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PROPOSAL FOR A NEW USABILITY INDEX FOR PRODUCT DESIGN TEAMS AND THE GENERAL PUBLIC

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Abstract

Usability is a key notion in most of products, especially for the medical devices. Nevertheless, sometimes this notion can be shelved in favour of other priorities such as reliability of the product. However many incidents related to products find their origin in bad usability. It's the reason why usability should reaffirm its role in product design by a greater inclusion. The challenge of this situation is to introduce the usability notion in the design process of products as medical devices in a simple and easily understandable way while the sector of medical devices for example is mostly made up of SMEs. A usability quantification would enable the enforcement of its role in this type of design. Moreover, usability quantification tools are often seen with a point-in-time approach that inhibit a complete integration in the design process. Finally usability quantification in the form of an index monitoring the product during its design process could be a solution to help the design team in decision-making, enhance the communication in the design team about usability and popularize the notion among the general public.

Keywords: Evaluation, Design methods, Teamwork, Usability index

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1 INTRODUCTION

Medical devices are a product category which is an important component of the industry with a high innovation potential. This particular product type is defined by a legal framework, which may differ in different countries (CEE, 1993) (OLRC). This group contains a wide diverse range of products. For a long time, medical devices manufacturers focused on product reliability and shelved other notions such as ergonomics. This orientation tended to decrease the incidents involving medical devices but numerous incidents still present and for some of them find their origin in usability problem. It's the reason why ergonomics seem to play a leading role in the design of medical devices (Clarkson et al, 2004). Therefore, ergonomics should reaffirm its role in medical devices by a greater inclusion in the design of the products. The challenge of this situation is the introduction of the notion of usability in the design process of medical devices in a simple and easily understandable way while the sector is mostly made up of SMEs (MedTech, 2014) (Department of Commerce USA, 2016). A usability quantification would enable the enforcement of its role in the design process of medical devices. Such tools already exist but aren't well adapted with the framework (type of product, design constraints of medical devices and stakeholders with various skills). Moreover, these tools are often seen with a point-in-time approach that inhibit a complete integration in the design process.

2 USABILITY IN MEDICAL DEVICES DESIGN

2.1 The notion of usability

Usability is a notion taking its origin in the field of software development in the 1980s. Usability has several definitions with academic or industrial origin. Usability is also defined by international standards (ISO, 1998). Among these definitions, we have chosen for the study the one proposed by Nielsen. Nielsen disaggregated usability into five components (learnability, efficiency, memorability, errors (as low rate), satisfaction) (Nielsen, 1993) and appears as the simplest to measure the usability of a product (Liljegren, 2006).

2.2 The usability tools

In the aim to take usability into account during the product design process, dozens of tools are available to designers. These tools can be classified in five categories: testing, inspection, inquiry, analytical modelling, simulation (Ivory, 2001). By refocusing on medical devices and restraining the tools commonly used (Martin et al., 2006) (Martin et al., 2008), a mapping (Figure 1) about implementation requirements and level of information available can be created.

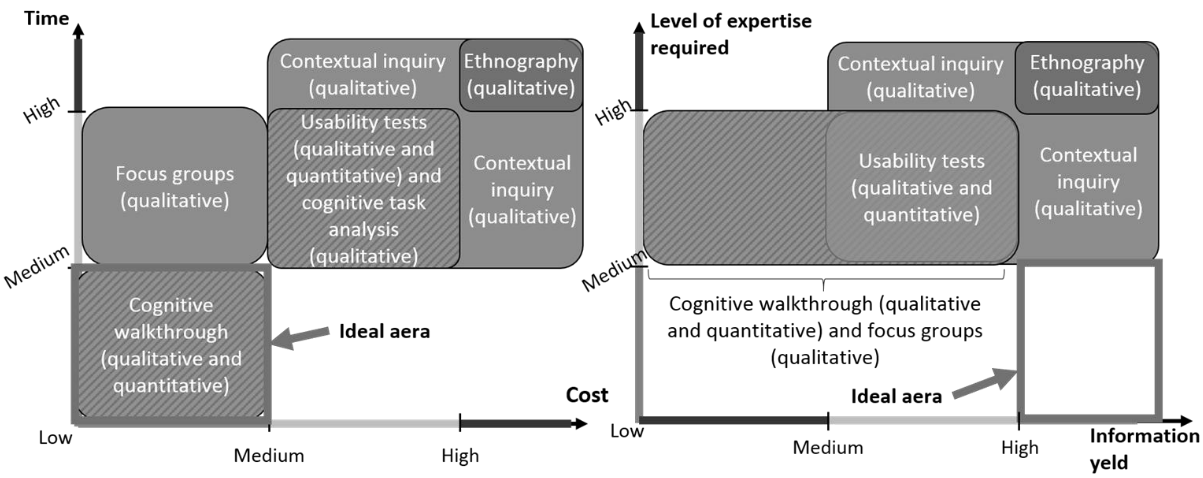

Figure 1. Mapping of usability tools used in design project of medical devices

In the SMEs context, ideal sections minimizing time, cost and expertise required for the usability tool implementation and maximizing the level of information available can be delimited (Figure 1). In this

case, considering its proximity with the ideal sections and its types of data available (quantitative and qualitative), usability test seems like the best compromise.
Moreover, many tools are provided to designers but the field of medical devices generates operating constraints on the inclusion of end users in the product design process (Martin et al., 2006).

2.3 Towards a usability quantification

Usability tests can provide quantitative and qualitative data. One of the benefits of quantitative data is its high capacity to communicate information and making them understandable to a very broad sample of people (Martin et al., 2006) among the project team (engineers, designers, ergonomists) or the other project stakeholders. Usability quantification tools have already been proposed, based either on metric data (number of clicks, distance covered by the mouse pointer, task duration) or on questionnaires which are completed after a product (or intermediate representation) test. These questionnaires as usability assessment tools have standard models. These standards are separated into two categories: the post-study questionnaires and the post-task questionnaires. The post-study questionnaires are applied after the completion of the test whereas the post-task questionnaires are shorter (usually no more than 3 questions) and applied for each task of the action. Many standards questionnaires are available for product designers with different number and types of questions and consequently with various validity and sensitivity levels (Klaassen et al., 2016). In the literature, the most common usability questionnaires are SUS (Brooke, 1996), PSSUQ (Lewis, 1992), SUMI (Kirakowski and Corbett, 1993), WAMMI (Kirakowski et al., 1998), CSUQ (Lewis, 1995), QUIS (Chin et al., 1988), UMUX (Finstad, 2010), UMUX-LITE (Lewis, 2013), SUPR-Q (Sauro, 2015). At these questionnaires quantifying the usability notion, other questionnaires related to a part of usability exist such as NASA-TLX (Hart and Staveland, 2006) about task load or AttrakDiff (Hassenzahl et al., 2003) about enjoyment and pragmatic qualities.

2.4 Usability index requirements

The setting up of a usability index and more generally of a quantification tool must primarily provide a reliable result. This reliability depends on the calculation model of the tool and on its data input (type of data and means to obtain the information). Moreover, for a good level of detail (of the analysis), the tool should analyse the tasks but also the totality of the action (composed of a set of tasks). Today, the use of this kind of tool still needs a certain degree of knowledge about usability and user test. It's the reason why the new usability quantification proposed in this study should be available at least to any person of the project team. This property will also create support to implement usability and more generally ergonomics into the design process. Despite the existence of usability rating parts, the communication potential of this measure appears to be under-utilised contrary to other indicators used in various field (energy consumption, dietetics, consumer satisfaction, etc.). Because it can be an important lever in improving the spread of usability notion and the communication both internally and externally, the usability quantification proposed in this study should be designed as such. Finally, it would be better to have a monitoring tool rather a one-shot measure tool. The tool with a complete implementation on the design process would allow a monitoring of the usability level of the product (intermediate representation and final product) during its design and development. These previous points imply that the usability quantification tool should take the form of an index applicable on a wide range of product representations.

3 THE USABILITY INDEX

Based on the usability ISO definition (ISO, 1998) the framework of a usability test is made up of the user, the product (or its representation), the goal and the context of use. The usability index should reliably quantify it. In addition to this concern, the industrial context adds other constraints such as time, cost and necessary competence for the use of this tool.
In order to take into account the usability with both high-level and detailed approach, the usability index is composed of two parts. On the one hand, a global quantification of the use of the product as a whole (post-study) and on the other, a detailed quantification of each task (post-task) of the global action. The post-study part is based on the SUS questionnaire whereas the post-task part is based on the five components of usability as seen from the definition given by Nielsen (i.e., learnability, efficiency, memorability, errors (as low rate), satisfaction). The post-study part contains nine questions (one less than SUS with various rewordings to enhance understanding) and the post-task contains one question

for all of the five components of usability. Finally, the whole usability index questionnaire (Figure 2) contains fourteen items and used a five-point Likert scale for each of them (from one to five point assigned for each question). As the usability test needs to take into account the users, the usability index will contain weights of the five usability components. Each user assesses the several weightings by choosing the most important usability components for each combination of two components (five components giving ten different combinations). In this way, each user can easily fix his/her personal weightings; a function of the number of each component that was chosen. Each question of the index usability questionnaire (post-task and post-study) will be associated with one of the five usability components and its related weight.

Usability Index questionnaire

Five points Likert Scale

1 – Strongly disagree | 2 - Disagree | 3 - Undecided | 4 - Agree | 5 – Strongly agree

Post-Task (PT)	**Rate per question**
1) I think the task is easy to learn.	Scale position
2) I think I made use of force or I needed to think a lot to accomplish the task.	5 - Scale position
3) I think there is many things to know to accomplish the task.	5 - Scale position
4) I think the product allows to avoid operating errors.	Scale position
5) The task I realized gived me a feeling of satisfaction.	Scale position

Post-Study (PS)	**Rate per question**
6) I think I would often use this system when necessary.	Scale position
7) I think the system is too complex.	5 - Scale position
8) I thought the system was easy to use.	Scale position
9) I think that I would not need the support of a person to be able to use this system	Scale position
10) I found the various functions in this system were well integrated.	Scale position
11) I would imagine that most people would learn to use this system very quickly.	Scale position
12) I found the use of the system very fluid.	Scale position
13) I felt very confident using the system.	Scale position
14) In the goal to use this system I needed to learn a lot of things.	5 - Scale position

Figure 2. Questionnaire of the Usability Index (English translation of the French version)

The calculation of the usability index is realized as follows (Figure 3): For a same representation of the product, n participants (respondents) (1,2, …, i, …, n) have been used the product to achieve a specified goal decomposed in a set of k tasks. Each participant completes k times the post-task questionnaire PT (noted PTi1, PTi2, …, PTik for the participant i) related to each task (identified in advance by the project team) of the global action, and only one time the post-study questionnaire (noted PSi for the participant i). For a participant i, the weightings are named WLi, WEFi, WMi, WERi, WSi respectively corresponding to weightings assigned by the participant to learnability, efficiency, memorability, errors (as low rate) and satisfaction. Averages (noted LTi, EFTi, MTi, ERTi, STi) of the participant answers (1 to 5 points allocated for each question) of the k post-task questionnaires are calculated for each corresponding usability components. Moreover, averages (noted LSi, EFSi, MSi, ERSi, SSi) of the participant answers of the post-study questionnaire are also calculated for each corresponding usability components. In the aim to obtain for the participant i, the rates (Li, EFi, Mi, ERi, Si) related to each corresponding usability components, an average of the post-task rates (LTi, EFTi, MTi, ERTi, STi) and the post-study rates (LSi, EFSi, MSi, ERSi, SSi) is calculated. The above sequence is realized n times (as many times as there are participants). The rates (RLearn, REff, RMemo, RErr, RSat) related to each corresponding usability components for the representation of the product are obtained by the average of all intermediates rates of the participants. The weightings (WLearn, WEff, WMemo, WErr, WSat) related to the corresponding usability components are obtained by the average of all weightings allocated by the participants for each usability components. Finally, the usability index is calculated by a weighted average from the rates (RLearn, REff, RMemo, RErr, RSat) and the corresponding weightings (WLearn, WEff, WMemo, WErr, WSat).

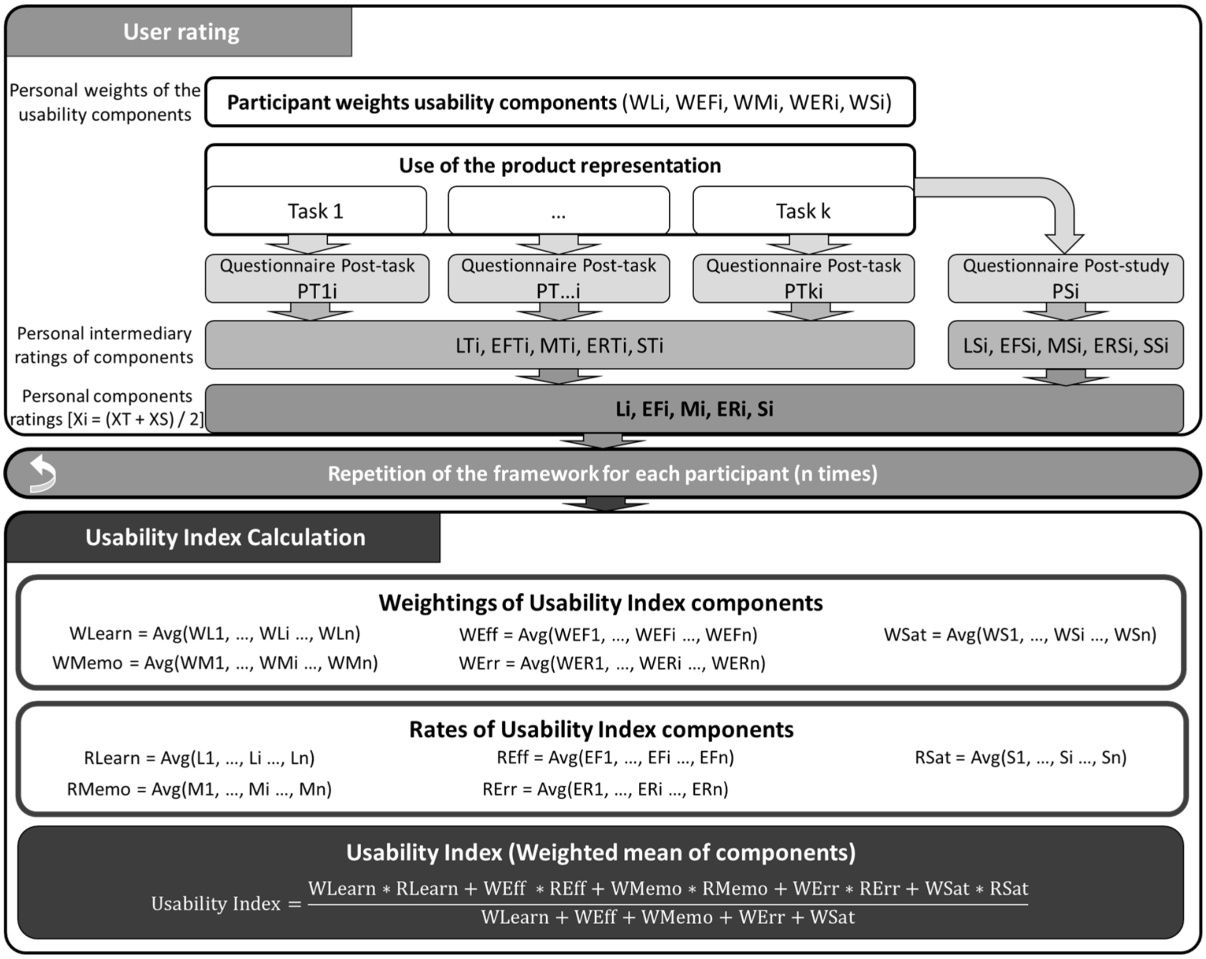

Figure 3. Framework of the Usability Index

4 EXPERIMENTATION

The experimentation concerning the usability index contains two main parts. On the one hand, the first part focuses on the usability quantification using the usability index. On the other hand, the second part deals with the communication potential of the usability index by graphical representations. This experimentation was done in French language.

4.1 Usability quantification

4.1.1 Experimental protocol

The experiment concerned several users (n=10) with various profiles from design field (engineers, designers) or not in the goal to individually realize usability tests. This experiment enabled to simulate the use of the usability index throughout a design project by the use of intermediate representation of the product (Figure 4). During this experiment, individual participants were requested to use or mimic the use of the product to achieve a specific goal. In the case of the experiment, the selected product is an infrared (temporal) thermometer, a medical device used to measure the patient temperature. The action requested was to realize a self-measurement of their own temperature with the device. This action was broken down in three tasks (gripping of the thermometer, sampling of the temperature around the head, repositioning on the thermometer holding) in terms of post-task part. The different intermediate representations (Idea card, CAD, Low-fi mockup, Hi-fi mockup) were the evaluation support by the intermediary of the questionnaires. Following each test of an intermediate representation the participants completed the usability index questionnaire. In the goal to watch the behaviour of the index and to compare it with a reference, the participant also completed a SUS questionnaire after each test of a product representation. The questionnaire SUS is qualified as "quick and dirty" but in reality, it has a good reliability and is used in many companies (Brooke, 1996). This questionnaire has the advantage of being able to measure the usability of a wide variety of products and services (Bangor et al., 2009).

Given its performance, its industrial implementation and its use as reference in many studies, the questionnaire SUS was also taken as a reference in this study.

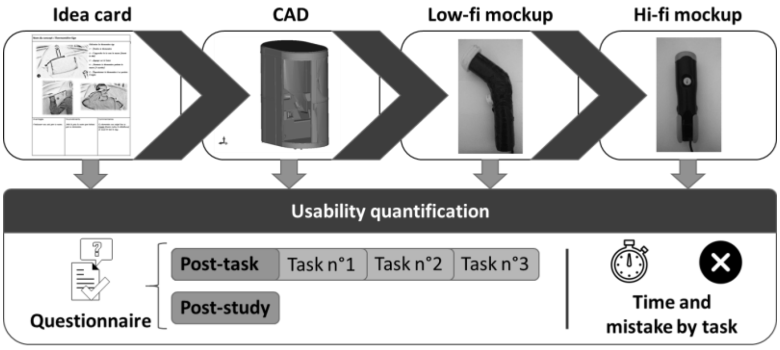

Figure 4. Experimentation framework

4.1.2 Results

Results of the usability index for each product representation are presented below (Table 1). The table contains the values of the usability index and its components for each tested representation. The table contains also SUS score enabling a comparison with the usability index.

Table 1. Usability Index results

			Idea card	CAD	Low-fi mockup	Hi-fi mockup
Usability index (1 to 5)			**3.77**	**3.64**	**4.10**	**4.33**
	Index component	Weighting (1 to 5)				
	Learnability	**2.80** s = 1.08	**4.23** s = 0.27	**3.89** s = 0.66	**4.68** s = 0.31	**4.56** s = 0.33
	Efficiency	**3.20** s = 1.08	**3.72** s = 0.61	**3.58** s = 0.82	**4.27** s = 0.26	**4.43** s = 0.40
	Memorability	**2.10** s = 1.22	**3.70** s = 0.82	**3.80** s = 0.72	**4.52** s = 0.40	**4.48** s = 0.46
	Errors prevent	**3.40** s = 1.36	**3.73** s = 0.50	**3.57** s = 0.99	**3.75** s = 0.78	**4.25** s = 0.44
	Satisfaction	**3.50** s = 1.28	**3.53** s = 0.38	**3.48** s = 0.60	**3.57** s = 0.79	**4.03** s = 0.42
SUS score (over 100)			74.75	64.25	79.00	86.50
SUS score (1 to 5)			3.99 s=0.35	3.57 s=0.84	4.16 s=0.41	4.46 s=0.33
Delta Usability index - SUS (rates between 1 to 5)			-0.22	+0.07	-0.06	-0.13

4.1.3 Discussion

The intermediate representations which are used in this study take their origin from real concepts of a thermometer design project. During this project, the concepts evolved as design project team and potential end users had made feedbacks. For this reason, we made the assumption that the usability of this product was enhanced through successive improvements. If the usability index has an appropriate behaviour, it should evolve towards a higher value. As the results can show us, the usability index and the SUS (as a reference) seem to have a same evolution and effectively show a progressive improvement of the usability of the product.

4.2 The usability index as a communication tool

This section about the second part of the experimentation deals with the question of the communication potential of the usability index by graphical presentations.

4.2.1 Experimental protocol

An online questionnaire was send by email to participants without distinction. In this message no instruction about use restriction of the online questionnaire was given (participant may forward the link of the questionnaire to other persons without limitation). The questionnaire contained three parts, the first part specified the participant's profile, the second part dealt with the graphical presentation of the usability index for design teams and the last part dealt with the graphical presentation of the usability index for the general public. On the part dedicated to design teams (Figure 5), the first illustration (type A) displays the values of the index components of each intermediate representation and the objectives to reach in a "radar" graph with 5 axis (one for each component). The value of the usability index and the objective to reach is displayed for each representation below the graph. The second illustration (type B) displays the usability index and its related objective on a vertical scale. Moreover the rates of the index components are displayed for each intermediate representations in a chart next to the usability index including the objectives components rates. On the part dedicated to general public (Figure 6), two types of usability index illustration are also displayed (different from the illustrations tailored for design teams) for this assessment. On the first illustration (Type C) the usability index is displayed on a coloured circle (from red to green respectively related to low and high value of the usability index). Moreover, rates of the index components (usability components) complete the illustration with the same colour code. On the second illustration (Type D) the index value is displayed on a vertical coloured scale (same colour code). Thus, rates of each index components are displayed on a vertical coloured scale next to the value of usability index. This second illustration has the particular feature of containing definitions about some non-trivial usability components (efficiency, memorability, errors prevent). Participants who had mentioned in the first part at least one participation in product design activities answered the two other parts. Other participants answered only the last part about the graphical presentation of the usability index for the general public.

4.2.2 Results

The questionnaire was completed by 19 respondents. 12 of them participate or have already participated in product design activities. This sample includes 11 women and 8 men whose average age is 34.

- Usability index illustration for product design project team
  The respondents for this part are persons who are included in the sample and had mentioned at least one participation in product design activities. This group includes 12 respondents (6 women and 6 men with an average age of 36.). The questionnaire enabled to test the level of understanding of two graphical presentation types of usability index tailored for product design teams (Figure 5). Understanding comprehension is composed of the comprehension of the global usability index, the set objective, the usability components values and related objectives. In the aim to check the comprehension of the usability index, 3 usability index respectively related to 3 intermediate representations of the product (thermometer) were displayed for two types of usability index graphical presentation. Thus, for each index illustration, a series of questions was asked to the participant who had to find what intermediate representation of the product have the best usability or the worst usability according the usability index. Participants was also asked to find for each usability index illustration what is the stated objective value of the index and the stated objective values related to the five index components. A respondent was counted into the calculation of the comprehension percentage if only all his answers regarding the related topic associated with this rate representation were right. At the end of the online questionnaire part, subjective questions was asked to the participant (clarity, interest, communication and outreach).

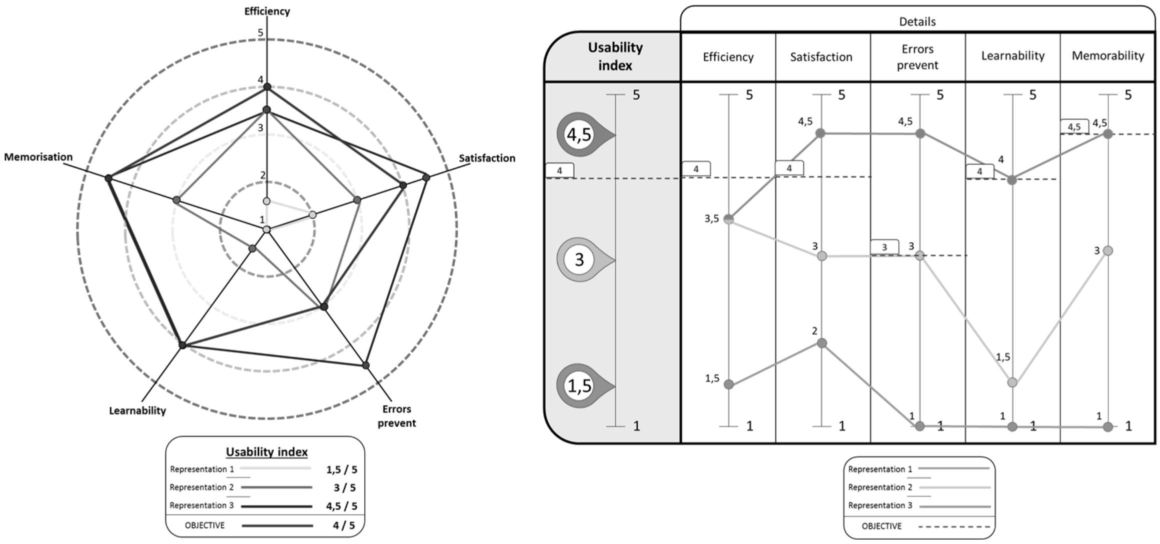

Figure 5. Illustrations of Usability Index (Left: Type A, Right: Type B)

Table 2. Questionnaire results about Usability Index Illustrations used for design team

	Type A (radar)	Type B (segments)
Range of comprehension - Global usability index	100 %	92 %
Range of comprehension - Objective of the global usability index	75 %	92 %
Range of comprehension - Values of usability index components	67 %	83 %
The presentation is clear. (1 to 5)	4.0 (s=0.82)	4.3 (s=0.94)
The presentation is interesting in project tracking. (1 to 5)	4.0 (s=0.82)	4.3 (s=0.62)
The presentation enables to enhance the interdisciplinary communication. (1 to 5)	4.0 (s=0.91)	4.3 (s=0.60)
The presentation is a useful tool for promoting usability. (1 to 5)	3.8 (s=1.07)	3.9 (s=0.76)
Graph preference (over 11 participants - 1 no opinion)	36 %	64 %

The result of this part suggests a significant potential offers by the type B illustration of the usability index. Moreover, this trend is illustrated by the results related to the type B which are better than the results related to the type A in all fields, except for the global comprehension of the index. One might add that the subjective results are consistent with the objective results because the type B is the respondents' preference. Finally, the type B illustration seems to be a good mean to represent and distribute the usability index because it seems to have a good communication potential and generates substantial interest from product designers.

- Usability index representation for the general public
  In the case of the assessment of the usability index illustration for the general public, the whole sample (19 respondents) answered this part. The questions were asked to the participants in the aim to evaluate the understanding of the usability index (global and components) and collect subjective data (similar questions from the product design team part).

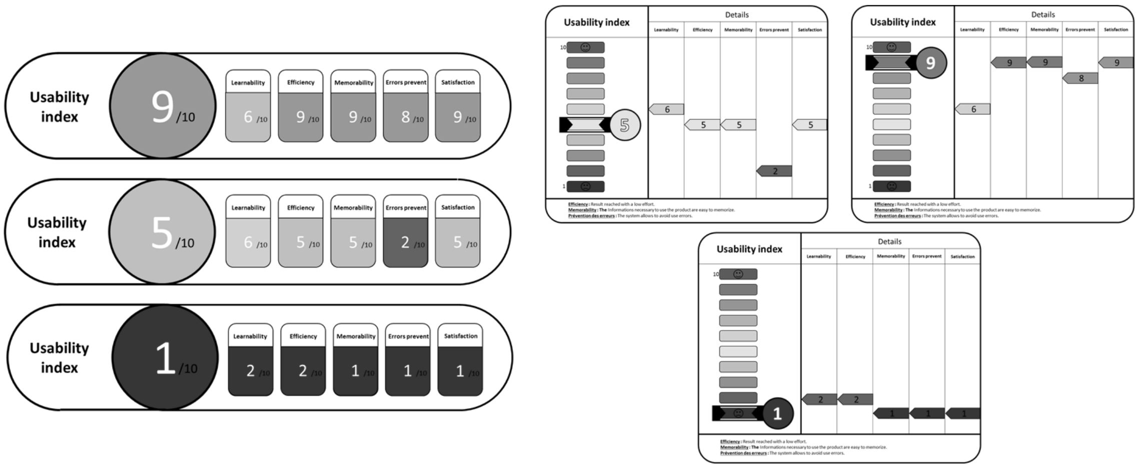

Figure 6. Illustrations of Usability Index (Left: Type C, Right: Type D)

Table 3. Questionnaire results about Usability Index Illustrations used for the general public

	Type C	Type D
Range of comprehension - Global usability index	68 %	84 %
The presentation is clear. (1 to 5)	4.8 (s=0.41)	4.3 (s=0.94)
The presentation is a useful tool for promoting usability. (1 to 5)	4.7 (s=0.49)	4.3 (s=0.54)
This kind of labelling could be a tool that assists in the product selection at the time of purchase (1 to 5)	4.4 (s=0.59)	4.3 (s=0.46)
Graph preference	47 %	53 %

4.2.3 Discussion

All the graphical representations of the usability index proposed in the study were quite well received by the respondents (product designers and general public). Indeed, the comprehension rate of each illustration is quite high for each. Moreover, the participants showed a real interest for a tool such as the usability index. These kinds of graphical representations seem to be a good way to expose the outcome of the usability index because in addition to have good results on the objective part, they have also good results about the subjective part. Finally, the results of the survey guide the choice on the type B illustration for the usability index illustration tailored for the product design team. Nevertheless, the orientation concerning the illustration tailored for the general public is not explicit (opposition between objective and subjective results). Ameliorations based on respondents' comments should to be done before to make a choice.

5 CONCLUSION

The experimentation related to a new usability quantification tool highlighted a possibility of integration in the product design process. Moreover, it enabled to focus on a real interest from the product designers about these tools showing reliability marks and a high communication (outreach included) potential. Notwithstanding, the universality of its implementation in a design process by a product design team of a SME still need to be dealt with in more depth. This investigation concerns the benefits of the usability index on the project, the team project, the product, and the commercial development of the product. These remaining outstanding elements will be clarified by its use on a real product design project in an industrial context. The practical application of such a tool should imply the creation of an application protocol in the aim to make it accessible and understandable for persons without specific knowledge on usability. In relation to this protocol, it seems that the data analysis used to calculate the usability index should to be simplest for the user. It's the reason why it seems necessary to create a computer-based tool (e.g. Excel macro, dedicated application) to simplify the use of the index and to put out the data treatment of the user's scope. Ideally, this computerized based tool might be a software suite designed to configure the questionnaire, save the questionnaire results, process data and display usability index (results and graphical representations).

REFERENCES

Bangor et al., (2009). “Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale”, *The Journal of Usability Studies* 4, 114–123.

Brooke, J., (1996). “SUS - A quick and dirty usability scale”, *Usability evaluation in industry* 189, 4–7.

CEE, "Directive 93/42/CEE", *Journal officiel des Communautés européennes*, 1993

Chin, J.P., Diehl, V.A., Norman, K.L., (1988). “Development of an Instrument Measuring User Satisfaction of the Human-computer Interface”, in: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI ’88. ACM, New York, NY, USA, pp. 213–218. doi:10.1145/57167.57203

Clarkson, P.J., Buckle, P., Coleman, R., Stubbs, D., Ward, J., Jarrett, J., Lane, R., Bound, J., (2004). “Design for patient safety: A review of the effectiveness of design in the UK health service”, *Journal of Engineering Design* 15, 123–140. doi:10.1080/09544820310001617711

Department of Commerce USA, (2016), *Top Markets Report Medical Devices*

Finstad, K., (2010). “The Usability Metric for User Experience”, *Interacting with Computers*. 22, 323–327. doi:10.1016/j.intcom.2010.04.004

Hart, S.G., Staveland, L.E., (1988). “Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research”, in: Meshkati, P.A.H. and N. (Ed.), *Advances in Psychology*, Human Mental Workload. North-Holland, pp. 139–183.

Hassenzahl, M., (2003). “The Thing and I: Understanding the Relationship Between User and Product”, in: Blythe, M.A., Overbeeke, K., Monk, A.F., Wright, P.C. (Eds.), *Funology*. Springer Netherlands, Dordrecht, pp. 31–42.

ISO, (1998), Part 11: Guidance on usability”, *ISO 9241-11 Ergonomic requirements for office work with visual display terminals*

Ivory, M.Y., Hearst, M.A., (2001). “The State of the Art in Automating Usability Evaluation of User Interfaces”, *ACM Computing Surveys*. 33, 470–516. doi:10.1145/503112.503114

Kirakowski, J., Claridge, N., Whitehand, R., (1998). “Measuring the Usability of Web Sites”, *Presented at the 4th Conference on Human Factors & the Web*, Basking Ridge, NJ, USA, 05/06/1998.

Kirakowski, J., Corbett, M., (1993). “SUMI: the Software Usability Measurement Inventory”, *British Journal of Educational Technology* 24, 210–212. doi:10.1111/j.1467-8535.1993.tb00076.x

Klaassen, B., van Beijnum, B.J.F., Hermens, H.J., (2016). Usability in telemedicine systems—A literature survey”, *International Journal of Medical Informatics* 93, 57–69. doi:10.1016/j.ijmedinf.2016.06.004

Lewis, J.R., (1992). “Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ”, Presented at the *Proc. of the Human Factors and Ergonomics Society Annual Meeting*, pp. 1259–1263.

Lewis, J.R., (1995). “IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use”, *International Journal of Human-Computer Interaction* 7, 57–78. doi:10.1080/10447319509526110

Lewis, J.R., Utesch, B.S., Maher, D.E., (2013). “UMUX-LITE: When There’s No Time for the SUS”, in: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI ’13. ACM, New York, NY, USA, pp. 2099–2102. doi:10.1145/2470654.2481287

Liljegren, E., (2006). “Usability in a medical technology context assessment of methods for usability evaluation of medical equipment”, *International Journal of Industrial Ergonomics* 36, 345–352. doi:10.1016/j.ergon.2005.10.004

Martin, J.L., Murphy, E., Crowe, J.A., Norris, B.J., (2006). “Capturing user requirements in medical device development: the role of ergonomics”, *Physiological Measurement*. 39, 271-283. doi:10.1088/0967-3334/27/8/R01

Martin, J.L., Norris, B.J., Murphy, E., Crowe, J.A., (2008). “Medical device development: The challenge for ergonomics”, *Applied Ergonomic*s 39, 271–283. doi:10.1016/j.apergo.2007.10.002

Medtech Europe, (2014) *The European Medical Technology Industry in figures*

OLRC, Federal Food Drug & Cosmetic (FD&C) Act, section 201(h)

Sauro, J., (2015). “SUPR-Q: A Comprehensive Measure of the Quality of the Website User Experience”, *Journal of Uability Studies* 10, 68–86.