Usability: A Critical Analysis and a Taxonomy

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Usability: A Critical Analysis and a Taxonomy
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Abstract

A major obstacle to the implantation of User-Centered Design (UCD) in the real world is the fact that no precise definition of the concept of usability exists that is widely accepted and applied in practice. Generally speaking, the literature tends to define usability in overly brief and ambiguous terms and to describe its application in informal terms. This is one of the main reasons why ad hoc techniques predominate in usability study methodologies. The aims of this article are to investigate the concept of usability and to describe it by means of a detailed taxonomy that is organized hierarchically and which contains exhaustive descriptions of usability attributes. This taxonomy can be used to support different stages in the development of usable systems.

Keywords

Usability, usability definitions, taxonomy of usability attributes, context of use, product lifecycle, usability evaluation.
Usability: A Critical Analysis and a Taxonomy

The concept of usability derives from the term user friendly, defined as “an expression used to describe computer systems which are designed to be simple to use by untrained users, by means of self-explanatory or self-evident interaction between user and computer” (Chandor, Graham, & Williamson, 1985). With time, the term user friendly came to be criticized as having “acquired a host of undesirably vague and subjective connotations” (Bevan, Kirakowski, & Maissel, 1991), among them that of being “unnecessarily anthropomorphic” and of suggesting that “users’ needs can be described along a single dimension” (Nielsen, 1993). The concept of usability was then coined in order to overcome the limitations of the term user friendly. So far, several definitions of usability and the characteristics that define it have been proposed. However, these definitions tend to be brief and informal, and neither researchers nor standards bodies have achieved consensus with regards to the concept of usability (Abran, Khelifi, & Sury, 2003).

The aim of this article is to describe a clear, detailed taxonomy that fully reflects each of the attributes that conform the usability of a product in a structured and non-redundant way. This taxonomy is designed to support different stages in a product’s lifecycle and to ensure a common vision of the usability concept in the work group. It will, furthermore, provide a framework for focusing on the specific aspects that need to be prioritized in the specification, design, and evaluation phases, thereby facilitating the development of more usable products. Such a taxonomy would be especially useful for creating computerized tools for partially automating usability studies.

1. Background

The definitions of the concept of usability most widely used at present are those of the International Organization for Standardization (ISO), in particular, those given in ISO 9241-11 (ISO, 1998) and ISO/IEC 9126-1 (ISO/IEC, 2001).

Usability is defined in ISO 9241-11 as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” Effectiveness, in turn, is defined as “the accuracy and completeness with which users achieve specified goals,” efficiency as the “resources expended in relation to the accuracy and completeness with which users achieve specified goals,” and finally, satisfaction is the “freedom from discomfort and positive attitudes towards the use of the product.”

The aforementioned definition of usability also indicates that its attributes are not absolutes but should be assessed in terms of the context of use. Context of use is described, in the same standard, in terms of users, tasks, equipment, and environment.

ISO 9241-11 does not define usability further, but illustrates the concept using a non-exhaustive list of examples. The Annex B of said document, thus, refers to several measures of usability, with effectiveness measured in terms of the “percentage of goals achieved, percentage of users successfully completing tasks and average accuracy of completed tasks,” efficiency
measured in terms of the “time to complete a task, tasks completed per unit time and monetary
cost of performing the task,” and finally, with satisfaction measured in terms of a “rating scale
for satisfaction, frequency of discretionary use and frequency of complaints.”

Subsequently, ISO/IEC 9126-1 (2001) classified usability as one of the components
representing internal and external software quality, defining it as “the capability of the software
product to be understood, learned, used and attractive to the user, when used under specified
conditions.” In this case, usability is referred to in terms of five attributes, namely
understandability, learnability, operability, attractiveness, and usability compliance.
Understandability is defined as the “capability of the software product to enable the user to
understand whether the software is suitable and how it can be used for particular tasks and
conditions of use”; learnability as the “capability of the software product to enable the user to
learn its application”; operability as the “capability of the software product to enable the user
to operate and control it”; attractiveness as the “capability of the software product to be attractive
to the user”; and usability compliance as the “capability of the software product to adhere to
standards, conventions, style guides or regulations relating to usability.”

Another standards body, the Institute of Electrical and Electronics Engineers (IEEE),
proposes as a definition for usability “the ease with which a user can learn to operate, prepare
inputs for and interpret outputs of a system or component” (IEEE, 1990).

To these definitions we can add those proposed by a number of usability experts, as
follows:

- The classifications by Nielsen (1993) and by Nielsen and Loranger (2006) refer to
  learnability, efficiency, memorability, errors, and satisfaction as usability attributes.
  Some researchers, including Holzinger (2005), consider these to be widely accepted
  attributes.

- Preece et al. developed an initial classification that included safety, effectiveness,
  efficiency, and enjoyableness (Preece, Benyon, Davies, Keller, & Rogers, 1993).
  Subsequently, they proposed a new classification composed of learnability, throughput,
  flexibility, and attitude (Preece et al., 1994).

- Quesenbery (2001, 2003, 2004) lists the attributes of a usable product as effectiveness,
  efficiency, engagement, error tolerance, and ease of learning.

- Abran et al. (2003) proposed extending the ISO 9241-11 definition by adding two
  further attributes, namely learnability (already adopted by IEEE, 1990; ISO/IEC 9126-
  1, 2001; Nielsen, 1993) and security.

- The classification by Seffah, Donyae, Kline, and Padda (2006), which also departs
  from ISO 9241-11, is the most complete, as it defines a total of ten usability factors
  (efficiency, effectiveness, productivity, satisfaction, learnability, safety, trustfulness,
  accessibility, universality, and usefulness) associated with 26 measurable usability
criteria. Each of these criteria is associated with other, interrelated factors—privacy, for
example, with trustfulness, universality, and usefulness (given that it measures aspects
associated with each of these factors).

Broadly speaking, the existing literature on usability is characterized by definitions that are
overly brief and imprecise; furthermore, the application of concepts is illustrated informally,
using only a few examples. This means that usability tends to be evaluated in an ad hoc manner and in a way that makes agreement between experts difficult. Another problem with the literature is that it is almost exclusively limited to software systems. Required therefore is a comprehensive and precise definition of usability and of its components. Only on this basis is it truly possible to set goals, establish requirements, communicate concepts, and automate some of the activities, in a usability study.

2. A Usability Taxonomy

In this section we describe the construction procedure and the attributes of the taxonomy we propose. We first describe the different phases of the methodology used in developing the taxonomy. We then define each usability attribute and subattribute in detail and compare these with the attributes described in the usability literature (a comparative summary of the different taxonomies appears in a subsequent section).

2.1 Constructing the Taxonomy

In order to build the taxonomy we first examined published usability classifications, weighing their pros and cons, and then identified the best way of defining and structuring the attributes in several refinement cycles.

As a first step in the construction process we listed all the attributes described in existing classifications. Given the lack of consensus in the usability field, existing classifications are clearly divergent. Furthermore, when classifications do overlap, they tend to do so only partially and unevenly, with different terms used to designate the same attribute or with the same term used to describe different concepts. Given the ambiguity of the definitions that have been proposed in these classifications, it is also difficult to match concepts in different classifications. This preliminary study nevertheless served as the groundwork for our own synthesis. The purpose of this synthesis is to cover the usability aspects of any type of system and to be adaptable to different contexts of use. As a result, we made use of some of the attributes in the literature, redefined other attributes, and added new attributes that had not been covered by any of the existing classifications. Finally, for each attribute we coined a precise definition of its meaning.

Once we defined the attributes, we structured and ordered them in such a way as to populate a first level in the taxonomy with generic attributes that could be progressively refined to obtain more specific subattributes that would populate subsequent taxonomic levels. It was important that the criteria used to structure the taxonomy permitted to group related attributes together and separate unrelated attributes as much as possible. Another important issue was to pay special attention to avoiding redundancy in the different attributes. By preventing overlapping, attributes can be evaluated in isolation from other attributes, thereby simplifying the usability study, ensuring greater thoroughness, and ultimately guaranteeing that results will not be contradictory.

An initial analysis round was followed by a series of revisions and progressive refinements
of the taxonomy that consisted of adding new attributes, regrouping attributes in more suitable categories, eliminating redundant attributes, and developing more appropriate terms for certain attributes.

The taxonomy resulting from this process of construction has the first-level usability attributes depicted in Figure 1.

![Usability attributes](image)

Figure 1. Usability attributes.

### 2.2 Description of the Taxonomy

**Knowability.**

*Knowability* is defined as the property by means of which the user can understand, learn, and remember how to use the system. This attribute has subattributes as follows (Figure 2):

- **Clarity**, defined as the ease with which the system can be perceived by the mind and the senses. We draw a distinction between three kinds of clarity:
  - *Clarity of the elements*, classified in turn in terms of *formal clarity* (capacity of the system to facilitate perception of individual system elements through the senses) and *conceptual clarity* (capacity of the system to facilitate comprehension of the meaning of the system elements).
  - *Clarity of the structure*, divided in turn into *formal clarity* (property of the system in terms of having its elements organized in a way that enables them to be perceived with clarity) and *conceptual clarity* (property of the system in terms of having its elements organized in a way that enables their meaning to be easily understood).
  - *Clarity in functioning*, referring to both the way user tasks are performed and the way system tasks are automatically executed.

- **Consistency**, defined as system uniformity and coherence. It is subdivided in a similar way to clarity.

- **Memorability**, defined as the property of the system that enables the user to remember the elements and the functionality of the system. This attribute, like *clarity* and *consistency*, is also referred to in terms of individual elements, structure, and functioning.

- **Helpfulness**, defined as the means provided by the system to help users when they cannot infer or remember how to use the system. For this attribute a distinction is drawn between two aspects:
  - *Suitability of documentation content*, that is, content should be useful and adequate, bearing in mind that it includes definitions, descriptions, and examples.
- **Interactivity of assistance**, that is, the extent to which the help provided by the system responds to the actions of the user.

![Knowability subattributes diagram]

Figure 2. Knowability subattributes.

The term *knowability* does not feature as an attribute in existing classifications in the usability literature. Some classifications describe attributes that partially reflect related parameters, such as *learnability* (ISO/IEC 9126-1, 2001; Nielsen, 1993; Preece et al., 1994; Quesenbery, 2001; Abran et al., 2003; Seffah et al., 2006), *memorability* (Nielsen), and *understandability* (ISO/IEC 9126-1). We are of the opinion that the *knowability* attribute—which covers all the abovementioned aspects of knowing but with a broader meaning—must be located at the highest level of the taxonomy.

Furthermore, most of the existing classifications describe the attributes at a superficial level. *Understandability*, for example, is defined as the capacity of the product to enable the user to understand how it should be used, but there is no distinction drawn between different types of *understandability*, nor is there an indication of the specific characteristics that contribute to *understandability*. In our taxonomy, on the other hand, we provide detailed descriptions of the factors that determine the *knowability* of a system, as it is definitely important that the system be clear, consistent, and easy to remember. Also, a user should have available the help necessary in order to be able to understand the system.

**Operability.**

*Operability* is defined as the capacity of the system to provide users with the necessary functionalities and to permit users with different needs to adapt and use the system. It is divided into the following subattributes (Figure 3):

- **Completeness**, defined as the capacity of the system to provide the functionalities necessary in order to implement the tasks intended by the user.
- **Precision**, defined as the capacity of the system to perform tasks correctly.

- **Universality**, defined as the extent to which the system can be used by all kinds of users. It is broken down as follows:
  - **Accessibility**, defined as the extent to which the system can be used by all kinds of users regardless of any physical or psychic characteristic they may have (e.g., disabilities, limitations, age, etc.). This attribute is subdivided into others in accordance with specific characteristics (visual, auditory, speech, motor, and cognitive).
  - **Cultural universality**, defined as the extent to which users from different cultural backgrounds can use the system. We identify this attribute as having two features, namely, language and other cultural conventions (use of symbols, measurement units, numeric formats, etc.).

- **Flexibility**, defined as the capacity of the system to adapt and to be adapted to different user preferences and needs. It has two distinct aspects:
  - **Controllability**, defined as the capacity of the system to permit users to choose the most appropriate way to use the system. A distinction is drawn between two subattributes:
    - **Configurability**, defined as the capacity of the system to permit users to personalize the system, with a distinction drawn between the configurability of technical aspects and of formal aspects.
    - **Workflow controllability**, defined as the capacity of the system to permit users to control tasks as they are implemented. This attribute includes controllability over the steps to be followed (i.e., the system permits alternative approaches to performing tasks) and enabling task reversibility (i.e., the system allows users to reverse actions).
  - **Adaptiveness**, defined as the capacity of the system to adapt itself to user preferences and to different types of environments.
Most of the existing classifications do not include an attribute that is defined in equivalent terms as our operability concept. ISO/IEC 9126-1 (2001) does refer to operability but describes it as related to aspects of suitability (coinciding partially with our completeness attribute), error tolerance (reflected in our robustness attribute), and controllability.

Our completeness and precision attributes are very similar to those that conform the definition of effectiveness in ISO 9241-11 (1998), which was subsequently adopted by Quesenbery (2001), Abran et al. (2003) and Seffah et al. (2006).

The study by Seffah et al. (2006) is the only classification that includes attributes related to accessibility and cultural universality (although these authors merely refer to universality). Our classification describes both these concepts in greater detail, including new kinds of disabilities, such as speech and cognitive handicaps, and specifying types of cultural universality. Since both these attributes share the notion that a system should be capable of use by all potential users, we have grouped them under the universality attribute.

Preece et al. (1994) refer to flexibility, briefly defined as “the extent to which the system can accommodate changes to the tasks and environments beyond those first specified.” Our classification is more precise in that we explicitly distinguish between the system’s own capacity to adapt and its capacity to be adapted.

**Efficiency.**

Efficiency is the capacity of the system to produce appropriate results in return for the resources that are invested. The taxonomy for the branch of usability referring to efficiency (Figure 4) reflects four subattributes:

- **Efficiency in human effort**, referring to the capacity of the system to produce appropriate results in return for the physical or mental effort that the user invests.
• **Efficiency in task execution time**, referring to the time invested by the user in performing actions and the time taken by the system to respond.

• **Efficiency in tied up resources**, both material and human.

• **Efficiency in economic costs**, which refers to different types of expenses, namely, the cost of the system itself, human resource costs, the cost of the equipment that is required to work with the system, and the cost of consumables.

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Although the term *efficiency* features in most of the classifications in the literature, our understanding of this concept is somewhat different. Nielsen (1993) describes *efficiency of use* as referring to the level of performance achieved by expert users (users who have learned to use the system) and measured as “the time it takes users to perform some typical test tasks.” The classification by Preece et al. (1994), which also refers to users with experience, includes the attribute *throughput* but also considers new measures such as *tasks accomplished* and *errors made*. A key problem with these classifications is that they take into account only expert users, and thus ignore the fact that usability depends on the context of use. This means that a usability study of a system should consider the skills and knowledge of its intended users, which might not be proficient in its use.

The ISO 9241-11 (1998) definition of *efficiency* is the most complete, as it not only takes into account task execution time but also mental and physical effort, materials used, and financial cost. Our definition reflects all the aspects mentioned in ISO 9241-11 but extends it further by adding new subattributes.

**Robustness.**

*Robustness* is defined as the capacity of the system to resist error and adverse situations. It is broken down into subattributes as follows (Figure 5):

• *Robustness to internal error.*

• *Robustness to improper use.*

• *Robustness to third party abuse.*

• *Robustness to environment problems.*
Nielsen (1993) refers to errors in terms of the user making few errors when using the system and being able to easily recover from them. He draws a distinction between catastrophic errors and errors that just slow down the user’s transaction rate (pointing out that the latter should be included in his efficiency of use attribute). The Quesenbery (2001) classification includes the attribute error tolerance, analogous to Nielsen’s errors but taking into account errors that are not caused by the user (for example, system failures). Our robustness attribute differs somewhat from the attributes described by these other authors. Firstly, we specify different sources of error; secondly, we restrict the meaning of the term to the system’s capacity to resist adverse situations; and, finally, we also take into account the need for the system to be able to recover by itself. Note also that in the error tolerance attribute, the Quesenbery classification includes the capacity of the system to reverse actions. Our taxonomy, however, reflects this reversal capacity as an element of operability.

Other classifications reflect robustness as an element in other attributes. ISO/IEC 9126-1 (2001), for example, includes error tolerance in the operability attribute. Our perception of robustness, however, is that it needs to be dealt with as a separate attribute, given that it covers aspects that go beyond the mere operation of the system, such as robustness against abuse by third parties and against problems in the environment.

Safety.

Safety is defined as the capacity to avoid risk and damage derived from the use of the system. It is broken down into the following subattributes (Figure 6):

- User safety, defined as the capacity to avoid risk and damage to the user when the system is in use. Specifying risk or damage in more detail, we distinguish between notions such as physical safety, legal safeguarding, confidentiality, and the safety of the material assets of the user.
- Third party safety, defined as the capacity of avoiding risk and damage to individuals other than the user when the system is in use.
- Environment safety, defined as the capacity of the system to avoid risk and damage to the environment when being used.
Safety does not appear in most of the classifications described in the literature. Although Abran et al. (2003) and Seffah et al. (2006) do refer to the concepts of security and safety respectively, they remain only defined briefly. Furthermore, only physical harm or damage to people and resources is mentioned in their descriptions of specific types of safety. Our concept of this attribute is broadened to also include the capacity of the system to avoid any breach of the law or of the confidentiality rights of the user or of other individuals.

**Subjective satisfaction.**

Subjective satisfaction is the capacity of the system to produce feelings of pleasure and interest in users. It consists of two subattributes (Figure 7):

- **Interest**, defined as the capacity of the system to capture and maintain the attention and intellectual curiosity of the user.
- **Aesthetics**, defined as the capacity of the system to please its user in sensorial terms. Depending on the type of sensation, this attribute can be subdivided into visual, acoustic, tactile, olfactory and gustatory aesthetics.
All the classifications in the literature describe attributes that fully or partially reflect this concept. Preece et al. (1994) define the attribute \textit{attitude} as the capacity of the system to produce positive feelings in the user. ISO/IEC 9126-1 (2001) refers to the attribute \textit{attractiveness} as the capacity of the system to be aesthetically pleasing to the user (for example, in terms of color use and graphic design). ISO 9241-11 (1998), Nielsen (1993), and Seffah et al. (2006) give their preferred term, \textit{satisfaction}, a broader meaning by considering other subjective sensations such as, for example, the absence of discomfort when using the system and the capacity of the system to fulfill the aims of the user. Quesenbery (2001) refers to the attribute \textit{engagement} in a similar way, and also mentions aspects such as user interface interaction style (gamelike simulation, menu command, etc.). Our \textit{subjective satisfaction} attribute differs from the abovementioned attributes in two ways. Firstly, while the freedom from discomfort is considered by some authors to comprise part of subjective satisfaction, we made the decision to exclude it from our taxonomy. Absence of discomfort is related to the absence of risk and damage, and is thus covered by our \textit{physical safety} attribute. Its inclusion here could therefore create redundancy in the taxonomy. Secondly, we view \textit{subjective satisfaction} as composed of two distinct concepts: satisfaction from an intellectual perspective and satisfaction from a sensorial perspective. The subdivision of satisfaction into these two dimensions is necessary in order to be able to generalize the concept to all types of systems. As can be appreciated from the literature (which focuses on software systems), it is only possible to explore more specific kinds of satisfaction when the domain is restricted to a particular type of system.

3. Comparative Summary of the Taxonomies

Taking the first-level attributes in our taxonomy as a baseline, Table 1 represents correspondences between the attributes described in the different usability classifications in the literature. It should be pointed out that in most cases there is no full equivalence between concepts, even though several classifications use the same or very similar terms in order to refer to similar attributes. The differences arise for a range of reasons: the meaning of attributes is not identical; attributes may correspond to different levels of granularity; and what is rated an attribute in one classification may be a metric or guideline in another classification. Finally, an added difficulty arises in the fact that terms are often defined ambiguously.

A number of terms feature in most of the classifications, namely, \textit{satisfaction}, \textit{efficiency}, \textit{learnability}, and \textit{effectiveness}. The first two terms are present in our taxonomy; the second two are also included but form part of the \textit{knowability} and \textit{operability} concepts, respectively, both of which are more complete.

Other attributes that appear in several classifications, but with less frequency, are \textit{robustness} (or the related concept, \textit{errors}) and \textit{safety} (or \textit{security}). These attributes, incidentally, have not been included in the two ISO standards.

ISO/IEC 9126-1 (2001) includes, however, the \textit{usability compliance} attribute. This does not feature as an attribute in our taxonomy, given that it consists of aspects that are covered by a range of standards, conventions, style guides, and regulations that already form part of attributes—such as \textit{accessibility}, \textit{cultural universality}, \textit{consistency}, and so forth—already
included in the taxonomy. In other words, the creation of a new attribute for this concept is not justified.

Table 1

*First-Level Usability Attributes from our Taxonomy Featuring in Other Classifications*

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<tbody>
<tr>
<td>Knowability</td>
<td>Understandability; learnability</td>
<td>Learnability; memorability</td>
<td>Learnability</td>
<td>Ease of learning</td>
<td>Learnability</td>
<td>Learnability</td>
<td></td>
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<tr>
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<td>Effectiveness</td>
<td>Operability</td>
<td>Flexibility</td>
<td>Effectiveness</td>
<td>Effectiveness</td>
<td>Effectiveness; usefulness; accessibility; universality</td>
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<td>Efficiency</td>
<td>Efficiency</td>
<td>Throughput</td>
<td>Efficiency</td>
<td>Efficiency</td>
<td>Efficiency; productivity</td>
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<td>Error tolerance</td>
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<tr>
<td>Subjective satisfaction</td>
<td>Satisfaction</td>
<td>Attractiveness</td>
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<td>Attitude</td>
<td>Engagement</td>
<td>Satisfaction</td>
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<td></td>
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</table>

To conclude this section, Tables 2 through 7 list the attributes described in the classifications analyzed above that explicitly refer to second-level concepts in our taxonomy; that is, the subattributes of knowability (Table 2), operability (Table 3), efficiency (Table 4), robustness (Table 5), safety (Table 6), and subjective satisfaction (Table 7). From these tables we observe that two things become more apparent at this level of detail: firstly, the lack of consensus among the different classifications, and secondly, the new concepts covered by our taxonomy which are not included in other classifications.
### Table 2

**Knowability Subattributes from our Taxonomy Featuring in Other Classifications**

<table>
<thead>
<tr>
<th>Proposed subattributes</th>
<th>Attributes in other classifications</th>
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<tbody>
<tr>
<td></td>
<td>ISO/IEC 9126-1 (2001)</td>
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<td>Nielsen (1993)</td>
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<td></td>
<td>Preece et al. (1994)</td>
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<td></td>
<td>Quesenbery (2001)</td>
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<td></td>
<td>Abran et al. (2003)</td>
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<td></td>
<td>Seffah et al. (2006)</td>
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<tr>
<td>Clarity</td>
<td>Ease of learning</td>
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<tr>
<td>Consistency</td>
<td>Learnability</td>
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<tr>
<td>Memorability</td>
<td>Memorability</td>
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<tr>
<td>Helpfulness</td>
<td>Understandability</td>
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<tr>
<td></td>
<td>Ease of learning</td>
</tr>
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<td></td>
<td>Learnability</td>
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</table>

### Table 3

**Operability Subattributes from our Taxonomy Featuring in Other Classifications**

<table>
<thead>
<tr>
<th>Proposed subattributes</th>
<th>Attributes in other classifications</th>
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<tr>
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<td>Nielsen (1993)</td>
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<tr>
<td>Completeness</td>
<td>Effectiveness</td>
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<td>Effectiveness</td>
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<td>Precision</td>
<td>Effectiveness</td>
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<td>Effectiveness</td>
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<td></td>
<td>Effectiveness; usefulness</td>
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<tr>
<td>Universality</td>
<td>Accessibility; universality</td>
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<tr>
<td>Flexibility</td>
<td>Operability</td>
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<td></td>
<td>Flexibility</td>
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<td></td>
<td>Effectiveness; trustfulness; usefulness</td>
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### Table 4
**Efficiency Subattributes from our Taxonomy Featuring in Other Classifications**

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</thead>
<tbody>
<tr>
<td>Efficiency in human effort</td>
<td>Efficiency</td>
<td>Efficiency</td>
<td>Efficiency</td>
<td>Efficiency; usefulness</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Efficiency in task execution time</td>
<td>Efficiency</td>
<td>Efficiency; Throughput</td>
<td>Efficiency</td>
<td>Efficiency; productivity; usefulness</td>
<td></td>
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<tr>
<td>Efficiency in tied up resources</td>
<td>Efficiency</td>
<td>Efficiency; usefulness</td>
<td>Efficiency</td>
<td>Efficiency; productivity; usefulness</td>
<td></td>
<td></td>
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<tr>
<td>Efficiency in economic costs</td>
<td>Efficiency</td>
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</tbody>
</table>

### Table 5
**Robustness Subattributes from our Taxonomy Featuring in Other Classifications**

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<tbody>
<tr>
<td>Robustness to internal error</td>
<td>Error tolerance</td>
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<tr>
<td>Robustness to improper use</td>
<td>Operability</td>
<td>Errors</td>
<td></td>
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<tr>
<td>Robustness to third party abuse</td>
<td></td>
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<td></td>
<td>Trustfulness</td>
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<tr>
<td>Robustness to environment problems</td>
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</table>
Table 6

*Safety Subattributes from our Taxonomy Featuring in Other Classifications*

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<tr>
<td>User safety</td>
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<td></td>
<td>Safety; trustfulness</td>
</tr>
<tr>
<td>Third party safety</td>
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<td></td>
<td>Safety; trustfulness</td>
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<tr>
<td>Environment safety</td>
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</tbody>
</table>

Table 7

*Subjective Satisfaction Subattributes from our Taxonomy Featuring in Other Classifications*

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<tbody>
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<td>Interest</td>
<td>Satisfaction</td>
<td>Satisfaction</td>
<td>Attitude</td>
<td>Engagement</td>
<td>Satisfaction</td>
<td>Satisfaction</td>
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<tr>
<td>Aesthetics</td>
<td>Satisfaction</td>
<td>Attractiveness</td>
<td>Satisfaction</td>
<td>Engagement</td>
<td>Satisfaction</td>
<td>Satisfaction</td>
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</tbody>
</table>

4. Discussion and Conclusions

The purpose behind this research was to develop an exhaustive and thorough taxonomy of the attributes underlying the concept of usability. The literature features many publications that have endeavored to describe the concept and attributes of usability. However, we repeatedly found—as pointed out by van Welie, van der Veer, and Eliëns (1999) with respect to ISO 9241-11—that the proposed definitions are too brief and ambiguous, and that the classifications contain too little detail. This, along with the fact that usability is clearly a complex concept, helps to explain the lack of consensus existing between experts in relation to the precise meaning of the different terms. All these circumstances greatly add to the difficulty of applying the usability concept in the real world. In practice, studies of usability are conducted in an informal, difficult to automate way.

Another problem with the existing literature on usability is that it is overly focused on software tools. Usability is a concept that affects all kinds of systems, and a usability taxonomy
should consequently reflect this fact. For this reason we propose a taxonomy that covers the concept of usability applied to any product. The fact that we have tried to be as comprehensive as possible does not mean that the usability expert is obliged to use all attributes. In any case, different systems have different characteristics, and not all attributes will always be applicable. The taxonomy can then be adapted to different systems by determining the relative importance of each attribute corresponding to the concept of usability for a given system. In our future work we intend to model this adaptation and study the possibility of assigning weights to the usability attributes. The latter issue has been explored by Sauro & Kindlund (2005) with the aim of computing a single comprehensive usability metric.

Our taxonomy is structured hierarchically and goes from the general to the particular. This enables related attributes to be grouped together and unrelated attributes to be separated as much as possible. It is thus possible to focus at any given moment on specific branches of the taxonomy, thereby restricting the analysis to specific aspects of usability, relevant attributes of the system, or a particular level of detail. In building the taxonomy, we paid special attention to eliminating redundancies between attributes so as to help increase independence between concepts (the evaluation of one attribute should not repeat or contradict the evaluation of another attribute). The parts of the process for constructing the taxonomy that are most open to debate are the organization of the attributes and the decision as to the characteristics to eliminate in order to avoid redundancy. That said, what is important is that appropriate concepts are present in the taxonomy, irrespective of the fact that there may be different and equally valid ways of representing and organizing usability attributes.

Possibly the greatest difficulties in terms of drawing up a taxonomy arise in regard to the ambiguities inherent in natural language. The only way to resolve these problems is to choose terminology carefully and clearly define the meaning of the different attributes. The fact that usability is a relatively new concept means that it has no specific vocabulary of its own. Researchers have therefore had to borrow terms from other disciplines such as psychology, philosophy, or the arts. In some of the definitions proposed in this article we deliberately simplified the meaning of these borrowed terms with a view to restricting ourselves to aspects of relevance only to the usability of a system. Likewise, in subdividing the attributes, we used a series of dichotomies that in other areas could be considered simplistic, but which can be considered to be perfectly valid and useful for the domain that concerns us here (i.e., usability).

Our taxonomy provides a conceptual framework for introducing the study of usability over the different lifecycle phases of a product. It can help people discuss relevant usability issues that may have otherwise been ignored, thus contributing to the design of more usable systems. It can also be used as a basis for different usability activities. We intend, for instance, to use it to specify the usability requirements of a given system and to evaluate its usability through metrics or subjective questionnaires. These kinds of activities belong to different stages of the lifecycle of a product: for example, the specification of requirements highlights usability issues before designing the system; usability evaluation can be used during the design phase and after the system is finished; and so on. The taxonomy constitutes a structured model that can also be used as a basis for partially automating some of these tasks.

The taxonomy forms part of a more extensive project that has as its aim the construction of a usability methodology. It is absolutely essential to include the concept of context of use in the methodology, given that the usability of a product is not an intrinsic property but depends on the context of use (Bevan & Macleod, 1994; ISO 9241-11, 1998; Maguire, 2001), with the relative
importance of different usability attributes determined by different types of users, tasks, environments, and so forth. In the real world, context of use is generally taken into account in some form in usability studies. However, just like with usability, there is no consensus with regard to context of use in terms either of its precise attributes or its relationship with usability attributes. This has led to the concept of context of use being included in usability studies in an ad hoc manner.

For these reasons, it is also necessary to have precise definitions of the attributes associated with context of use. We plan to construct a taxonomy for context of use in a similar way to that created for usability. We also intend to link up both taxonomies to define how context of use attributes affect usability attributes. This will make it possible to model the relationship between context of use and usability in a way that will enable the automation of new usability studies conducted in response to variations in the context of use.
References


