

Defining and Structuring the Dimensions of User Experience with Interactive Products

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Abstract. The goal of this research is to define the dimensions of User Experience (UX) with interactive products and systems in order to lay the ground for the construction of a subjective assessment tool for UX. After defining UX, we describe several characteristics of UX and present key elements of some UX models in order to understand the ins and outs and the process of UX. Then we present the results of two empirical studies wherein 77 persons were asked to tell UX stories with products. From their stories we extracted 12 UX dimensions which can be grouped around two poles : Product and User. Thereafter we present the underpinning model and an outline of a new UX subjective assessment tool based on the assessment model of NASA-TLX, a well-known tool for assessing mental workload. As conclusion, we indicate the next steps of the construction and validation of the new tool.

Keywords: User Experience (UX), UX dimensions, Interactive product, Subjective assessment, Assessment tool, NASA-TLX.

1 Introduction

Since the beginning of the year 2000, the concept of User Experience (UX) has gradually dethroned (without rejecting) the concept of usability to account for the quality of our interactions with different products, systems, or services [N.B. : for brevity, we only use the word product in the rest of paper]. Even a large professional association, called UPA, changed its name for UXPA (User Experience Professional Association) in 2012 to mark the turning.

The concept of UX was rapidly adopted by the communities of Industrial Design, Interaction Design, Human-Computer Interaction, and Ergonomics/Human Factors which are all concerned by the quality of products and the challenge of creating positive UX with them. Not surprisingly, UX was accepted from the start for products that are intended for a large public, such as Web sites, smart phones, video games, and popular software applications where the issues of pleasure, emotions, and aesthetics are important, and where there is a fierce competition on the market. But UX is more and more adopted by designers of serious products which are clearly associated with work, performance, efficiency, and security, such as aircrafts [1], flight simulators, production planning software, schedule optimizer software, etc. Because positive UX

has a great customer appeal and that counts on the market. The reasons of this rapid and widespread adoption are numerous: UX is considered as a richer, more global, more inclusive, more interesting, and more profitable concept than usability. It is directly related to the goal that is being pursued : create a rich and positive experience that will help to sell the product. It is clearly another mean to satisfy the customers' claims and expectations, to project a better corporate image, and to be more competitive on the market.

Despite its short history, UX has already been the topic of an abundant scientific literature [7] [18] so that several definitions, models, methods and tools for approaching UX are available. Yet the evaluation of such a phenomenon remains a challenge because it is subjective, multidimensional, dynamic, and context-dependant. As for usability three major categories of measures are available: physiological (in rapid progress), behavioral, and subjective. In this paper we will focus on subjective evaluation because it is rich and lends itself well to the capture of complex subjective phenomena. Our goal is to identify and define UX dimensions and sub-dimensions, and use them in new subjective assessment tool for UX. We will present an outline of the tool we are developing.

This paper is structured as follows : after this introduction, first we present some definitions and different characteristics of UX; second we describe the key elements of some UX models in order to understand the ins and outs and the process of UX; third, we define several UX dimensions and show data on their frequency and importance; fourth, we present the assessment model of the NASA-TLX (Task-Load Index), a well-known tool for evaluating mental workload which can serve as model for UX evaluation; and finally we present an outline of a new UX evaluation tool. In the conclusion, we suggest some activities for constructing and validating the tool.

2 UX Definitions

We selected three definitions of UX from a large set of definitions in order to show different facets of UX.

First, the ISO 9241 definition [5] states that UX is “*A person’s perceptions and responses that result from the use and/or anticipated use of a product, system or service.*” So UX is a *subjective* phenomenon. What is open to criticism here is that an UX could result only from the anticipated use of a product. While fully recognizing the role of anticipation in the creation of an UX, it is difficult to imagine an UX without a real use of the product.

Nielsen-Norman’s definition [11] states that « *User experience" encompasses all aspects of the end-user's interaction with the company, its services, and its products"*. So UX is not only concerned with the product itself but also with the company and its services. « All aspects » include the different activities with or about the product, such as searching for information, buying, downloading, installing, learning how to use, using, repairing, doing the maintenance, dealing with the customer service, installing the updates, etc. So UX is *global* and *cumulative*.

Finally, Robert & Lesage’s definition [15] states that « *UX is a multidimensional construct that defines the overall effect over time on the user of interacting with a*

system or service in a specific context ». Several characteristics of UX stand out : apart from being a construct, it is multidimensional, it is an overall and cumulative effect that builds up with time, and it is situated in a context.

3 UX Characteristics

To have an UX you must have a User who interacts with a Product for doing an Activity in a some Context. These basic elements are present in several UX models ([2] [4] [7] [15] [17]). If there is no product in use (e.g., looking at a sunrise), there is no UX. Different types of products may be involved: interactive (e.g., smart phone, video game), adjustable (e.g., mountain bike, car seat), a combination of both, or not adjustable (e.g., seat in the subway). Finally the user of a product may be active (e.g., using the Wii console), creative (e.g., designing), or passive (e.g., sitting in a train). In this paper, we focus on interactive products and active users.

In light of several UX definitions and UX stories ([15]), we can identify several characteristics of UX:

- *subjective*: “UX happens inside the person” ([17]); since UX is based on user’s perception and responses, it is a personal and subjective. Several characteristics of the person are involved: knowledge, abilities, goal, motivation, philosophy, past experience, values, attitudes, expectations, preferences, sensitivity to aesthetics, anxiety, fatigue, culture [8], etc.
- *multidimensional*: When persons report their usage of different products and tell the reasons why they appreciate or criticize them, several factors emerge: it is easy, they get the right information, they feel competent, they exchange with people, they have fun, they feel cool, etc. These terms correspond to different UX dimensions.
- *holistic*: UX covers all aspects of our interactions with the company, its services and its products. This includes all the steps we go through with the product when we search information, buy, transport, install, learn how to use, use, talk to the customer service, etc. UX is the global result of our perceptions and responses at each step.
- *situated in a context*: Elements of context are very diversified: time pressure, period of the day, location, presence and pressure of people, weather conditions, competition, issues at stake, etc. They definitely impact on UX and contribute to determine its positive or negative valence, its strength, its memorable character.
- *dynamic*: UX evolves in time as we develop abilities with the product, go through positive and negative experiences, operate in easy/difficult personal conditions (e.g., stress, fatigue), and test different contexts. So UX becomes richer, more complete, more precise, better defined. Each new usage is likely to alter our perceptions.
- *cumulative*: This quality is the corollary of the previous one. UX depends both on the our expectations about the product based on what we saw (publicity), heard, read or imagined about it, on the real experience of using it, and on the global evaluation we make afterwards, when we combine the past and the present.

- *several granularity levels*: UX can be about the interaction with a single product for doing an activity in a short period of time (e.g., register at a terminal) as well as the interaction with several products for doing several activities over a long period of time (e.g., planning and doing a flight trip).

4 4UX Models

Several UX models ([4] [9] [10] [15]) present important elements that come into play to create UX. Fortunately they have much in common.

First, as seen above, to have a UX, there must be an *User interacting* with a *Product* for doing an *Activity* in a *Context*. These elements are indispensable.

Second, when we interact with a product, we come into contact with its *instrumental* and/or *non-instrumental* qualities. The former refer to what the product enables us to do (*do-goals*) and to the external services it provides: for instance, make a phone call, take a photo, compose a letter, send an email, etc. The latter refers to what the product enables us to be (*be-goals*) and to the inner satisfaction it brings to us because of wellbeing, self-achievement, sense of aesthetics, etc. Fortunately these two sets of qualities are not exclusive of each other. Instrumental qualities are more naturally associated with *extrinsic goals*, i.e. that are external to us, like making money, having good marks, winning a contest, etc. And non-instrumental qualities are naturally associated with *intrinsic goals*, i.e., that are internal to us, like having fun, feeling good, achieving oneself, etc. When we use the product (and after using it), we have various perceptions, feelings, and emotions which create our UX with the product and make it positive/negative, rich/poor, striking/not striking, memorable/not memorable.

Third, the outcomes of UX may differ in forms. If the UX is positive, we will be inclined to reuse the product, buy it, talk about it positively, recommend it to others, do something to support it, etc. Furthermore, our attitudes and expectations will be positive for the next usage of the product.

5 UX Dimensions

What we call an UX dimension is a major or significant factor that can explain the creation of an UX. Based on the results of empirical studies presented below, we distinguish two types of dimensions: those that are the Product input to the UX creation and those that are the User input to the UX creation. Let us illustrate the difference with two examples. When a mother says "I like my cell phone because it allows me to always keep in touch with my daughter", it is the Usefulness dimension of the product that stands out and contributes to create the UX. When an user says "I like playing with this video game because I have fun", it is the Psychological dimension (sub-dimensions: pleasure) that stands out. It is essential to identify and define UX dimensions rigorously because they form the basis of the new tool we are developing for assessing UX. Several studies allowed us to identify and define UX dimensions, either directly or through the UX models they present.

Robert & Lesage [15, 16] interviewed and/or observed six persons interacting each with a different system (smart phone, Wii console, mountain bike, interactive

monitor in airplane, ...) for doing different activities (work, communicate, play video games, go biking, ...) in different contexts (at home, in transport, in a city, in the wild). With this material they could construct six UX stories of 10-15 lines each describing what the user is doing and what his/her UX consists of. Here is an excerpt of the UX story of the mountain biker: "... He specifically enjoys those short challenging segments that require all his attention, physical abilities and wits, for minutes on end; and lead him to total, exhilarating exhaustion after two hours or so. The usability of the bike, although essential, is obviously just a part of the interaction with the device. UX is more a question of extreme fun, strong emotions, hard challenge, pride, intense physical effort, acquisition of abilities, and self-accomplishment". They extracted six dimensions of UX: Functional, Physical, Perceptual, Cognitive, Psychological, and Social. They will be defined in the next section.

The research work of Larouche [6] and Robert & Larouche [14] aimed at identifying, defining, and measuring the frequency and importance of UX dimensions in order to lay the ground for the construction of a subjective evaluation tool. Based on a literature review Larouche identified nine UX dimensions : the six ones mentioned above plus *Contextual*, *Informational*, *Cultural* [8]. She then collected empirical data to test the frequency and importance of these dimensions. To do so, she asked 52 persons in a questionnaire to describe a positive and a negative UX with two different products of their choice they had interacted with. Three participants reported only one UX story so that there was a total of 101 UX stories. The products involved in the UX stories were very diversified : 72 interactive products (Web sites, smart phones, video games, ...), 12 adjustable products (ergonomic chair, car seat for children, bike, ...), 10 interactive and adjustable products (video camera, Global Positioning System, ...), and 7 not adjustable products (train, bus, subway, ...). Three judges with good knowledge in Ergonomics/ Human Factors for Human-Computer Interaction examined the UX stories, individually at first and then collectively, in order to: a) check if the nine dimensions were present in the UX stories and measure their frequency; b) evaluate their importance on a Likert scale (0 = absent, 1 = slightly, 2 = moderately; 3 = very) ; the average of the three scores of judges was calculated for each dimension; c) search for new UX dimensions; and d) see if the same dimensions appeared in positive and negative UX stories. Results indicate the presence of nine UX dimensions : eight of the above ones and temporal (see Larouche in Table 1); they will be defined in the next section. *Temporal* includes the time saved or lost. Some dimensions (*Functional*, *Psychological*, *Cognitive*, *Contextual*, *Informational*) are much more frequent and important than others. The same dimensions appear in positive and in negative UX: so no dimensions are exclusively related to negative or positive UX. We are critical about the *Contextual* dimension because we rather see it as one of the four basic components of any UX. For this reason, we consider it should not be considered as a dimension.

Provost [12] and Provost & Robert [13] pursued the same objectives as Larouche : identify, define and measure the frequency and importance of UX dimensions; Provost used a different method and appealed to a different group of persons to collect empirical data on UX. In light of a literature review, she identified 10 UX dimensions. To test them, she conducted semi-structured interviews by phone with 25 persons, asking them to tell a positive and a negative UX stories with a product of

Table 1. Dimensions and sub-dimensions extracted from UX stories

Robert & Lesage [15]	Larouche [6] *	Provost [12] **		
Dimensions	Dimensions	Pole Prod uct	Dimensions	Sub-dimensions
Functional	Functional 96%; i: 2,32			Functionality 88%; s : 4,25
			Usability 88%	simplicity, rapidity ease of use, efficiency
	Informational 74%; i: 1,48		Informational 70%; s: 3,68	presence, relevance, quality
Physical	Physical 50%; i: 0,81		Physical characteristics 42%; s: 2,88	weight, dimensions size, adjust- ments
			External characteristics 56%	customer service brand, eco-system
			Other qualities 48%	accessibility, secur-ity, reliability avail-ability, robustness
	Contextual 79%; i: 1,46			
	Temporal 49%; i : 0,77			
Perceptual	Perceptual 54%; i: 0,85	Pole User	Perceptual 66%; s: 3,18	aesthetics, presence & quality of multi- media, sense stimulation
Cognitive	Cognitive 80%; i: 1,68		Cognitive 74%; s : 3,34	understanding, concentration, learning reflection, attention memory, stimulation
Psychologi- cal	Psycholo- gical 90%; i: 1,92		Psycholo- gical 90%; s: 3,68	pleasure /frustration, motivation, expectations, values, evocation, meaning; positive emotions: negative emotions
Social	Social 49%; i: 0,73		Social 54%; s: 1,80	presence of others, quality of inte- ractions in/dependence from/ to others, ob- taining info about others
			Physical 40%	physical activity, transport, com- fort movement, displacement
			Other person- al impacts 62%	productivity profitability return on investment

* The % is the ratio: Nb of UX stories wherein the dimension is present / 101 UX stories;
i (importance) is the average of the three judges' scores (0=absent, 1=slightly, 2=moderately, 3=very).

** The % is the ratio : Nb of UX stories wherein the dimension is present / 52 UX stories.

s (strength) indicates the evaluation of the strenght of each dimension made by the user on a 5- point scale (0: nul, 1: very low; 2: low; 3: moderate; 4: high; 5 : very high). The user answers to this question : To what extent do you think the dimension has contributed to your UX? Some results sre not available.

their choice, explain the reasons why it was positive and negative, and complete an evaluation grid about the UX dimensions present in the story (the grid was given to the participant after s/he had told his/her two stories). The interviews were recorded to allow three judges to listen to them and extract UX dimensions. The products mentioned in the UX were very diversified : web sites, software and personal computers, small electronic devices (camera, video camera, ...), transportation (cars, motorcycles, bikes, ...), etc. Results indicate that 12 dimensions can account for the positive and negative UX stories with a large variety of interactive systems (see Provost in Table 1). Interestingly, these dimensions can be grouped around two poles : Product and User. The pole *Product* encompasses six dimensions (the % indicates the frequency of the dimension in the 52 UX stories) : Functionality (88%), Usability (88%), Informational (70%), Physical characteristics (42%), External characteristics (56%), other Qualities of the product (48%). The pole *User* also encompasses six dimensions : Perceptual (66%), Cognitive (74%), Psychological (90%), Social (54%), Physical (40%), et other Personal impacts (62%). The number of dimensions present in each UX varies from one UX to another. Results confirm Larouche's findings, showing that the same dimensions can be found in positive and negative UX. Finally the study allowed to find several sub-dimensions; these will be useful to orient the construction of the evaluation tool.

6 Definitions of UX Dimensions

In light of the above results, in the following paragraphs we define eight basic UX dimensions and their sub-dimensions (see Table 1).

Functional : This dimension corresponds to qualities that make a product reliable, compatible with others, accessible, available, and well adapted to its physical and human environment.

- Reliable: quality of a product that works without failure, that does not break easily when it hits something or when dropped.
- Compatible: quality of a product that is well integrated with its environment, its ecosystem, and that can therefore be used in conjunction with other products.
- Accessible: quality of a product that meets the needs of specific users: for example the disabled, elderly, people with reading deficiencies, in disabling conditions.
- Available: quality of a product that can be used at any time or when users need it, and in any place or where users need it.

Usefulness/Usability

- Usefulness: quality of a product that enables the user to satisfy his/her needs and achieve his/her objectives.
- Usability: quality of a product that is easy to learn and use. The ISO definition is more elaborate : it also includes efficiency and user's satisfaction.
- Performance characteristics: these include for example response speed, memory capacity, computing power, and image quality.

Informational: This dimension corresponds to the utility, right balance, and appropriateness of the information provided by the product depending on the context. It includes two sub-dimensions:

- Quality of information : the product provides information that is reliable, exact, precise, and accessible both in its form and its content.
- Quantity of information : the product provides exhaustive information with a degree of finesse and precision sufficient for the user in a given context.

Physical characteristics (under the pole Product):.

- Physical characteristics: include for example the weight, the shape, the dimensions (e.g., keyboard, display), the battery life, ...

Sensory/Perceptual: This dimension corresponds to the impression left by the product on the sense organs, to the impact on the user's perception. It includes three sub-dimensions:

- Visual : all that is related to the appearance and aesthetics of the product and that is perceived by the user.
- Hearing : all that is related to the sound emitted by the product during its use and that is perceived by the user.
- Tactile : all that is related to tactile sensations with the product and that is perceived by the user.

Cognitive: This dimension refers to human information processing done while using the product; it includes different types of activities such as analyzing, evaluating, reflecting, learning, creating, etc.

- Cognitive effort /development: the use of the product solicits or stimulates the user's intellect to acquire new knowledge or skills, analyse, reflect, solve problems, respond quickly, etc.

Psychological : This dimension refers to the emotions felt by the user when s/he interacts with the product, and to the values and opinions that this interaction triggers. It includes several sub-dimensions:

- Stress: the use of the product generates stress to the user because of an imbalance between what is required to interact with the product and the resources or time that are available.
- Pride: the use or possession of the product brings a high sense of dignity, honor or satisfaction to the user.
- Pleasure: the use or possession of the product brings a state of contentment to the user because s/he satisfies a need or a desire.
- Frustration: the product brings dissatisfaction to the user, for example because it is blocked or it does not meet the user's expectations and desires appropriately.
- Evocation: the product evokes memories for the user.

- Attachment: this corresponds to the intensity of emotional attachment to the product.
- Moral value: the use or possession of the product reflects life principles that guide moral judgment of users and apply to their consciousness as an ideal.

Social : This dimension is about linking the user with other people through the product. It includes two sub-dimensions:

- -Contact: the product allows the user to contact and interact with other people.
- -Culture: the product allows to connect the user to his/her culture which is defined by the set of distinctive spiritual, material, intellectual and emotional features that characterize a society or social group.

Physical (under the pole User)

- Physical effort/stimulation: the use of the product requires exertion or physical activity from the user.

Synthesis

The underlying rationale of trying to evaluate UX only with these dimensions and sub-dimensions is the following. Although it is obvious that the user's predispositions, the context of use, and the types of user's activities are likely to have a determinant impact on UX, we do not take them explicitly into account when evaluating UX because we do not control them. We rather focus on the user's perception of the product characteristics (dimensions around the pole *Product*) because we control these characteristics as designers, and we focus on the user's appreciation, feelings and emotions (under the pole *User*) because they are at the core of UX. The perception of the dimensions under the pole *Product* is the perception of the input stimuli to UX whereas the perception of the dimensions under the pole *User* is the perception of the user's responses to these inputs. We suggest to add *Aesthetics* as a dimension under the pole *Product*, because it is clearly a product characteristic, it is not fully covered by the dimension Physical characteristics, it has become an important issue of several products, and it is likely to impact the user's perception. The Physical dimension appears on both sides but with different meanings. Under the Pole *Product*, it means that the user perceives the objective product characteristics (e.g., life battery, weight) whereas under the pole *User* it means that the user gives an appreciation of the physical effort or stimulation.

7 NASA-TLX as an Assessment Model for UX

There are strong similarities between the concepts of UX and mental workload: both belong to the domain of Cognitive Ergonomics and are subjective, multidimensional (with a limited number of dimensions), and holistic. The results of their evaluation depend, among other things, on both the user's predispositions, the type of activity, and the context. Of course there also exists a major difference between the two: mental workload cannot be negative whereas UX can be so. Yet it is worth verifying if

lessons can be learned from the way mental workload is evaluated with the NASA-TLX tool, a widely accepted tool in the community [3].

NASA-TLX is a questionnaire completed by the person who accomplishes a task. It includes six dimensions of workload : Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration Level. The first three dimensions deal with the evaluation of work demand such as it is perceived by the user, whereas the last three ones deal with the evaluation of the person's reactions. The tool allows the person to indicate which dimension is present or not for a task and weigh it, and it provides a global score of workload. Here is the procedure of use :

- The user performs a task; during that task or right after it, s/he completes the NASA-TLX;
- The person evaluates each of the six dimensions on a 20-point Likert scale;
- The person circles the name of a dimension on each of 15 cards showing different pairs of dimensions; then we count the number of times each dimension was chosen and this gives the weight of each dimension;
- The results of evaluations in the previous two steps are multiplied together : this give the adjusted score for each dimension;
- the total of the adjusted scores is divided by 15 : this gives the global score of mental workload.

8 Building an UX Assessment Tool on the Model of NASA-TLX

In our opinion a similar approach to that of NASA-TLX can be followed for UX assessment. The procedure will be as follows :

- ask the user to use an interactive product for doing an activity in a certain context, or ask him/her to think about a past interaction with a product; during the interaction or after it, use the UX evaluation tool;
- ask the user to indicate on a Likert scale if each dimension (see Table 1) is present or not in his/her UX with the product;
- ask the user to weigh each dimension; here we cannot use the same stratagem as NASA-TLX with its 15 cards showing two dimensions among which we must choose. The reason is that with 12 dimensions or so, the number of pairs of dimensions explode so that it would be much too long for the user to circle one dimension per pair;
- combine the two evaluations to calculate the adjusted score of each dimension;
- add the adjusted scores: this gives the total of adjusted scores;
- divide this total by the number of dimensions and this gives a global score of UX.
- The tool offers these facilities:
 - - it provides the user with definitions of UX dimensions and sub-dimensions to facilitate the use of the tool;
 - - it allows the user to indicate if the UX is positive, neutral or negative;
 - - it allows the user to revise an evaluation already entered;

- - it calculates automatically the adjusted scores of each dimension and the global score;
- - it gives an overview of the dimensions and sub-dimensions that come into play in an UX.

9 Conclusion

In this paper we defined several UX dimensions and sub-dimensions for the assessment of UX with interactive products. These dimensions form two groups which can be placed under two poles : Product and User. We used the NASA-TLX, a well-established tool for the subjective assessment of mental workload, as a model of assessment for UX, because of strong similarities between the two concepts of UX and mental workload. A very promising idea taken from NASA-TLX for UX assessment is to allow the user to give a double evaluation of each UX dimension : the first is about the presence of a dimension in the UX, and the second is about the weigh (or importance) of this dimension on the UX. We described the rationale and procedure of UX assessment following the model of the NASA-TLX. We gave an outline of the UX assessmen tool. The next step of this research will consist in prototyping and testing the tool, validating it with UX experts and end-users, and evaluating how it really helps designers and developers to improve their products.

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