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Usability in Product Design - The importance and need for systematic assessment models in product development – Usa-Design Model (U-D) ©

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Abstract. In product design, human factors are considered as an element of differentiation given that today´s consumer demands are increasing. Safety, wellbeing, satisfaction, health, effectiveness, efficiency, and other aspects must be effectively incorporated into the product development process. This work proposes a usability assessment model that can be incorporated as an assessment tool. The methodological approach is settled in two stages. First a literature review focus specifically on usability and developing user-centred products. After this, a model of usability named Usa-Design (U-D©) is presented. Consisted of four phases: understanding the use context, pre-preliminary usability assessment (efficiency/effectiveness/satisfaction); assessment of usability principles and results, U-D© features are modular and flexible, allowing principles used in Phase 3 to be changed according to the needs and scenario of each situation. With qualitative-quantitative measurement scales of easy understanding and application, the model results are viable and applicable throughout all the product development process.

Keywords: design, usability, assessment model, product development, human factors.

1. Introduction

The concern with aspects related to the use of products has been increasingly highlighted, due to several factors, some of which can be mentioned: legal aspects, accidents, consumer's demands, inspection agencies, market losses, among others. These factors have been provoking several reactions, such as, a wider concern with aspects of use of products offered on the market. Thus, it is possible to say that, besides the aesthetical, formal, functional, qualitative, technological and economical aspects, amongst other aspects, their real use has been present when decisions are made for their production or purchase.

In this sense, the design, as one of the main actors on the product development, has been incorporating human factors (ergonomics), specifically in projects where usability is concerned. However, even though human factors are being taken into account on the process of product development (PDP), it is believed that the incorporation of assessment tools that can be

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used before/during/after the development of products is a necessary and imperious strategy.

Product development for human use is a complex process where the knowledge from different fields of engineering, biomechanics and the human factors along with the experience on the manufacturing, marketing, etc., are combined in order to achieve a product that meets the consumers and company expectations [1:11]. This point of view meets the principles of ergonomics and their relation with the products, as highlighted by [15:14].

"The history preceding the official emergence of ergonomics and design is so far little explored. Man starts building his stone tools around 2,5 thousand years ago. However it is possible to understand that these first tools were rather simple, and their shape was determined by the necessity of the moment and especially by the material available, which is to say they were manufactured without a previous project."

The need for a planned project is clear, where the human factor is taken into consideration, as much regarding physical aspects as the mental aspects. A few problems then unfold, among which is the limited consideration for human factors during the process of product development, on the aspects of production/assembly and especially on their further use (central focus of this research – user focused project) and on following stages of the process (after-use).

This information supports the need for a model of assessment of products focused on usability, bringing the following as a result: the products present problems of use when this factor is not evaluated with depth during the process of product development.

The relevant importance of developing strategies to verify the ergonomic conformities of products, as much in their initial project as in those that already exist in the market (focus on redesign), can especially benefit the consumer and consequently the company itself since it can improve its market performance.

In this regard, the aspects of safety, health, functionality, resistance, anthropometric adaptation and certification, can be mentioned [7], considering the characteristics of ergonomic quality and usability, which must be present from the raw material up to the point of meeting the standards that rule the legislation for the development of products [22].

In this way, even if the maximization of a product's functionality is desired and indicated by literature [13] there is still shortage of strategies that allow mediation between theory and practice in a way that integrates the concepts of production, design, usability and ergonomics.

Design and product design in this specific case, still needs wider studies viewing the formulation and validation of propositions for assessment and analysis. The actual studies highlight those needs and give the first steps towards and attempt to standardise and guide the actions on the most varied market insertions considering products in general.

In the case of the present investigation, such indications become even more imperious, since for the development of a product, several areas interact to achieve a final result. In that case, ergonomics makes possible the development of an adequate product that does not harm the user/consumer, taking into account as much the organization for the development of activities with this product, as the physical and psychological integrity of those users/consumers. Usability, on its turn, allows the users to achieve their goals and satisfy theirs needs in a particular use context. For such, the products must be suitable to serve individuals with distinct characteristics.

Thus, the alignment of the contributions of Design, Ergonomics and Usability comes to favour the assessment of new products and of existing ones, creating alternatives for it's re-projecting in the case of existing products and for its project in the case of new products.

The proposition of a usability assessment model that can be used on the process of product development is the general purpose of this research. The specific purposes are:

- To understand the traditional process of product development, identifying the stages where usability is considered;
- To identify and organise the basic principles of usability, based [21];
- To propose an assessment model, considering the principles of usability;
- To check the applicability and relevance of an usability model on the process of product development.

The research presents a methodological route, which can be divided into two stages. The first one a theoretical stage, where technical-scientific information are raised and analysed, information that is related to the following central themes: process for the development of products, ergonomics, usability, along with a further deepening of aspects in product use and of techniques/tools of assessment, complemented by information regarding the usability of products and having as a basic reference the rule of ISO 9241-11.

The information raised, analysed and discussed on this first stage of the research, permit the develop-

ment of the second stage of the research. The latter has a practical-experimental character, where, based on the rule mentioned above and the principles proposed by [21] a model for analysis is introduced, based in qualitative-quantitative measurements that can serve as support for the process of product development, in different moments.

2. Product Development and its conditioning factors

The development of products to be used by the human being is a complex process where the knowledge from different fields of engineering, biomechanics, and human factors are combined along with the experience on the manufacturing, marketing, etc, to achieve a product that satisfies the consumer needs and those of the company [1:11].

In this process, the need for multi-disciplinary team acting in an integrated way is clear. The human factors, present on products of direct use by man, represent one of the elements of differentiation that design can incorporate into the thought of the enterprises, either on the corrective design or on the conceptive design. Such idea is corroborated by [7:358] who states that the product development process:

"... is a set of activities leading a company to the launching of new products or to the improvement of existing ones. Naturally, it is a complex process, involving the work of several professionals, with the main decisions taken by the company's management."

In these terms the Product Development Process (PDP) can be defined as:

"A set of activities through which it is sought, from market necessities and from technological possibilities and restrictions, and considering the company's competitive strategies and product strategies, to get to the project specifications of a product, so that manufacture is capable of producing it." [6:03].

Such definition clearly shows that it is the case of a planned and controlled project, where the possibility of the largest number of variables is an important aspect in order to achieve the goal. However, the contribution of this research, as previously mentioned, converges into the human factor as the structural element for the development of products focused on use, which, in the opinion of [20:24], leads to the understanding that aspects of planning and projecting, throughout the phases undergone by a product, since "planning, market research, product project, project for the product's manufacturing, distribution, use, maintenance and discarding, are all fundamental".

The same author complements saying that with the opening and globalization of markets, products have had to become more competitive when facing international competition, consequently, they have had to (explicitly) incorporate differentiation, quality and a high aggregated value.

The development of new products is a complex activity involving several interests and abilities, amongst which [16:02] mentions:

- Consumers wish for novelties, better products, reazonable terms;
- Sellers wish for competitive differentiations and advantages;
- Production engineers wish for simplicity on the manufacture and ease on the assembly;
- Designers would like to experiment new materials, processes and formal solutions; and
- Entrepreneurs want smaller investments and fast return of capital.

[9] states that the development of a product is a process, in a statement that is corroborated by [4], who regards design as: creativity, concept, tendencies, aesthetics (shapes and colours), social and cultural aspects, functionality, ergonomics, plural and interdisciplinary experience. It can be observed, as a result of this process, that the development of products cannot attend to all the problems, and is thus characterised as a set of compromise solutions that depend on contingencies of the journey, in other words, it cannot be regarded as something simple or direct.

It requires research, careful planning, meticulous control and, more importantly, the use of systematic methods. Systematic methods require an interdisciplinary approach, involving methods of marketing, engineer of methods and the application of knowledge about aesthetics and [16:03].

In this way, the design can be regarded as a tool favouring the knowledge of these new necessities and as a creative, technological and multidisciplinary process, oriented to the creation of new models or to the re-design of other methods [23].

In this line of thought it becomes clear that design, as a projectual activity, should take into account the largest number of aspects possible, which can be specific for the company (products, technology and resources), related to the market (competition, logistics) and to the socio-cultural context [4:34]. "Industrial design is the activity promoting changes on a product" [16:02].

Design can cease being seen as something aesthetical, changing into a conscious form of project development in all its complexity. That will also

opment in all its complexity. That will also determine the coherence between design and its meaning in terms of solutions.

In summary, the aspects so far introduced and discussed allow to highlight the importance of design on the development of products, consisting of a process that presents multiple factors to be considered. However, the human factor, used on the central and consequently strategic element for product design, needs further analysis and discussion. To design products compatible with the standards on human use, without producing injuries to users, makes products more effective and frequently increase learning and dexterity with the product [2:90]. Focusing on this aspect, product design requires that the usability of its project solutions attend their users in the best way possible.

3. Usability: a basic and necessary concept

Product development has been regarding, with increasing intensity, the aspects of usability, performance and safety of products, since the markets have become increasingly competitive, the normative requirements have become more and more rigorous, and the technological innovations have become more recurrent and spread throughout a society of consumption [14].

For this research, the concept proposed by the International Organization for Standardization (ISO) related to concepts of efficacy, efficiency and satisfaction with which specific users can achieve specific goals in a particular environment, will be used as a main reference for the term usability, Efficacy refers to the degree of accuracy and completeness through which users achieve certain targets in a given environment. Efficiency is related to the accuracy and completeness of the goals achieved in relation to the resources used, whereas satisfaction is defined as the comfort and acceptance on the use of a system [8].

For some authors such as [13-14] usability is the maximization of a product's functionality, on the interface with its user. For [19-10] usability is an important factor for the success of the product, and for [25], besides these definitions, usability favours health and wellbeing by means of adaptation to work.

[17] have highlighted seven principles, based on the Universal Design Centre of the State University of North Carolina, to determine the usability and accessibility of products, environments and systems;

1. Equitable Use: the project must attend to people with different qualities;

2. Flexibility upon Use: the project attends to a range of individuals with different preferences and skills;

3. Simple and Intuitive Use: easy and intelligible use, not depending on the user's experience, knowledge, way of communicating or level of understanding;

4. Perceptible Information: the project must facilitate the transmission of information to the user in an effective way independently from environmental conditions or from the users' sensorial skills;

5. Tolerance to mistake: the project must minimise the mistakes/errors and adverse consequences of accidental actions;

6. Low physical effort: the project must be used with efficiency, comfort and a minimum of fatigue;

7. Adequate size and space for access and use: the project must feature adequate access size and space, use and manipulation of objects, independently from anthropometrics, posture or the individual's mobility;

[11:35], complementing this information say: "part of the process of understanding the user's needs, regarding the project of an interactive system that meets them, consists of being clear as to the main object. So the authors propose the targets of usability, focused on specific criteria (*ie*, efficiency) and the targets derived from the user's experience (*ie*, aesthetically pleasant)."

Figure 1 shows the targets of usability (shown in the internal circle) and the targets resulting from the user's experience (shown in the external circle), which can serve as support for a better understanding of the human behaviour when before products.

Fig.1: Usability targets and the resulting user's experience ones. Adapted and corrected from [11:41].

According to the NBR: 9241, the structure of usability and its application are shown in Figure 2 where is possible to identify the existing relation between the real use of a product and the intended (projected) result, inside a specific use context. Thus, besides being thought of and planned out to be efficacious, efficient and satisfactory, they also must offer safety and comfort.

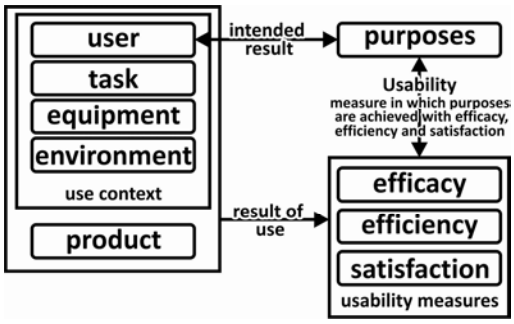

Fig.2: Usability structure, from NBR: 9241-11.

The terms of ISO 9241, which are regularly used, are introduced bellow:

Usability: The measure in which a product can be used by specific users to achieve specific purposes with efficacy, efficiency and satisfaction, in a specific context of use.

Efficacy: Accuracy and completeness with which users achieve specific purposes.

Efficiency: Resources spent in relation to accuracy and coverage with which users achieve purposes.

Satisfaction: absence of discomfort and the presence of positive attitudes towards the product use.

Use context: users, tasks, equipment (hardware, software and materials), and the physical and social environment in which a product is used.

Work System: System, composed by users, equipment, tasks and the physical and social environment, with the purpose of achieving specific results.

User: person interacting with the product.

Purpose: Intended result.

Product: Part of the equipment (hardware, software and materials) for which usability is specified and evaluated.

Measure: value resulting from measurement and the process used to achieve such value.

Specifically associating the use context, it can be said that the understanding of how activity happens in a general way is fundamental for the projecting the product. Relating it directly with the principles proposed by ergonomics, where the consideration of reality and its context is indispensable for an understanding of the real activity.

According to what has been mentioned before this research finds support on ISO 9241 (1998) and on the principles proposed by [21]. Such principles, according to the author, should be taken into consideration on a product so that it can be regarded as in conformity with usability. Figure 3 introduces a synthesis of these principles.

Some of the models are used to evaluate usability, among which the following can be mentioned: heuristic, cognitive essays and standard questionnaires, besides the traditional verification lists better known as check lists. However “many of these methods are specific for the assessment and project of human-computer interfaces and usually are not used for the design of industrial products” [15:47].

CONSISTENCY	Projecting a product for consistency means that similar tasks must be performed in similar ways.
COMPATIBILITY	The way in which a compatible product works must relate to the user’s expectation, created from the experiences lived.
CAPACITY	The user has certain capacities for each function, and these must be respected. It is important that when using a product, the consumer doesn’t have their capacities suppressed or overlooked.
FEEDBACK	It is important that the interfaces or products give back to the users information about the consequences of any action undertaken by them.
PREVENTION AND ERROR CORRECTION	The products must be projected in a way that minimizes the possibilities of errors and that the user can correct any eventual mistakes in a fast and easy way.
CONTROL BY THE USER	The users must have the maximum possible control over the interactions they will have with the product.
VISUAL CLARITY	Information must be made available in a way that allows it to be quickly and easily read, without causing confusion over its understanding. Functionality and operation method must be explicit.
PRIORITIZING OF FUNCTIONALITY AND INFORMATION	Products with a large variety of functions must be properly prioritising some of these functions when projecting the product’s interface. The products must be accessible and easily operated.
ADEQUATE TRANSFERENCE OF TECHNOLOGY	The assimilation of technologies developed for other areas can potentially bring major benefits to the users and their likely consequences and problems in order to highlight the product’s usability.
EVIDENCE	The product’s formal solution can clearly indicate its purpose and operating mode.

Fig.3: Principles of Usability, as shown by [21]

The decision to apply one usability method or another depends on a few factors, such as the phase of project development where there is the intention of investigating the product's interface, the amount of resources available, material as much as time resources, the evaluator's experience, the kind of interaction the product presents, the type of result it is intended to achieve, among other. On usability assessments combinations and several methods can be used to achieve the expected results." [15:54].

In summary, the information discussed to present allow the conclusion that there is a need for a deeper investigation, with the proposition of strategies and tools for analysis and assessment where the product can be assessed as to its usability aspects, favouring a user centred project.

As answers the production demands, the market and especially the consumers/users demands, showing the value the statement that "Ergonomics, as much as Design have come as an answer to life complexity after the Industrial Revolution." [12:25]. In this same line of thought the author also reasons:

Ergonomics and design are two sides of the same coin. The coin is interface, such as defined by Gui Bonsiepe in his book Design: form material to digital. Whereas ergonomics studies the interaction between human beings (people, users, consumers, electors, operators) and technology, it is the designer's responsibility to design the project for the interfaces between technologies and the human being [12:24].

Complementing the author, [11], say that to develop interactive products that are usable is a main concern of interaction design. Such idea can be better understood, according to the very authors: "easy to learn products, with efficacy upon use, offering the user a pleasant experience."[11:24]

4. Assessment Model of Usability: Usa-Design (U-D) ©

As mentioned before, the development of U-D© model (blank example can be found on Figure 4) is grounded on the rule of ISO 9241-11 and on principles by [21]. The model is divided into four phases:
Phase 1: Understanding the use context.
Phase 2: Preliminary assessment of usability (efficiency/efficacy/satisfaction).
Phase 3: Assessment of the usability principles.
Phase 4: Results.

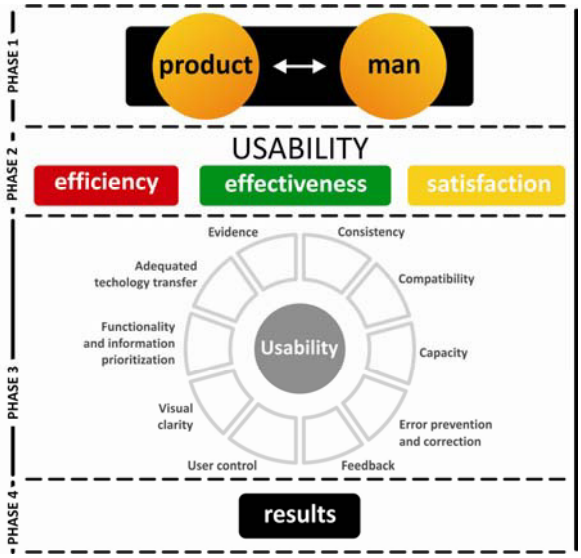

Fig.4: Usa-Design (U-D)© Model blank example.

On Phase 1, it is necessary to analyse the real use context of the product under assessment. For that several tools and techniques can be used, such as: functional analysis, morphological analysis, analysis of the scenery, among others. The choice for the suitable one will depend on the situation and the product under analysis as well as the evaluator's knowledge.

After the reality of the context of the product's use is understood, it is recommended a preliminary analysis of efficacy, efficiency and satisfaction regarding the product, according to the rule in ISO 9241-11 (1998) and corroborated by [24]. For this global analysis of usability a measure is taken for each of the usability targets, namely: Efficacy: percentage of targets achieved; percentage of users completing the task with success; accuracy average on the tasks performed. Efficiency: time used to complete one task; tasks completed per unit of time; financial costs to accomplish the task. Satisfaction Scale. Use frequency. Complaints Frequency.

These assessments can be completed by other models, from which stand out [18], as they feature mathematical formulas for the efficiency and efficacy targets, based on the quality and amount components, on efficacy and time to accomplish the task, efforts and errors for efficiency.

The results of Phase 2 are graphically represented by a chromatic scale, using the colours red (does not attend), yellow (partially attends) and green (totally attends). In this regard, the combinations for the es-

tablishment of each item's level follow the order shown on Figure 5. These phases can be visualised in Figure 7, where is given an example and measurement scales. It is important to highlight that the principles used on Phase 3 (based on [21]), are flexible and the model itself has a modular structure allowing either the withdrawal or the incorporation of principles according to the project and its contingencies.

		does not attend	partially attends	partially attends
EFFICACY	Percentage of targets achieved	0 - 59%	60 - 89%	90 - 100%
	Percentage of users completing the task with sucess	0 - 59%	60 - 89%	90 - 100%
	Average accuracy of completed tasks	0 - 59%	60 - 89%	90 - 100%
EFFICIENCY	Time to complete a task	0 - 59%	60 - 89%	90 - 100%
	Tasks completed per unit of time	-	-	-
	Financial cost to accomplish the task	0 - 59%	60 - 89%	90 - 100%
SATISFACTION	Satisfaction scale	0 - 59%	60 - 89%	90 - 100%
	Use frequency	0 - 59%	60 - 89%	90 - 100%
	Complaints frequency	100 - 70%	69 - 11%	10 - 0%

Fig.5: Measurement structure of Phase 2.

Regarding the measuring form, a quantitative scale of numeric order and a qualitative scale of chromatic order have been chosen showed in Figure 6.

The results of Phase 3 can be graphically visualised in figure 8, where a generic case is introduced, and it is possible to quickly and directly observe the ten principles evaluated, allowing an easy identification of the stage of each one. In the same Figure, the complete model is introduced, qualitatively identifying phases 2 and 3. Such visual and global identification meets the proposal where visualization aspects prevail for a better understanding by the analyst.

	MEASUREMENT		
QUANTITATIVE	1	2	3
QUALITATIVE			
READING	does not attend	partially attends	completely attends

Fig.6: Measurement Structure of Phase 3.

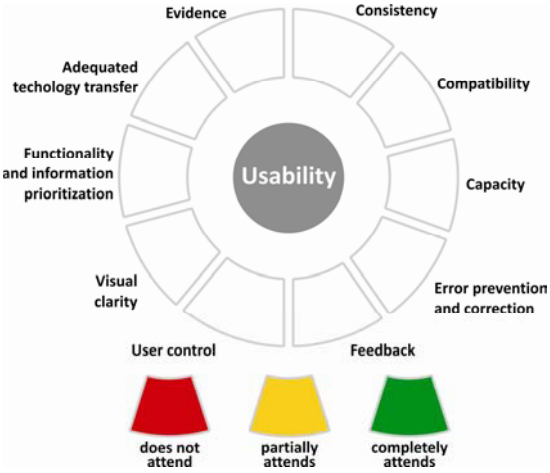

Fig.7. Phase 3 of U-D© in blank and assessment scale.

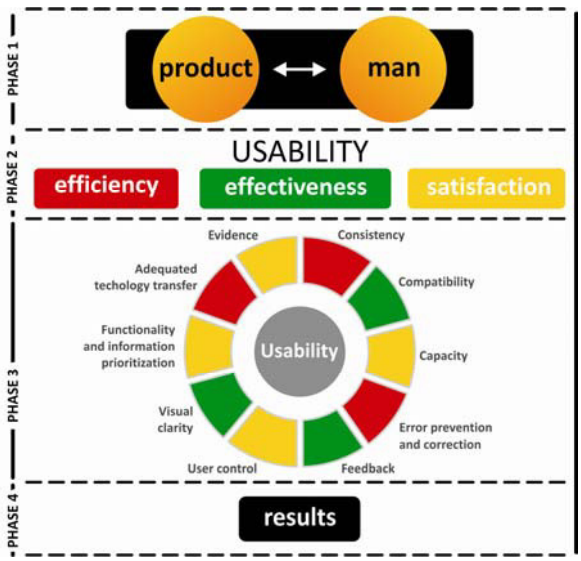

Fig.8: Complete U-D© Model (generic example).

5. Final Considerations

The user centred project has been solidifying as an indispensible item for the development of products. Such fact is met by this research whose purpose was to comprehend the importance of usability on products, specifically on the way of evaluating them. A few authors along the way of this research have pointed out the need for the investment on research that result in integrated application of products and their assessment, incorporating usability principles.

"Henry Dreyfuss, one of the pioneers on Industrial Design, has established the foundation of what is

today called Product Ergonomics. From the project pratical needs Dreyfuss developed several studies, especially on Anthropometrics, which became referential for following researchers. One of his merits – at a time when artefacts were manufactured with a logic that disregarded the needs, skills and limitations of their users – was to have associated the concern with safety, efficiency and comfort upon use with the success on business." [12:27]

In this regard the conceptual proposition of a usability model for the design (U-D©) comes to create the opportunity of this kind of study, so that the basic targets of usability can be achieved (efficiency/ efficacy/ satisfaction), configuring a scenario favourable to a significant improvement of existing products and also the new products undergoing project.

The methodological route here presented, configured into four phases, can serve as reference for product assessment. With a flexible and modular proposition, each principle is adjustable, depending on each situation and on research advance. The use of qualitative-quantitative and specifically the use of the colour, following universal conventions (red, yellow and green) allow a quick and clear identification of stages in each phase that is evaluated (Phase 2 and 3).

Thus, the role of design is relevant for product development. Also, consider the need for wider integration into the design culture and into the other areas involved in this process, is vital in theory and practice

"Although the designer cannot be responsible, or made responsible, for all of the decisions in the project (even those in the process of product development), the final result that shows/involves/protects/ expresses is the form of the product. This form must be safe, comfortable and enjoyable. Rather than that, it must be perceived as safe, pleasant and comfortable." [12: 144].

This proposition cannot be regarded as definitive, quite the opposite, it is necessary that the studies and especially applications with a practical character are deepened so that the potentials and weaknesses in each situation under analysis can be checked. In this respect, the U-D© is already being applied and the results will be published on scientific media.

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