. Web Site Evolution (WSE 2005), IEEE Press, Sep. 2005, pp. 30-36, doi: 10.1109/WSE.2005.1.

[10] A. Fernandez, E. Insfran, and S. Abrahão, “Usability evaluation methods for the web: A systematic mapping study,” Information and Software Technology, vol. 53, Aug. 2011, pp. 789-817, doi: 10.1016/j.infsof.2011.02.007.

[11] R. Fitzpatrick, “Additional Quality Factors for the World Wide Web,” Proc. and Cybernetics – Part A: Systems and Humans, 1999, pp. 29-386.

[12] C. Lallemand, “Toward a closer integration of usability in software development: a study of usability inputs in a model-driven engineering process,” ACM SIGCHI symposium on Engineering interactive computing systems (EICS '11), Jul. 2011, pp. 299-302, doi: 10.1145/1996461.1996541.

[13] J. O. Bak, K. Nguyen, P. Risgaard, and J. Stage, “Obstacles to usability evaluation in practice: a survey of software development organizations,” Proc. Nordic conference on Human-computer interaction: building bridges (NordiCHI '08), IEEE Press, Oct. 2008, pp. 23-32, doi: 10.1145/1463160.1463164.

[14] B. Kitcheman, Guidelines for performing Systematic Literature Reviews in Software Engineering. Durham, UK: University of Durham, 2007.

[15] S. Jalali and C. Wohlin, “Systematic literature studies: database searches vs. backward snowballing,” Proc. ACM-IEEE international symposium on Empirical software engineering and measurement (ESEM '12), IEEE Press, Sep. 2012, pp. 29-38, doi: 10.1145/2372251.2372257.

[16] Cisco. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017, 2013.

Appendix I – Primary Studies Included in the Mapping

[#1]G.Lindgaard, C.Dudek, D.Sen, L.Sumegi, P.Noonan," An exploration of relations between visual appeal, trustworthiness and perceived usability of homepages"(2011) [#2]R.West,K. Lehman, "Automated summative usability studies: an empirical evaluation"(2006) [#3]A.T.Neto, T.J.Bittar, R.P.M.Fortes, and K.Felizardo, "Developing and evaluating web multimodal interfaces - a case study with usability principles"(2009) [#4]A.Seffah, M.Donyanee, R.B.Kline, H.K.Padda, "Usability measurement and metrics: A consolidated model" (2006) [#5]P.A.Davis, F.M.Shipman, "Learning usability assessment models for web sites" (2011) [#6]C.Ryan, A.Gonsalves, "The effect of context and application type on mobile usability: an empirical study"(2005) [#7]A.Fernandez, S.Abrahão, E.Insfran, "Towards to the validation of a usability evaluation method for model-driven web development"(2010) [#8]A.P.Massey, V.Khatri, V.Vamesh, "From the Web to the Wireless Web: Technology Readiness and Usability"(2005) [#9]A.Anandhan, S.Dhandapani, H.Reza, K.Namasivayam, "Web Usability Testing ? CARE Methodology"(2006) [#10]T.Tirapat, T.Achalakul, "Usability Assessment for Hyperlink Methods"(2006) [#11]T.Conte, J.Massolar, E.Mendes, G.H.Travassos, "Usability Evaluation Based on Web Design Perspectives"(2007) [#12]A.P.Massey, V.Khatri, M.M.Montoya-Weiss, "Online Services, Customer Characteristics and Usability Requirements"(2008) [#13]H.Y.Kao, "Usability Testing of AMC Hospital's Website for Home Users: Case Study for On-Site Registration Design"(2007) [#14]A.Granie, I.Mitrovic, N.Marangunie, "Usability Evaluation of Web Portals"(2008) [#15]T.Conte, J.Massolar, E.Mendes, G.H.Travassos, "Web usability inspection technique based on design perspectives"(2009) [#16]U.K.Yusof, L.K.Khaw, H.Y.Chang, B.J.Neowa, "Balancing between usability and aesthetics of Web design"(2010) [#17]A.Al-Wabil, L.Al-Husian, R.Al-Murshad, A.Al-Nafjan, "Applying the Retrospective Think-Aloud Protocol in Usability Evaluations with Children: Seeing Through Children’s Eyes"(2010) [#18]W.F.W.Ahmad, S.Sulaiman, F.S.Johari, "Usability Management System (USEMATE):A Web-Based Automated System for Managing Usability Testing Systematically"(2010) [#19]M.Freeman, M. Bowden, "Usability as a Panacea"(2010) [#20]L.Punchoojit, T.Chintakovid, "Influence of Age Group Differences on Website Cultural Usability"(2012) [#21]M.A.Mayz, D.M.Curtino, A.de la Rosa, "Avoiding laboratories to collect usability data: two software applications"(2012) [#22]A.Oztekin, "A decision support system for usability evaluation of web-based information systems"(2011) [#23]X.Fang, C.W.Holsapple, "An empirical study of web site navigation structures' impacts on web site usability"(2007) [#24]A.Fernandez, S.Abrahão, E.Insfran, "Empirical validation of a usability inspection method for model-driven Web development"(2013) [#25]M.Allen, L.M.Currie, S.Bakken, V.L.Patel, J.J.Cimino, "Heuristic evaluation of paper-based Web pages: a simplified inspection usability methodology"(2006) [#26]C.K.Coursaris, K.Hassanein, M.M.Head, N.Bontis, "The impact of distractions on the usability and intention to use mobile devices for wireless data services"(2012) [#27]E.K.Delice, Z.Gungor, "The usability analysis with heuristic evaluation and analytic hierarchy process"(2009) [#28]A.Holzinger, M.Errath, "Mobile computer Web-application design in medicine: some research based guidelines"(2007) [#29]M.Vigo, A.Aizpurua, M.Arrue, J.Abascal, "Quantitative assessment of mobile web guidelines conformance"(2011) [#30]W.Oyomno, P.Jappinen, E.Kerttula, K.Heikkinen, "Usability study of ME2.0,"(2012) [#31]D,Schreiber, M.Hartmann, F.Flentge, M.Mühlhäuser, M.Görtz, Thomas Ziegert, "Web based evaluation of proactive user interfaces"(2008) [#35]J.Nielsen, "Usability Engineering"(1993) [#36]ISO/IEC FDIS 25010, "Systems and software engineering – Systems and Software Quality Requirements and Evaluation (SQUARE) – System and software quality models"(2010) [#37]MICROSOFT, "Windows Enviroment" [#38] T.V.Raman,"Design principles for multimodal interaction"(2003) [#39]L.M.Reeves, J.Lai, J.A.Larson, S.Oviatt, T.S.Balaji, S.Buisine, P.Collings, P.Cohen, B.Kraal, J.C.Martin, M.Mctear, T.Raman, K.M.Stanney, H.Su, Q.Y.Wang, "Guidelines for multimodal user interface design"(2004) [#40]A.Fernandez, E.Insfran, S.Abrahão,"Integrating a Usability Model into Model-Driven Web Development Processes"(2009) [#41]J.M.C.Bastien, D.L.Scapin, "Ergonomic Criteria for the Evaluation of Human-Computer Interfaces"(1993) [#42]ISO9241-11,"Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability" (1998) [#43]K.Keeker, Improving Web Site Usability and Appeal, 1997".

Appendix II – List of Characteristics and Usability Attributes Mapped

	Desktop
	Mobile Devices
	Web

CHARACTERISTICS / ATTRIBUTES	Integration of Communication #22	From User Control #41 #19 #22 #23 #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Navigation / guidance #5 #22 #28 #41 #19	Recursos visuais	Efficiency #42 #2 #35 #3 #40 #4 #5 #6 #7 #9 #10 #11 #13 #14 #16 #17 #18 #19 #20 #21 #24 #26 #27 #29 #30 #31 #6 #17	Effectiveness #42 #2 #40 #4 #5 #7 #10 #11 #13 #14 #17 #18 #20 #21 #24 #26 #29 #30 #31	Satisfaction #42 #2 #40 #4 #5 #6 #7 #10 #13 #14 #16 #17 #18 #20 #21 #24 #26 #29 #30 #31	Visibility of System Status #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Flexibility #35 #3 #5 #7 #11 #14 #19 #24 #27	Consistency interaction #39 #3 #28 #41 #43	Multimodal #3	Mapping between system and real world #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Liberty #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Minimalist #35 #3 #4 #7 #11 #14 #15 #19 #24 #25 #27	Help #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Documentation #35 #3 #4 #7 #11 #14 #15 #19 #24 #27	Management Errors #41 #19	Ease of use #4 #6 #7 #8 #9 #12 #24 #27	Productivity #40 #4	Learnability #40 #4 #6 #16 #20 #35 #3 #36 #4 #7 #11 #14 #15 #41 #19 #24 #27	security #40 #4 #22 #35 #3 #4 #7 #11 #14 #15 #41 #19 #24 #25 #27	Trustworthiness #40 #4 #16 #22	Accessibility #40 #4 #36 #7	Universality #40 #4	Utility #40 #4	Workload (Memory) #41 #19 #25 #30	Adaptability #6 #41 #19 #8 #12 #30 #36 #4 #7	Operability #41 #19 #36 #4 #7
Feedback #41 #19 #40 #4 #39 #3 #8 #12			x		x	x						x							x													
Load minimal memory #40 #4					x		x														x				x	x	x						
Operability #40 #4					x		x																	x	x		x						
Minimal Action #40 #4					x		x														x				x								
Navigability #40 #4					x	x																		x	x	x							
Flexibility #40 #4 #41 #19						x	x																		x	x	x				x		
Charge Time #40 #4					x															x					x	x							
Consistency #40 #4						x																x			x	x							
User guidance #40 #4							x														x				x	x							
Self-Description #40 #4																					x			x	x	x							
Simplicity #40 #4																					x				x	x							
Controllability #40 #4																								x	x	x	x						
Privacy #40 #4																								x		x	x						
Legibility #41 #19 #40 #4			x																						x	x							
Temporal behavior #40 #4						x														x								x					
Use of resources #40 #4						x														x								x					
Accuracy #40 #4							x															x						x					
Completeness #40 #4							x															x											
Enjoyability #40 #4								x																									
Familiarity #40 #4																					x				x								
Fault Tolerance #40 #4																						x		x				x					
Safety Features #40 #4																						x						x					
Assurance #40 #4																						x		x									
User Experience #43 #41 #19				x																												x	
Density #1 #41 #19				x																											x		
Customization #23 #8 #12				x																												x	
Attractiveness #36 #4 #22 #7 #40				x				x																			x						
Explicit user action #41 #19	x																																
Solicitation #41 #19			x																														
Grouping and distinguish items #41 #19			x																														
Synchronism #38 #3												x																					
Visible transition #38 #3												x																					
Interaction state shared #38 #3												x																					
Predictability #38 #3												x																					
Adaptation at middle #38 #3 #9												x																					
Design Input Output #38 #3												x																					
Comments #39 #3												x																					
Prevention of errors #35 #3												x																					
Support for the user to recognize, diagnose and recover errors. #35 #3 #4 #7 #11 #14 #15 #19 #24 #27																			x														
Error Treatment #39 #3																			x														
Error prevention #4 #7 #14 #15 #19 #24 #27																			x														
Quality of Error Messages #41 #19																			x														
Number of Errors #6 #28 #30																			x														
Error protection #41 #19 #36 #4 #7																			x														
Correction of Errors #41 #19																			x														
Objective#8 #12																				x													
Structure #8 #12																				x													
Brevity #41 #19																															x		
Community #8 #12																																x	
Sophistication #8 #12																																x	
Symmetry #1				x																													
Balance #1				x																													
Contrast #1				x																													
Interface/Layout #23 #43				x																													
Functionality #23				x																													
Quality Content #8 #12 #22 #23				x																													
Coordination #23				x																													
Pattern #35 #3 #4 #7 #11 #14 #15 #19 #24 #27 #25 #36				x																													
Aesthetic design #35 #3 #36 #4 #7 #11 #14 #15 #19 #24				x																													
Textual information #25 #28 #43				x																													
Colors #28 #43				x																													
Scope #30				x																													
Importance code #41 #19				x																													
Emotion #8 #12				x																													
Promotion #8 #12				x																													
Compatibility #41 #19				x																													
Commands #43				x																													
Message #43				x																													
Windows #43				x																													
Font #43				x																													
Animations and Transitions #43				x																													
Graphic elements #43				x																													
Sound #43				x																													
Components #43				x																													
Icons #28 #43				x																													
Devices #43												x																					