Proceedings of the 2009 IEEE International Conference on Systems, Man, and Cybernetics
San Antonio, TX, USA - October 2009

Usability Taxonomy and Context-of-Use Taxonomy for Usability Analysis

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***Abstract*—The interest in developing usable products has led to the inclusion of usability aspects in product development processes. Generally speaking, the literature tends to define usability in overly brief and ambiguous terms and to describe its application in informal terms. Also there is a tendency to overlook characteristics of the context in which a product is to be used, and this usually means that the usability of a product in its operational environment is often diminished. For these reasons we propose in this work a detailed taxonomy which contains exhaustive descriptions of usability attributes, and a comprehensive taxonomy that describes context of use and its attributes by means of precise definitions.**

***Keywords*—usability, context of use, usability analysis, product lifecycle**

I. INTRODUCTION*

There are several definitions of usability and the characteristics that define it have been proposed. However, these definitions tend to be brief and informal, and no consensus has as yet been achieved by either researchers or standards bodies in regard to the concept of usability [2]. One of the most widely used definitions of the term usability is that given in ISO 9241-11 [3], as follows: "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". This definition indicates that usability depends on the context of use, which, according to ISO 9241-11, covers users, tasks, equipment, and the environment. This means that a product or system that may be usable in one context of use may not be usable in another context characterized by different user, task, equipment or environmental attributes.

Despite the fact that context of use is widely recognized to be important, experts have not yet arrived at a model that clearly describes all its features. This knowledge gap is one of the reasons why most usability studies are excessively simplified, either failing to take context into account or doing so in an ad hoc way. To quote Karat and Karat [4]: "We may know that context is important, but we still do not know exactly what to do about it."

The aim of this work is to describe in one hand 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, and, in the other hand, a detailed taxonomy that lists and comprehensively defines context-of-use attributes of relevance to usability. Nevertheless it is important to take into account that space limitations do not permit us to fully describe all the attributes in detail. A more detailed description of the usability taxonomy, and a comparison with other taxonomies, can be found in [5].

II. 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 [3] and ISO/IEC 9126-1 [6]. 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" [7].

To these definitions we can add those proposed by a number of usability experts, as follows: Nielsen [1], Nielsen and Loranger [8], Preece, Benyon, Davies, Keller, and Rogers [9], Preece et al., [10], Quesenbery [11][12][13], Abran, Khelifi and Suryn [2], Seffah, Donyaee, Kline, and Padda [14].

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. 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 usability studies for products.

On the other hand the usability literature refers to the idea of context of use extensively, but as yet no consensus exists in

* This research has been partly funded by the Xunta of Galicia Regional Government under Project 08SIN010CT

978-1-4244-2794-9/09/$25.00 ©2009 IEEE

the field as to the specific components of the context of use that affect the usability of a system. More recently, standardization bodies and researchers have proposed more detailed classifications of context-of-use attributes. The most important classifications are the ISO 9241-11 standard classification [3], the classification by Bevan and Macleod [15], the classification by Thomas and Bevan [16], the classification by Kirakowski and Cierlick [17] and the classification by Maguire [18].

Most of the classifications, however, have the main drawback of proposing attribute definitions that are overly brief or ambiguous. In fact, definitions are not even provided in some cases—for example, in Bevan and Macleod [15] and ISO 9241-11 [3]. Thus, an evaluator endeavoring to conduct a context-of-use study would find it difficult to assess and determine the true scope of some of the attributes. The hierarchies in existing classifications, furthermore, tend to have too few layers of attributes, making it impossible to describe context in sufficient detail. Another problem is that practically all the classifications establish sets of attributes that are relevant to IT products but which are incomplete or inappropriate for the study of other types of systems. What is needed is a taxonomy that comprehensively and exhaustively reflects all the attributes that determine context of use in a general sense. Such a taxonomy would enable to specify the context of use in a systematic way. A taxonomy would also simplify the context description process, thereby reducing the dependence on usability experts to perform the analysis.

III. USABILITY TAXONOMY

In this section we describe the attributes of the taxonomy that we propose. The taxonomy has the following first-level usability attributes: Knowability, Operability, Efficiency, Robustness, Safety and Subjective satisfaction (Table I).

TABLE I. USABILITY TAXONOMY MAIN ATTRIBUTES

Knowability	Operability	Safety
Clarity Elements Structure Functioning ***Consistency*** Elements Structure Functioning ***Memorability*** Elements Structure Functioning ***Helpfulness*** Suitability . Interactivity	***Completeness*** ***Precision*** ***Universality*** Accessibility Cultural universality ***Flexibility*** Controllability Adaptiveness	***User safety*** Physical safety Legal safeguard Confidentiality Safety of assets ***Third party safety*** Physical safety Legal safeguard Confidentiality Safety of assets ***Environment safety***
Efficiency	**Robustness**	**Subjective satisfaction**
In human effort ***In task execution time*** ***In tied up resources*** ***In economic costs***	***To internal error*** ***To improper use*** ***To third party abuse*** ***To environment problems***	***Interest*** ***Esthetics*** Visual Acoustic Tactile Olfatory Gustatory

A. 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:

- *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 sensorial clarity and semantic clarity. *Clarity of the structure*, divided in turn into formal clarity and conceptual clarity. And *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. This include two aspects: *Suitability of documentation content*, that is, content should be useful and adequate, bearing in mind that it includes definitions, descriptions, and examples; and *Interactivity of assistance*, that is, the extent to which the help provided by the system responds to the actions of the user.

B. 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:

- *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 disability they may have. This attribute is subdivided into others in accordance with specific kind of disabilities (visual, auditory, speech, motor, and cognitive). *Cultural universality*, defined as the extent to which the system can be used by users from different cultural backgrounds. We identify this attribute as having two features, namely, language and other cultural conventions.
- *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 and Workflow Controllability). On the other hand we have *Adaptiveness*, defined as the capacity of the system to adapt itself to user preferences and to different types of environments.

C. Efficiency

Efficiency is the capacity of the system to produce good results in return for a small investment in resources. The taxonomy for the branch of usability referring to efficiency reflects four subattributes:

- *Efficiency in human effort*, referring to the capacity of the system to obtain good results in return for little user physical or mental effort.
- *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 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.

D. Robustness

Robustness is defined as the capacity of the system to resist error and adverse situations. It is broken down into subattributes as follows: to internal error, to improper use, to third party abuse, and to environment problems.

E. 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:

- *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.

F. Subjective Satisfaction

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

- *Interest*, defined as the capacity of the system to capture and maintain the attention and intellectual curiosity of the user.
- *Esthetics*, defined as the capacity of the system to please its user in sensorial terms. This attribute can be subdivided into visual, acoustic, tactile, olfactory and gustatory esthetics.

Once the usability taxonomy is finished our next objective is the definition of a context-of-use taxonomy, taking into account that the context has an influence in the usability.

IV. CONTEXT-OF-USE TAXONOMY

The taxonomy has the following first-level attributes: User, Task and Environment (Table II).

TABLE II. CONTEXT-OF-USE TAXONOMY MAIN ATTRIBUTES

User	Task	Environment
Role	***Choice in system use***	***Physical***
Direct	***Complexity***	Sensorial cond.
Indirect	***Temporal characteristics***	Atmospheric cond
Support	Duration	Spatial cond.
Monitoring	Frequency	Safety
Experience	***Demands***	
With the system	Human resources	***Social***
With similar sys.	Material resources	Work relations
Education	***Workflow controllability***	Aims
Background	Performance freedom	Control
Knowledge of system domain	Reversibility	
Knowledge of system language	***Safety***	***Technical***
Knowledge of system culture	User	Physical equipment
Attitude to the system	Third party	Logic equipment
Physical characteristics	Environmental	Consumption material
Sensorial	System	
Speech	***Criticality***	
Motor	Precision	
Cognitivie characteristics	Robustness	
	Time	

A. User

A user is a person who interacts directly or indirectly with the system. The user attributes that are relevant to usability are listed as follows:

- *Role* is about how the user functions in the interaction with the system, whether in a direct role (operating with the system), in an indirect role (as a user affected by the interaction of another user with the system), in a support role (carrying out maintenance or installation tasks, etc.) or in a monitoring role (supervising the work of system users).
- *Experience* refers to the practical skills and knowledge of the user in relation to the system, with a distinction drawn between experience with the system and experience with similar systems.
- *Education* is the knowledge the user has acquired not through using the system but through formal education or from the social, cultural, or organizational environment. This attribute is further broken down as follows: *Educational background* refers to general knowledge, acquired through instruction or study.

Knowledge of system domain is the familiarity with the field to which the system pertains. *Knowledge of system language* refers to the ability of the user to understand the linguistic system of communication used by the system. *Knowledge of system culture* is the ability of the user to understand the cultural conventions used by the system.

- *Attitude to the system* refers to the feelings or emotions experienced by the user when operating the system.
- *Physical characteristics* describes the characteristics of the user's body that have an impact on usability, namely, *Sensorial characteristics*, *Speech characteristics*, and *Motor Characteristics*. Each characteristic is described in terms of disabilities (functional limitations of the user) and aptitudes (optimal performance of functions by the user). By drawing these distinctions, our taxonomy reflects specific situations in which the same physical characteristic simultaneously presents a disability and an aptitude.
- *Cognitive characteristics* refers to the mental characteristics of the user, with a distinction also drawn between disabilities and aptitudes.

B. Task

A task is a piece of work that the user carries out by interacting with the system. The task attributes that are relevant to usability are listed as follows:

- *Choice in system use* is the extent to which users may choose whether or not to use the system to complete the task.
- *Complexity* is defined as the degree to which completion of the task is difficult for the user.
- *Temporal characteristics* as an attribute includes both task duration and task frequency.
- *Demands* refers to the resources necessary to complete the task successfully. For this attribute we propose two subattributes to distinguish between *Demands on Human Resources* (subdivided in *Physical demands* and *Congnitive demands*) and *Demands on material resources* (that refers to the physical resources necessary for completing the task).
- *Workflow controllability* refers to the extent that the task can be controlled by the user during implementation. Within this attribute a distinction is drawn between: *Performance freedom* that refers to the extent to which there are alternative ways to complete the task and *Reversibility* that refers to the possibility for undoing actions and returning to a previous state.
- *Safety* refers to the degree to which the task as implemented does not cause damage or risk. This can affect users, third parties, the environment, or the system itself. Each type of risk is associated with a different subattribute: *Physical safety*, *Legal safety* (the extent to which task performance does not incur legal problems), *Confidentiality* (the degree to which implementation of the task does not incur any risk of unauthorized access to personal or organizational data) and *Safety of material assets* (the extent that implementation of a task does not damage the property of others).
- *Criticality* refers to the extent to which performance of the task is decisive. Depending on the aspect of the task in question, this attribute can be broken down into: *Precision criticality* refers to the level of accuracy required in the task, *Robustness criticality* refers to the importance of the task being resistant to error and adverse circumstances, and *Time criticality* refers to the speed with which the task is required to be completed.

C. Environment

The environment consists of the external factors that affect the use of the system. For the environment attribute we distinguish between the *Physical Environment* (the surroundings and space in which the user operates the system), the *Social Environment* (the people with whom the user interacts and who affect the user's interaction with the system), and the *Technical Environment* (the technical equipment and infrastructures that support the functioning of the system).

The attributes that refer to the *Physical Environment* are described as follows:

- *Sensorial conditions* refers to the characteristics of the physical environment that affect the sensorial perceptions of the user. For this attribute a distinction is drawn between: *Sensorial quality* (the conditions are appropriate for using the system), and *Sensorial stability* (the conditions do not change frequently). These two subattributes are broken down according to the five senses.
- *Atmospheric conditions* refers to the characteristics of the air. A distinction is drawn between: *Atmospheric quality* (the properties of the air are acceptable for working with the system), and *Atmospheric stability* (these properties does not change frequently).
- *Spatial conditions* refers to physical location within the environment in which the system is used. A distinction is drawn between: *Space availability* (having the space necessary to operate the system). *Location suitability* (further broken down into workplace suitability and system suitability). And *Postural suitability* (the work space permits the user's body to work in an adequate position).
- *Safety* refers to the degree to which the physical environment does not cause damage or risk. Depending on the circumstances, a distinction is drawn between the following subattributes: *User safety* refers to physical safety, legal safety, confidentiality, and property safety. *System safety* refers to the fact that the environment does not cause damage to the system.

The *Social environment* is described by means of the following attributes:

- *Work relations* refers to interactions between members of the organization within which the system is used. This attribute has the following subattributes: *Team work* (interactions with other persons while working), *Human support* (if the user can count on help from other persons) and *Interruptions* (if the work of a user can be interrupted by other persons).
- Aims refers to the intentions of the organization in regard to user interactions with the system.
- Control is the degree to which the organization checks and controls the work of the user so as to ensure a suitable level of productivity and quality. This can be broken down further as follows: *Monitoring* refers to supervision of the user's work by the organization, *Feedback* refers to information provided to the user in relation to the work with the system and *User autonomy* refers to the freedom granted to the user in terms of how to implement tasks.

Finally, the *Technical environment* is described by means of the following attributes:

- *Suitability of physical equipment to usability* refers to the extent to which the physical equipment supporting the functioning of the system enables the system to be usable. We divide this attribute into the following subattributes (extracted from the usability taxonomy): Suitability of physical equipment to knowability, operability, efficiency, robustness, safety, and subjective satisfaction.
- *Suitability of logic equipment to usability*, referring to the extent to which the logic (non-physical) equipment supporting the functioning of the system enables this to be usable. It is also further divided using the usability analysis attributes.
- *Suitability of consumption material to usability*, referring to the extent to which the materials used during the functioning of the system enable this to be usable. It is also further divided using the usability analysis attributes.

Once finalized the development of the two taxonomies proposed we compare these two taxonomies with those of the background studies

V. COMPARISON WITH THE BACKGROUND TAXONOMIES

A. Usability Taxonomy

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*, *memorability*, and *understandability*.

Most of the existing classifications do not include an attribute that is defined in equivalent terms as our *operability* concept. ISO/IEC 9126-1 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 [3], which was subsequently adopted by Quesenbery [11], Abran et al. [2] and Seffah et al. [14].

The study by Seffah et al. 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.

None of the classifications in the literature include *robustness* as a main usability attribute. Someone include attributes such as *errors* or *error tolerance*. Our *robustness* attribute differs from these attributes, 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.

Safety does not appear in most of the classifications described in the literature. Although Abran et al. and Seffah et al. do refer to the concepts of security and safety, respectively, these are defined briefly. Furthermore, only physical 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.

Finally, our *subjective satisfaction* attribute differs from the same concept in the other taxonomies in two ways. Firstly, we exclude physical comfort, as this is covered by our *physical safety* attribute, and so its inclusion would create redundancy in the taxonomy. Secondly, we view *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.

B. Context-of-use Taxonomy

Although many of our first-level *user* attributes are included in the classifications in the literature, they are not structured in the same way nor are they described in terms of the same set of subattributes. For example, the classifications in the literature include a broad-based attribute referring to user *experience, knowledge, and skills*. We, however, draw a distinction between experience in using the system (*experience*) and experience and knowledge that will help the user yet do not arise directly from using the system (*education*).

In the case of physical attributes our taxonomy takes a more refined view of the user, first of all by distinguishing between two specific issues that have different usability outcomes, namely, the capacity to perceive the system (*sensorial characteristics*) and the capacity to communicate commands to the system by means of physical actions (*speech characteristics*

and *motor characteristics*). We applied a similar approach to defining subattributes for cognitive characteristics.

Many of the existing classifications do not reflect the attributes that we propose for *task*. *Workflow controllability* does not correspond directly with any attributes in the existing classifications, only one of its components, namely, *performance freedom*, is similar to the *task flexibility* attribute included in all the classifications. Our second *workflow controllability* component, that is, *reversibility*, does not feature in any of the other classifications. Only some of the classifications include attributes or subattributes that correspond, even partially, to the criticality subattributes.

Finally, our taxonomy proposes generic attributes related to the *suitability of physical equipment to usability* and the *suitability of logic equipment to usability*, which makes the taxonomy applicable to any kind of system and not just computer systems. We also include a new component, namely *suitability of consumption materials to usability*, as consumption materials could also feasibly affect the performance of a system.

VI. CONCLUSIONS

The literature features many publications that have endeavored to describe the concept and attributes of usability. However, we repeatedly found that the proposed definitions are too brief and ambiguous. 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 usability taxonomy should consequently reflect this fact. For this reason we propose a taxonomy that covers the concept of usability applied to any product.

On the other hand 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, 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.

These taxonomies forms part of a more extensive project that has as its aim the construction of a methodology that explicitly describes usability aspects over lifecycle of a product. The taxonomies can then be adapted to different systems by assigning weights in a way that reflects the relative importance of each attribute for each particular case.

Finally, a future line of research will be to model the relationship existing between both taxonomies by means of a system of rules that will determine how each context-of-use attribute affects each usability attribute. For example, if the users have no experience with the system they need more feedback to assure that they are progressing to their objectives, this means to put more attention in the usability attributes of *Clarity*, *Consistency* and *Memorability*. On the other hand, experienced users do not need much feedback; they need more control over the task they are performing, so here we have to put more effort in attributes such as *Controllability*.

Taking into account the task attribute *Complexity* we can draw another example. In simpler tasks that are repetitive and momentary (e.g., loading/unloading a compact disc to/from the loading mechanism) the main concern is *Efficiency* and/or *Robustness*. On the contrary, for infrequent and complex activities (e.g., programming a recording function of a videocassette recorder) the attributes that we have to take into account are those related with *Knowability*: *Clarity*, *Consistency*, *Memorability*, etc.

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