Formal Specification of Usability Heuristics: How Convenient It Is?

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ABSTRACT
The challenge of developing highly usable interactive software systems has motivated several researchers to focus on providing new elements for designing and evaluating usability. The use of interaction and usability design patterns has been promoted to achieve this. A proposal to formally specify a new set of usability heuristics to be used in a heuristic inspection has appeared. It is still arguable if formal specification of such heuristics improves the performance of usability evaluations. This paper discusses the relevance of the use of patterns in the specification of usability heuristics, based on empirical evidence collected through query techniques. The results showed that formal specification of usability heuristics through patterns could facilitate the heuristic evaluations, regardless the evaluators' experience.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation/Methodology, Training, help, and documentation, User-centered design.*

General Terms
Design, Human Factors.

Keywords
Usability heuristics, usability evaluation, usability patterns, empirical evidences.

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1. INTRODUCTION
Patterns have shown to be effective in means of capturing and communicating software design experience. Design patterns have received considerable attention in HCI (Human Computer Interaction) due to their potential for communicating information and knowledge to support good design. The user interface design process has been supported by multiple proposals of patterns. Recently, a proposal to formally specify new sets of usability heuristics using a template (pattern of usability heuristic) has been developed.

However, despite the recognized relevance of using design patterns in software development process, it is still arguable if formal specification of heuristics improves the performance of usability inspections. This paper discusses the relevance of the use of patterns in the specification of usability heuristics, based on empirical evidence collected through query techniques.

Section 2 presents the main concepts related to usability evaluation. Section 3 collects the main aspects related to patterns and their implication in the Human Computer Interaction field. Section 4 presents a proposal of methodology to establish specific usability heuristics, including their formal specification. Section 5 shows the analysis of empirical evidence related to the need of providing a formal specification of heuristics. Finally, section 6 presents some conclusions and future work.

2. USABILITY EVALUATIONS
The standard ISO/IEC 9126 defines usability as "the capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions" [10]. The usability level of a software product is considered a key factor that could influence in its success of failure [5].

According to Nielsen [13] the usability could be characterized in quantitative and qualitative terms, through a set of five parameters called "attributes", which are (1) learnability, (2) efficiency, (3) memorability, (4) error avoidance, and (5) subjective satisfaction. These attributes can be measured through different methods that allow evaluating the usability degree in a software product.

Usability evaluations are conducted in order to detect specific usability problems that could difficult users' interaction with the system. According to Lorés [11], usability evaluation includes a set of methodologies and techniques for analyzing the usability of an interactive system, into different life cycle stages.

There is no unique classification of usability evaluation methods. Holzinger [8] groups the methods in two categories: (1) inspections and (2) tests. Inspections are conducted by experts, while tests are carried out with representative users of the system in evaluation.

The heuristic evaluation was developed by Nielsen [12] and is one of the most commonly used usability inspection methods. Its main characteristic is the use of a set of usability heuristics (recognized usability principles). Usability specialists use such principles as a guide for discovering usability problems in interactive software products.

There are different protocols for the heuristic evaluation method. However, the original methodology suggests that a group of 3 to 5 evaluators should individually inspect the software interface looking for usability issues. Next, they will share their individual findings, creating a unique list of usability problems. The evaluators should grade the severity and frequency of occurrence of each identified problem. From the sum of these values, a score of criticality is obtained.

It is important to mention that, the selected set of usability heuristics plays a key role in the performance of heuristic evaluation. Depending on evaluators' experience, they could need more specific heuristics or at least a detailed formal specification for generic ones. This detailed specification could be considered as a template or pattern.

3. PATTERNS IN HCI

In a simple way, a pattern is defined as a proven solution to a recurrent design problem [2]. The origin of patterns goes beyond informatics. The architect Christopher Alexander proposed the creation and use of patterns in urban design, in the late 1970's. Alexander developed a set of 253 patterns as reusable solution to recurrent problems in architecture and urban development [1].

In informatics, the use of patterns has been very useful in software development process and interface design specifically. Patterns have shown to be effective capturing and communicating software design experience [14].

There are different classifications of patterns. Buschmann [3] classifies the patterns into three categories, based on the level of abstraction: (1) Architecture Patterns, (2) Design Patterns, and (3) Language Patterns. The design patterns are most commonly used in design of software interfaces. Gamma [7] defines design patterns as descriptions of communicating objects and classes that are customized to solve a general design problem in a particular context. The power of design patterns comes from their ability to provide generic solutions to recurrent problems that can be specialized for particular situations.

In general, the structure of a design pattern is composed of four essential elements:

- The pattern's name as an identifier that can be used to describe a design problem, its solutions, and consequences.
- The problem that describes when to apply the pattern. It explains the problem and its context.
- The solution that describes the elements that are involved in the design, their relationships, responsibilities, and collaborations.
- The consequences that are the results and trade-offs of applying the pattern.

Recently, design patterns and pattern languages have received considerable attention in HCI (Human Computer Interaction) due to its potential for communicating information and knowledge to support good design [4]. Three kinds of design patterns could be included into the category of HCI design patterns: (1) Interface Software Design Patterns, (2) Interaction Design Patterns, and (3) Usability Design Patterns [6] [4]. The main difference between them lies in the domain in which the problems and solutions are expressed.

Despite the recognized relevance of using design patterns in software development process, many authors address the difficulty for selecting, understanding and applying patterns. If patterns are too complex, then only few of them will be able to be used effectively. On the other hand, detailed specification of design issues (through patterns) could increase learnability, but may have a negative impact on performance.

Over the last years, interface design process has been supported by multiple proposals of patterns and patterns' catalogues. However, no proposals of patterns in the field of usability evaluation process have been found. Section 4 presents a proposal for creating new usability heuristics and specifying them in a formally detailed way. The use of templates that could be considered as patterns for usability heuristics is recommended. The goal of detailed specification is to provide evaluators a tool which maximizes the discovering of usability problems, through a better understanding of the heuristics.

4. METHODOLOGY FOR USABILITY HEURISTICS DEVELOPMENT

Literature reveals the existence of many different sets of generic and specific usability heuristics. This fact has alerted the scientific community about the need to provide new sets of usability heuristics to be used in the usability inspections (heuristic evaluations) of different (and emerging) software products.

Most of proposals of usability heuristics were created as an extension or contextualization of the ten usability heuristics proposed by Nielsen [12]. In these works there is no information if a formal process was followed in order to create the new set of heuristics. Rusu and others [15] proposed a (preliminary) methodology to establish new usability heuristics, for specific applications. The methodology includes 6 iterative stages:

- STEP 1: An exploratory stage, to collect bibliography related with the main topics of the research: specific applications, their characteristics, general and/or related (if there are some) usability heuristics.
- STEP 2: A descriptive stage, to highlight the most important characteristics of the previously collected information, in order to formalize the main concepts associated with the research.

- STEP 3: A correlational stage, to identify the characteristics that the usability heuristics for specific applications should have, based on traditional heuristics and case studies analysis.
- STEP 4: An explicative stage, to formally specify the set of the proposed heuristics, using a standard template.
- STEP 5: A validation (experimental) stage, to check new heuristics against traditional heuristics by experiments, through heuristic evaluations performed on selected case studies, complemented by user tests.
- STEP 6: A refinement stage, based on the feedback from the validation stage.

The methodology also proposes a template for heuristics specification, which may be considered a pattern. Table 1 depicts the standard template used at *STEP 4*, in order to specify usability heuristics.

Table 1. Standard template for formal specification of usability heuristics

Field	Description
ID, Name and Definition	Heuristic's identifier, name and definition.
Explanation	Heuristic's detailed explanation, including references to usability principles, typical usability problems, and related usability heuristics proposed by other authors.
Examples	Examples of heuristic's violation and compliance.
Benefits	Expected usability benefits, when the heuristic is accomplished.
Problems	Anticipated problems of heuristic misunderstanding, when performing heuristic evaluations.

The methodology has been validated through different cases of study such as Grid Computing, Interactive Television, Virtual Worlds and Touchscreen Mobile Devices among others. The validation demonstrated that specific usability heuristics work much better than traditional Nielsen's heuristics, in the discovering of usability problems [16] [9] [17]. However, the objective of the present work is to analyze how necessary is for novice evaluators to count with specific heuristics, or at least a detailed (formal) specification of traditional ones.

5. EMPIRICAL EVIDENCE ABOUT THE NEED OF FORMAL SPECIFICATION OF HEURISTICS

Evidence has remarked the need of providing specific heuristics for usability evaluation in different kinds of applications. Nevertheless, it is arguable if providing a formal detailed specification of those usability heuristics is required. This section presents the analysis of empirical evidence about how necessary and useful for evaluators is to count with a formal specification of usability heuristics (patterns of heuristics).

The empirical evidence is based in two separated experiments. On one hand, the opinion of experts in usability inspections, about the use of the methodology for developing heuristics was collected. On the other hand, the perception of novice evaluators, about utility, clarity, and easiness of applying Nielsen's heuristics was measured.

5.1. Experts Opinion

As part of the validation of the methodology to establish usability heuristics, an inquiry test was developed. The questionnaire was applied to 5 researchers (experts) who had experience in the application of the methodology. Each expert had applied the methodology in order to develop a set of specific usability heuristics for a specific kind of application such as: Touchscreen Mobile Devices, Virtual Worlds, Grid Computing and Interactive Television.

The main objective of the inquiry was to join the individual experiences of each expert about the applications of the methodology. The inquiry test was constructed using both opened and closed questions. Closed questions were graded using a five-point *Likert* scale. Opened questions were used to collect additional information about the opinion of the experts.

The analysis of the results demonstrated that heuristics established through the methodology are more effective in discovering usability problems than traditional Nielsen's heuristics. At the same time, through the inquiry tests, experts formally opined about the need and utility of a template for detailing usability heuristics. The main positive observations about utility of a template for heuristics are summarized at the following:

- It is a complete specification and an easy way to document any heuristic discovered.
- It allows complementing each heuristic with additional information that could facilitate the understanding and application of each one.
- It allows establishing relationships with other heuristics identified.
- This detailed specification is quite useful for discovering much more quantity of usability problems in specific kinds of applications.
- Additionally, from the point of view of the methodology, experts mentioned some cons related with the use of a formal specification for heuristics:
- The use of the template can consume a considerable amount of time.
- It is not easy to decide what information should be included into the template.

In conclusion, this experiment allowed determining the impact of providing a formal specification of usability heuristics, in order to maximize findings of heuristic evaluation.

5.2. Novice Evaluators Perception.

An experiment to inquire the difficulty of using traditional Nielsen's heuristics was conducted. The experiment was designed in order to measure the perception of novice evaluators about Nielsen's heuristics, taking into account four dimensions: (1) Utility *D1*, (2) Clarity *D2*, (3) Easiness of use *D3*, and (4) Need of additional evaluation elements ("checklists") *D4*.

The experiment included the following steps:

1. A heuristic evaluation on a transactional website.
2. The application of an inquiry test for measuring the four above mentioned dimensions.
3. The statistical analysis of results, in order to find correlation factors between the opinions of the participants.

A group of 20 relatively novice evaluators participated in the experiment. All participants were students of the *Human-Computer Interaction* course, at the *School of Informatics Engineering* (*Escuela de Ingeniería Informática*) of the *Pontifical Catholic University of Valparaiso* (*Pontificia Universidad Católica de Valparaíso*) – Chile.

Two categories of participants were considered: (1) No Previous Experience *NPE* and (2) Previous Experience *PE*. The NPE category groups 15 of 20 participants who had never participated in heuristic evaluations before. The PE category groups only 5 of 20 participants, who had participated in just one previous heuristic evaluation.

The 20 participants were solicited to perform a heuristic evaluation of the transactional website "*HotelClub.com*". The evaluators followed the protocol of the heuristic evaluation proposed by Nielsen [12]. It is important to mention that the five evaluators of PE category had previously evaluated a similar kind of website (*Booking.com*).

After the heuristic evaluation was performed on "*HotelClub.com*", an inquiry test was applied to all evaluators. The questionnaire was designed in order to capture the evaluators' perception about each of the Nielsen's usability heuristic. The questions were elaborated in order to obtain information about the four dimensions mentioned above (*D1, D2, D3* and *D4*). A five-point Likert scale was used. It allowed grading each heuristic, in a poor to high level.

An ANOVA study was conducted over the results. The study included the analysis of variance of one factor in order to look for the correlation coefficient between the opinions of the 20 participants. The ANOVA study was developed considering two categories for each dimension: (1) Analysis of variance between groups and (2) Analysis of variance into the groups. Additionally, the ANOVA study uses the two following hypothesis:

H0: There are no significant differences.

H1: There are significant differences.

Table 2 and Table 4 present the analysis of variance about dimension D1 (*Utility of Nielsen's usability heuristics*) and dimension D3 (*Easiness of use of Nielsen's usability heuristics*) respectively. In both cases, the probability values are higher than 0.05 (0.32 and 0.187, respectively). Therefore H0 hypothesis cannot be rejected and, therefore, there is no evidence of significant differences between the 20 evaluators' perceptions on Nielsen's heuristics *clarity* (*D1*) and *easiness of use* (*D3*).

Table 3 and Table 5 present the analysis of variance about dimension D2 (*Clarity of Nielsen's usability heuristics*) and dimension D4 (*Need of additional elements "checklists"*) respectively. The results show that in both cases the probability values are lower than 0.05 (7.46E-06 and 2,47E-066, respectively). Hence, in both cases, the H0 hypothesis is rejected. We may conclude that there are significant differences between evaluators' perceptions of *utility of ten Nielsen's heuristics* (*D2*) and *Need of additional evaluation elements "checklists"* (*D4*).

Table 2. Analysis of variances in utility of Nielsen's heuristics (D1)

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	16.295	19.0	0.868	1.13	0.32	1.64
Into the groups	136.300	180.0	0.757			
Total	**152.595**	**199.0**				

Table 3. Analysis of variances in clarity of Nielsen's heuristics (D2)

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	67.680	19.0	3.562	3.432	7.46E-06	1.645
Into the groups	186.800	180.0	1.038			
Total	**152.595**	**199.0**				

Table 4. Analysis of variances in easiness of use of Nielsen's heuristics (D3)

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	23.78	19.0	1.252	1.302	0.187	1.645
Into the groups	173.00	180.0	0.961			
Total	**196.78**	**199.0**				

Table 5. Analysis of variances in need of additional evaluation elements "checklists" (D4)

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	62.175	19.0	3.272	3.643	2.47E-06	1.645
Into the groups	161.700	180.0	0.898			
Total	**223.875**	**199.0**				

So far, through the ANOVA study is possible to determine the existence of significant differences between the 20 evaluators, about their perceptions of usability Nielsen's heuristics in D2 and D4 dimensions. New analyses of variance were performed, considering separately the two categories of evaluators: (1) No Previous Experience *NPE* and (2) Previous Experience *PE* ones.

Table 6 and Table 8 summarize the analysis of variance about D2 and D4 dimensions respectively, taking into account only the *NPE* category of evaluators. In both cases, the H0 hypothesis is rejected and this allows concluding that there are significant

differences between NPE evaluators' perceptions of *utility of ten Nielsen's heuristics* (*D2*) and *need of additional evaluation elements "checklists"* (*D4*). The probability values of both dimensions (1.51E-06 and 4.57E-04, respectively) are lower than 0.05.

The analysis of variance about D2 and D4 dimensions, taking into account just the PE category of evaluators, are summarized in Table 7 and Table 9 respectively. Based on the probability value of D2 (0.14) which is higher to 0.05, the H0 hypothesis is not rejected; it is possible to conclude that there is no evidence of significant differences between PE evaluators' perceptions of *utility of ten Nielsen's heuristics*. The probability value (4.05E-04) of the D4 dimension is lower than 0.05; therefore H0 hypothesis is rejected and there are significant differences between PE evaluators' perceptions of the *need of additional evaluation elements* ("checklists").

Table 6. Analysis of variances in D2. NPE category of evaluators

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	57.093	14.0	4.08	4.47	1.51E-06	**1.77**
Into the groups	123.200	135.0	0.91			
Total	**180.293**	**149.0**				

Table 7. Analysis of variances in D2. PE category of evaluators

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	10.480	4.0	2.62	1.85	0.14	2.58
Into the groups	63.600	45.0	1.41			
Total	**74.080**	**49.0**				

The results of separate ANOVA for categories of evaluators allow concluding that the perceptions of PE evaluators in D2 dimension are homogeneous, while the perceptions of NPE evaluators showed significant differences.

Table 8. Analysis of variances in D4. NPE category of evaluators.

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	37.173	14.0	2.66	3.02	4.57E-04	1.77
Into the groups	118.700	135.0	0.88			
Total	**155.873**	**149.0**				

Table 9. Analysis of variances in D4. PE category of evaluators

Variations origin	Squares sum	Liberty degrees	Squares Average	F	Probability	F Critical value
Between groups	24.120	4.0	6.03	6.31	4.05E-04	2.58
Into the groups	43.000	45.0	0.96			
Total	**67.120**	**49.0**				

Average perception of Nielsen's usability heuristics in the four evaluated dimensions are presented in Table 10. It is possible to observe that, in average, usability heuristics obtained higher grades from novice evaluators (NPE) than those experimented ones (PE), in all four dimensions. The dimension about the easiness of use Nielsen's usability heuristics (D3) obtained the lowest value. However, there is no significant difference compared with the value obtained from experimented evaluators (PE). That could means that for both novice and experimented evaluators is not easy to use Nielsen's usability heuristics. On the other hand, both novice and experimented evaluators are agree in the need of additional evaluation elements "checklists" (D4) for supporting them in the discovering of usability problems.

Table 10. Averages of perception of Nielsen's usability heuristics in the four evaluated dimensions

Dimension	Average (NPE Evaluators)	Average (PE Evaluators)	General Average
D1	4.053	4.020	4.045
D2	3.773	3.720	3.760
D3	3.193	3.180	3.190
D4	3.913	3.760	3.875

When answering the open questions of the survey, evaluators highlighted the need for a detailed usability heuristics specification. The empirical evidences of this experiment support the need for formal specification of each usability heuristic, using a template that could be considered as a pattern for usability heuristics description.

6. CONCLUSIONS

Heuristic evaluation is a widely used usability inspection method. For novice evaluators, the use and understanding of generic usability heuristics, such us Nielsen's heuristics, could mean a barrier. The proposal of creating new specific usability heuristics and expressed them in a (formal) detailed way could be a good alternative.

Through experiments and experts opinion, the pertinence of providing a formal specification for usability heuristics was analyzed. Empirical evidences seem to prove that, regardless of evaluators' experiences, it is useful to provide detailed usability heuristics description, through a standard template (pattern).

A questionnaire was applied to 20 usability evaluators. It was possible to detect that Nielsen's 10 usability heuristics are similarly perceived as difficult of use, by both novice and (somehow) experimented evaluators. The perceptions of these two categories of evaluators about four dimensions (*D1-Utility, D2-Clarity, D3-Easiness of use*, and *D4-Need of additional elements of evaluation*) were analyzed through ANOVA studies.

The results show a consensus in the perception of the majority of the analyzed dimensions. With the complete group of evaluators, the analysis reflected similarity of opinions in dimensions D1 and D3, while D2 and D4 dimensions presented certain heterogeneity. D2 and D4 dimensions were analyzed separating evaluators with *No Previous Experience* (*NPE*) and *Previous Experience* (*PE*). D2 dimension presents significant differences in the perception of both groups of evaluators (NPE and PE).

Future work will be focused on the application of the questionnaire on other case studies, and to other evaluators. It is also necessary to analyze empirical evidences related with the perception of each individual Nielsen's heuristic taking into account the same four dimensions. Finally, the usability problems identified during the heuristic evaluations performed by the 20 evaluators will be analyzed. The subjective perception of the evaluators will be then compared with their ability of associating usability problems to Nielsen's heuristics.

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