A Study on Usability Factors for Haptic Systems

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***Abstract*—A lot of research has been done on usability evaluation of software systems that results in different usability factors proposed to evaluate the overall usability of a system. Despite the effort, there is no consensus on usability factors and criteria (sub-factors) to determine the appropriateness of these factors with respect to the system and domain under study. This paper attempts to find out which usability factors are more important for haptic systems in particular and for other systems in general. It also attempts to justify the relationship between usability factors and sub-factors for the evaluation of any system. It is found that efficiency, effectiveness, satisfaction, learnability, and safety are the most important factors to be considered for evaluating any haptic system. It also highlights sub-factors that have consistent relationship with these important factors. Furthermore, this work strengthens the available literature related to usability evaluation that mainly focuses on efficiency, effectiveness, satisfaction, and learnability for the evaluation of a system independent of any domain.**

***Index Terms*—Usability, factors, haptic systems, criteria, sub-factors.**

I. Introduction

Usability is not a new concept anymore. Many definitions [1]–[3] are proposed in literature. It is believed [4] that Shackel's definition "the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of environmental scenarios" [3] is still valid. This definition also provides guidance on usability evaluation of a system i.e. system should support users' tasks effectively and efficiently with ease of learning. Many other usability models propose different usability factors to assess the overall usability of a system. For example, speed of performance, time to learn, retention over time, rate of errors by users, and subjective satisfactions are proposed by [5] to measure usability. ISO standard 9241:11 [1] highlights efficiency, effectiveness, and satisfaction as major usability factors. Nielsen suggests efficiency, learnability, memorability, safety, and satisfaction as the important factors [6]. We may infer that efficiency, effectiveness, satisfaction, and learnability are considered the most important and common factors as proposed in different models [1], [3], [6].

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Consolidated usability model proposed by [7] is an attempt to provide comprehensive approach towards usability evaluation. This model highlights 10 usability factors that are efficiency, effectiveness, productivity, satisfaction, learnability, safety, trustfulness, accessibility, universality, and usefulness. To assess these 10 factors, 26 sub-factors are proposed. To measure these major and sub-factors, 127 specific metrics are proposed. Minimal memory load, time behaviour, resource utilization, and operability are few sub-factors associated with efficiency. Layout appropriateness is one of the metrics described in [7]. It is proposed to measure the expected time to complete a task by calculating the frequency of transition and distance between two visual objects. Despite this consolidated model [7], it is still the question of which usability factors are more important or relevant to specific systems or domains. These factors may not necessarily important for all systems. For example, trustfulness is more related to web systems whereas learnability or accessibility can be the most important factor for systems used by people having some disability.

Haptic systems are unique in nature as these systems deal with sense of touch i.e. haptic feedback. Haptic feedback is further classified into force and tactile feedback [8]. Sometimes these terms i.e. haptic, force and tactile feedback are used interchangeably. Due to limited work on usability evaluation of haptic systems as discussed in [9], it is worthwhile to find out whether the most common usability factors i.e. efficiency, effectiveness, satisfaction, and learnability are also equally important for haptic systems or any other factors to be considered for these systems. Addition to it, the relationship between major and sub-factors is not justified in [7]. It would be beneficial to explore further this relationship for systems in general that will also help to decide the most appropriate sub-factors for evaluation of haptic systems.

This paper attempts to address these issues by conducting interviews with some domain experts (doing research for haptic systems) and a study with a few selected faculty members using card sorting method. The rest of paper is organized as follows: Section 2 provides an insight on the important usability factors for haptic systems on the basis of interviews conducted. Section 3 discusses the relationship between usability factors and sub-factors based on card sorting method. Section 4 provides a discussion on the results obtained and limitations of the study while Section 5 concludes the paper.

II. Usability Factors for Haptic Systems

As described earlier, we are interested to find out which factors are more important when evaluating the usability of haptic systems. In the following sub-sections, we discuss it in detail.

A. Interviews

We conducted interviews with eight domain experts (working on haptic systems) separately. A few questions were asked about their background including their experience with different haptic devices and in particular domains to get a better insight from their feedback. Their average experience was six years. Their work was mainly related to medical, mining, entertainment, security, virtual reality, robotics, psychophysics, and cultural heritage. They were experienced in using different haptic devices like Phantom omni/desktop/premium, HapticMaster, Falcon, Force dimension omega, and Barrett hand. After having a brief discussion on usability factors, they were requested to rank the usability factors in terms of their importance for evaluation of haptic systems. The ranking scale was from 1 (i.e. the least important) to 10 (i.e. the most important).

B. Analysis

The selection of factors was made on the basis of the lowest score (i.e. sum of ranking scale for each factor) and five lowest score factors were selected. Based on the feedback of experts, five factors that are considered most important are efficiency, effectiveness, satisfaction, learnability, and safety. These factors are ranked as more important compared with the rest of the other factors. Variation in interviewees' ranking is also lower for the five selected factors as compared to the remaining ones. For example, usefulness is ranked as the most important by two respondents but three other respondents considered it as the least important. The variation in ranking is mainly due to the different domains in which interviewees were using the haptic systems. Table I shows the overall rating for each factor.

TABLE I: EXPERTS' RANKING OF USABILITY FACTORS FOR HAPTIC SYSTEMS

Factors	Experts							
	E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*
Satisfaction	5	3	3	4	3	6	8	7
Safety	8	2	6	2	3	8	1	10
Efficiency	8	1	5	4	4	8	5	5
Learnability	9	5	4	8	2	7	2	5
Effectiveness	10	1	3	1	1	9	10	7
Productivity	6	3	5	2	3	10	8	8
Usefulness	10	2	1	5	1	10	10	7
Universality	8	5	7	2	8	6	2	8
Accessability	6	8	2	5	5	6	10	5
Trustfulness	6	4	6	4	5	8	10	8

This study shows that the importance of usability factors may vary on the basis of domain. At the same time, it is noted that above mentioned five factors are the common for all systems despite of any domain. Efficiency, effectiveness, learnability and satisfaction are highlighted as the most important factors by different usability models as described earlier in Section 1. Our results also strengthen the literature for these factors including safety that is somehow addressed by the literature e.g. [6]. For haptic systems, safety is considered the important factor and it makes sense because of unique nature of haptic systems i.e. dealing with haptic feedback. After deciding on the most important usability factors for haptic systems, it seems relevant to further investigate usability sub-factors relationship with the selected factors.

III. RELATIONSHIP BETWEEN USABILITY FACTORS AND SUB-FACTORS

Usability sub-factors (26 in total) given in [7] are associated with usability factors based on experience and assumption. These sub-factors are accuracy, appropriateness, feedback, attractiveness, completeness, consistency, insurance, controllability, familiarity, fault-tolerance, flexibility, likeability, loading time, minimal action, minimal memory load, navigability, operability, privacy, readability, resource safety, resource utilization, security, self-descriptiveness, simplicity, time behavior, and user guidance. The following sub-sections discuss the assessment of relationship between the selected factors and sub-factors.

A. Card Sorting

We chose closed card sorting method [10] to assess the relationship between the above mentioned sub-factors for five selected usability factors. The main aim of this activity was to find out the most appropriate sub-factors with respect to every selected factor. We conducted this activity with seven faculty members who were involved in HCI (Human Computer Interaction) course at undergraduate level. We asked them to categorize sub-factors for the selected usability factors in general (not for haptic systems) based on their experience and intuition. The rationale for general categorization is that relationship between factors and sub-factors is not dependent on any system or domain.

To conduct the activity, each card represented one unique sub-factor so 26 cards in total were to sort by each participant. Participants were free to place a card in none, one, or more than one group (five selected usability factors). In case of placing card in more than one group, the participants were provided with extra blank cards to use.

B. Analysis

Table II summarizes the results and shows the association of sub-factors with each specific factor. The higher value shows the higher degree of association between factors and sub-factors. The last column (Max.Value) shows the highest value of association between the specific sub-factor and factors. Figure 1 shows the complete results of the activity. Effectiveness and satisfaction are associated with many sub-factors. Satisfaction is associated with eleven sub-factors and likeability is the only sub-factor that is associated with it by all participants. Effectiveness has associated with nine sub-factors and the most important are consistency, navigability, and operability. There are only two sub-factors that are associated with the same factor unanimously. These sub-factors are likeability associated with satisfaction and resource safety associated with safety.

IV. DISCUSSION

Use The findings of interviews strengthen the literature and are valuable. Efficiency, effectiveness, satisfaction, and learnability are four most common factors that are addressed

in the literature. By the experts' feedback, we also found that these factors are considered the most important for evaluation of haptic systems independent of any specific domain. Besides it, safety is considered as an important factor for haptic systems. The one possible reason is that haptic devices often have direct contact with user's body. Secondly, these systems deal with force feedback and the consideration of human limitations is an important aspect of safety.

Usability evaluation is a resource consuming activity and we should optimize it by at least considering the above five usability factors for haptic systems in general. Although it seems difficult to accommodate every possible usability factor for evaluation, we may say that efficiency, effectiveness, satisfaction, and learnability must be considered for every system independent of domain.

Card sorting activity to find out the relationship between usability factors and sub-factors is also preliminary in nature. It provides the idea on coherent relationship of factors and sub-factors but it would be more interesting if the same activity is conducted with usability professionals. Another interesting point is that these all sub-factors are associated with five factors compare to [7] where these sub-factors are related with ten factors. Although the participants were free to not associate a sub-factor with any factor but none of them did it. There is also difference in approach to associate sub-factors with major factors e.g. fault-tolerance is associated with effectiveness by three participants but it is not the case in [7]. Similarly, operability is associated with effectiveness by three participants whereas it has no relation with effectiveness in [7].

TABLE II: ASSOCIATION OF FACTORS WITH SUB-FACTORS (IN %)

Sub-Factors	Factors					
	Efficiency	**Effectiveness**	**Satisfaction**	**Safety**	**Learnability**	**Max. Value**
Accuracy	29	57	14	0	0	57
Appropriateness	15	31	31	8	15	31
Attractiveness	0	14	71	0	14	71
Completeness	0	50	50	0	0	50
Consistency	15	38	23	8	15	38
Controllability	14	29	29	29	0	29
Familiarity	13	13	13	13	50	50
Fault-tolerance	18	27	18	27	9	27
Feedback	11	22	44	0	22	44
Flexibility	0	25	63	0	13	63
Insurance	14	0	0	86	0	86
Likeability	0	0	100	0	0	100
Loading time	86	0	14	0	0	86
Minimal action	44	22	11	11	11	44
Minimal memory load	25	25	13	0	38	38
Navigability	10	50	30	0	10	50
Operability	38	38	0	0	25	38
Privacy	0	0	33	67	0	67
Readability	20	20	30	0	30	30
Resource Safety	0	0	0	100	0	100
Resource utilization	63	38	0	0	0	63
Security	14	0	14	71	0	71
Self-descriptiveness	10	30	10	0	50	50
Simplicity	15	15	31	8	31	31
Time behavior	63	25	13	0	0	63
User guidance	18	27	9	0	45	45

V. CONCLUSION

Usability of software systems is an important concept and different models are proposed to define and measure it. Despite of different factors proposed in these models, there is no consensus on the selection of these factors. This paper found that efficiency, effectiveness, satisfaction, learnability, and safety are five important factors for evaluation of haptic systems. Besides it, this study also recommends efficiency, effectiveness, learnability, and satisfaction as the key factors for usability of other systems. The relationship of these factors with sub-factors is also studied and consistent relationship is found between every factor and a few relevant sub-factors.

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