User Experience in HMI: An Enhanced Assessment Model

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***Abstract*—In recent years, User Experience has become increasingly recognized as an important and determinant factor in the design, development and evaluation in Human-Computer Interaction and Human-Machine Interaction. There are many user experience models reported in the literature to reflect this recognition. However, the industrial interpretation of the term user experience is largely based on traditional User-Centred Design methods and generally does not make a clear distinction of user experience from the perspective of user-centred design and usability. In reality, user experience is still often considered as a synonym of usability and user-centred design. In this paper, we briefly discuss important user experience models reported in the literature in the light of user experience and usability. Based on our analysis, we propose an enhanced usability model that can be used for user experience assessment in human-machine interaction. We also present the results of a pilot study to validate our proposed model and the instrument employed.**

I. Introduction

Over the years, the term 'usability' has been widely accepted as an important factor in product acceptance. Evaluations in Human-Computer Interaction (HCI) and Human-Machine Interaction (HMI) are important to determine the success and level of performance of artefacts in terms of usability. According to the International Organization for Standardization (ISO), usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [1]. *Effectiveness* means the user ability to fulfil intended goals through product use, *Efficiency* refers to the user ability in fulfilling these goals with a minimum of effort, and *Satisfaction* provides the overall attitude to the product and subjective perception on the product usage as to whether the user is pleased with the product or not. According to Tractinsky and Zmiri [2], usable products smooth the human-computer interaction, making it efficient and effortless, and in turn, can potentially enrich the users' experience and improve their satisfaction. The 'satisfaction' component of the ISO definition is related to the user perception of the effectiveness and efficiency of the product. That is, if the product users perceive that the product is effective and efficient, they can be assumed to be satisfied with the product [3]. Emphasizing product usage, Buxton [4] highlighted that the quality of experience invoked by interacting with products contributes to the satisfaction. An end-user experiences these aspects during a product interaction. Having performed a series of lab experiments to identify the factors that contribute to user satisfaction, Lindgaard [5] reported five categories of significance, namely: aesthetics, emotion, likeability, expectation, and usability. Moreover, Lindgaard suggests that user satisfaction is a statement about, or a judgment of, the user experience. A previous study of Lindgaard and Dudek [6] also acknowledged that user experience consists in some sense of 'satisfaction' (such as aesthetics, emotion, expectation, likeability and usability) that influence the interactive experience.

In this paper, we discuss important user experience models reported in the literature and derive an enhanced usability model and assessment criteria for user experience assessment in HMI and HCI. We also present details of a pilot study to validate our proposed model and instrument.

II. User Experience

In recent years, User Experience (UX) has become increasingly recognized as an important and determinant factor in design, development and evaluation of human-computer interfaces and man-machine interfaces. It aims to gain a more holistic understanding of users' experiences with products around new concepts like pleasure [7], fun [8], aesthetics [9] and hedonic qualities [10]. While there are many User-Centred Design (UCD) oriented methods and techniques exist for ensuring the usability of products, user experience design and evaluation methods are still evolving. Recent developments in UX research reflect a new trend and value that has become central to the design, development and evaluation of interactive systems and

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products. The term User Experience was initially proposed by Norman [11] who described it as encompassing all aspects of users' interaction with a product. Jeffries introduced UX as an aspect that include factors impacting the totality of one's experience with a product, from initial awareness through to upgrading to the next version [12]. A more recent ISO standard [13] defines the UX as a person's perceptions and responses that result from the use or anticipated use of a product, system or service emphasising two main aspects: 'use' and 'anticipated use'. This definition sits well with the description of experience given by McCarthy and Wright [14] which highlights that users sense the experience in six different ways, namely: connecting, interpreting, reflecting, appropriating, recounting, and anticipating. UX assessment is an evaluation of the user's experience of the usage of a product, system or service. Accordingly, 'use' (i.e., actual interaction experience) as well as 'anticipated use' (i.e., pre-interaction experience such as needs and expectations) is equally important for consideration in UX assessments.

III. User Experience Models

In the context of interaction design, Preece, Rogers and Sharp [15] have discussed UX and usability emphasising that UX goals were different from usability goals. According to them, UX goals are more concerned with how users experience an interactive system from their perspective rather than assessing how useful or productive a system is from the product's own perspective. Their definition of UX goals are: satisfying, enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing, supportive of creativity, rewarding and emotionally fulfilling. Their UX model is shown in Figure 1.

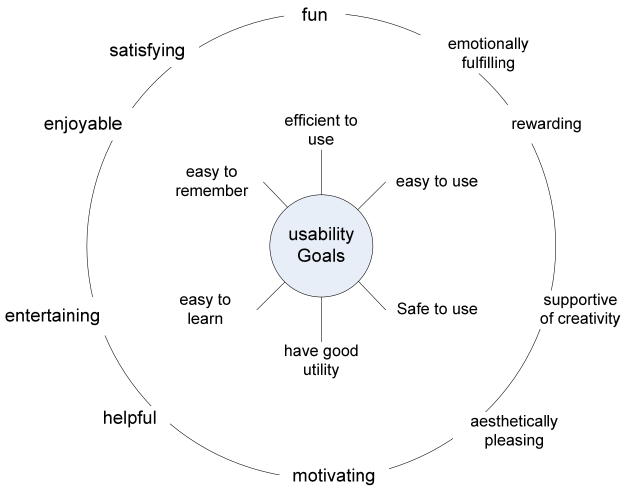

Fig. 1. Usability and UX goals [15].

Figure 1 clearly shows that UX is at a level beyond that of usability and occurs as a result of achieving usability goals during an interaction. The model consists of six usability goals namely: efficient to use, effective to use, safe to use, having good utility, easy to learn, and easy to remember. Importantly, the model does not consider 'satisfaction' as a usability goal at the operational level; instead, it shows as a UX goal. Another important difference in this model is that of 'safety' which has been included as a primary usability goal.

A newer ISO standard ISO/IEC CD 25010 [16] recognises 'Safety' as one of the main areas of quality in use and refers to an acceptable level of risk of harm to people, business, data, software, property or the environment in the intended context of use. From an end-user perspective, a safe and secure design is important in minimising occupational health and safety issues such as Repetitive Strain Injury (RSI) and in maximising secured user transactions and information security (i.e., to protect personal and business information). Accordingly, safety is an important factor to be considered as a usability attribute and goal. Preece, Rogers and Sharp also pointed out that interaction design should not only set usability goals for product design but also set UX goals to assess whether the product is enjoyable, satisfying and motivating. Taking this view further, Sharp, Rogers and Preece [17, p.26] described an enhanced version of UX goals that included additional positive as well as negative goals, namely: engaging, pleasurable, exciting, cognitively stimulating, provocation, surprising, challenging, enhancing sociability, boring, frustrating, annoying and cutesy. They described many of these goals as subjective qualities concerned with how a system feels to a user. They also highlighted that not all usability and UX goals will be relevant to the design and evaluation of an interactive product (or system) as some combinations will not be compatible.

According to Hassenzahl [18], the origins of UX can be seen from two different views: pragmatic quality and hedonic quality. Pragmatic quality refers to the product's perceived ability to support the achievement of *do-goals* (such as making a telephone call) whereas hedonic quality refers to the product's perceived ability to support the achievement of *be goals* (such as being competent or being related to others). In comparison, Pragmatic quality calls for a focus on the product; its utility and usability in relation to potential tasks while Hedonic quality calls for a focus on the self, i.e., the question of why does someone own and use a particular product. Hedonic quality is more general human needs beyond the instrumental such as a need for novelty and change, personal growth, self-expression and/or relatedness. In summary, Hassenzahl argues that the fulfilment of be-goals is the driver of experience, and that pragmatic quality facilitates the potential fulfilment of be-goals.

Hassenzahl and Tractinsky [19] define UX as a consequence of: the user's internal state (predispositions, expectations, needs, motivation, etc.), the characteristics of the designed system (complexity, purpose, usability, functionality, etc.) and the context within which the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.). In terms of technology interaction, they see UX as a combination of three perspectives: beyond the instrumental, emotion and affect, and experiential. Their view of UX is shown in Figure 2.

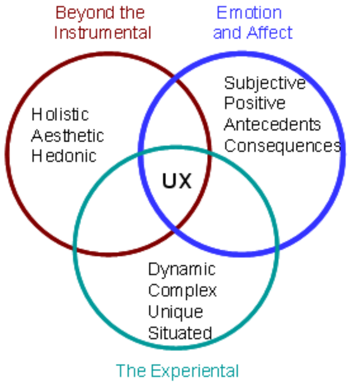

Fig. 2. UX view by Hassenzahl and Tractinsky [19].

Moreover, Hassenzahl [18] emphasises that UX is an evaluative feeling of the user while interacting with a product or service, with a shift of the attention from the product (i.e., content, function, presentation, interaction) to humans and feelings (i.e. subjective side of product use).

Many of the UX models reported in the literature are diverse, yet also share many common viewpoints. Specifically, these models seek to complement a purely functional analysis of user interaction with an account of the sensual, emotional, social and cultural aspects of peoples' relationships with technology [20]. Having discussed models and theories of experience, Forlizzi and Battarbee [21] state that experience in interactive systems can be examined and modelled from three perspectives, namely: product-centered, user-centered, and interaction-centered. Product-centered models provide information to assist the creation of products that invoke compelling experience. User-centered models help designers and developers to better understand the users of their products. Interaction-centered models help explore the role that products serve in bridging the gap between designer and user. The definition of UX given by Hassenzahl and Tractinsky [19] also includes user perspective (the user's internal state), product perspective (the characteristics of the designed system) and context of interaction perspective (the context within which the interaction occurs). Accordingly, UX is a mixture of these three perspectives: product-centred, user-centred and interaction-centred. Figure 3 shows a UX model based on the experience model given by Forlizzi and Battarbee [21] and the UX definition given by Hassenzahl and Tractinsky [19].

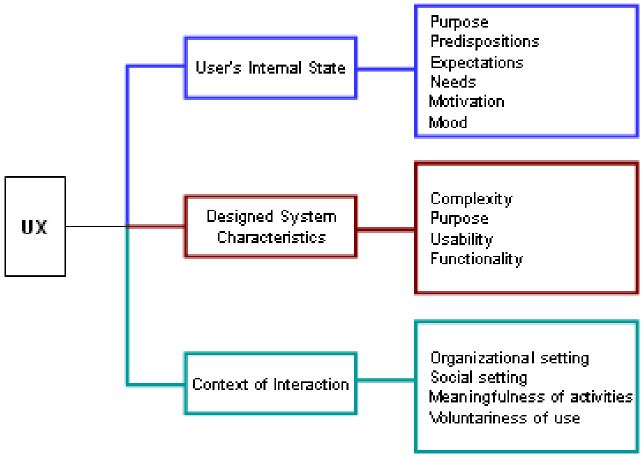

Fig. 3. UX model based on [21] and [19].

In Figure 3, User Perspective relates to the user's internal state (such as needs, expectations and motivation). Product Perspective is about the Designed system's characteristics (such as purpose, usability and functionality) and Interaction Perspective focuses on the context of interaction (such as organisational setting, social setting and activities), and all contribute to the overall consequence of UX.

Extending the interaction viewpoint of Figure 3 further, we present an abstract model of UX to show that overall UX is generated as a result of three abstract phases of a user's interaction with a product, service or a facility, namely; pre-interaction experience, actual-interaction experience and post-interaction experience (see Figure 4).

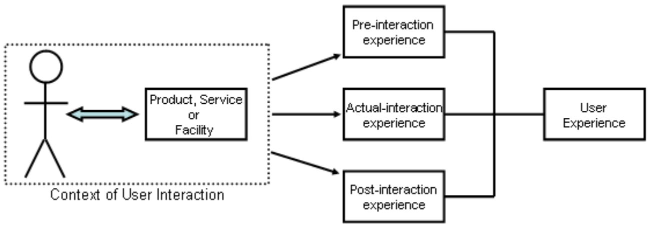

Fig. 4. Interaction UX model with three phases.

In a recent publication, Bevan [22] highlighted that how product attributes relate different aspects of UX. According to Bevan, direct measurement of actual experience of usage is difficult; the measurable consequences are the user performance, satisfaction with achieving pragmatic and hedonic goals, comfort and pleasure. User performance and satisfaction is determined by quality characteristics such as attractiveness, functional suitability, ease of use, learnability, accessibility and safety. Figure 5 presents Bevan's view on how the measures of usability and UX are dependent on the product attributes that support different aspects of UX [22].

Quality characteristic	UX	Functionality	User interface usability	Learnability	Accessibility	Safety
Product attributes	Aesthetic attributes	Appropriate functions	Good UI design (easy to use)	Learnability attributes	Technical accessibility	Safe and secure design
UX pragmatic do goals	To be effective and efficient					
UX hedonic be goals	Stimulation, identification and evocation					
UX: actual experience	Visceral	Experience of interaction				
Usability (= performance in use measures)	Effectiveness and Productivity in use: effective task completion and efficient use of time			Learnability in use: effective and efficient to learn	Accessibility in use: effective and efficient with disabilities	Safety in use: occurrence of unintended consequences
Measures of UX consequences	Satisfaction in use: satisfaction with achieving pragmatic and hedonic goals					
	Pleasure	Likability and Comfort				Trust

Fig. 5 Factors contributing to UX [22]

As an example, for the 'Learnability' quality characteristic in Figure 5, there should be learnability product attributes to ensure that the end-user is able to achieve UX pragmatic do goals for effective and efficient, and also achieve UX hedonic be goals for stimulation, identification and evocation. These pragmatic and hedonic goal achievements contribute to the actual UX and usability. Moreover, Bevan points out that the measures of UX consequences can be represented by means of satisfaction in use, with a specific focus on pleasure, likeability and trust. This view is shown as a model in Figure 6.

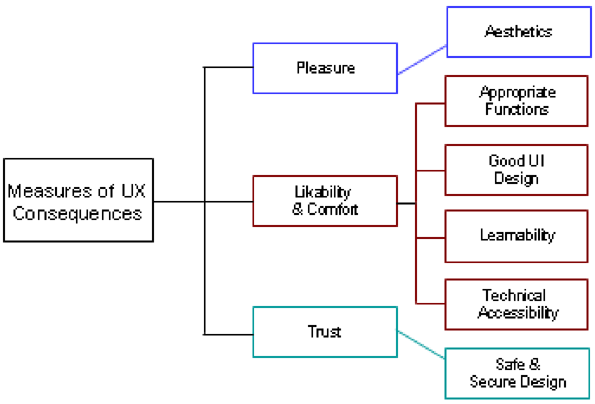

Fig. 6. UX model based on Figure 5.

Petrie and Bevan [23] have acknowledged that users of new technologies (such as the internet, portable media players, and new mobile phones) are not necessarily seeking just to complete a useful task, but also to amuse and entertain themselves. Accordingly, Petrie and Bevan consider that UX, as a concept, emerged to cover the components of users' interactions with, and reactions to, eSystems (electronic systems) that go beyond usability. Traditionally, usability emphasises the appropriate achievement of particular tasks in particular contexts of use with effectiveness, efficiency and conventional satisfaction.

We consider UX assessment as a development of extending usability with the enhanced criteria of assessment to determine the product success so that the product and its usage can be improved wherever necessary. Figure 5 also shows that UX and usability are not two distinct concepts, but have interrelated aspects that contribute equally to providing the overall UX and usability of a system.

IV. Extending Usability for UX Assessment

There are many definitions given to usability by different authors such as [24], [25], [15], [26] etc., where satisfaction is a commonly shared viewpoint. In their study, Lindgaard & Dudek [27] highlight that UX consists in some sense of satisfaction, and emphasise that aesthetics, emotion, expectation, likeability and usability all influence the interactive experience. In a recent research study on usability and UX, Naumann, Wechsung and Schleicher [28] reported that user satisfaction received the highest agreement as a criterion of UX. Accordingly, satisfaction can be used as an important attribute of usability for usability, as well as UX, assessment with relevant assessment criteria. Therefore, an enhanced usability model with more focus on satisfaction can be used to probe the satisfaction usability attribute in more depth, beyond the conventional satisfaction associated with traditional usability effectiveness and efficiency, so that insights can be explored to identify how the user feels about the interaction with a product, service or facility.

For UX assessments, we propose a usability model consisting of eight usability attributes: satisfaction, functional correctness, efficiency, error tolerance, memorability, flexibility, learnability and safety. This is an enhancement of the previous model presented by Adikari and McDonald [29], with an additional inclusion of the safety usability attribute. Our proposed usability model is shown in Figure 7 and it serves as an extension to Bevan's model shown in Figure 6.

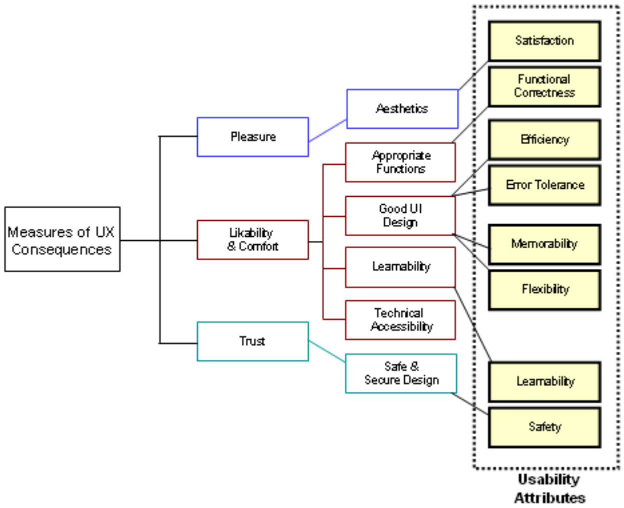

Fig. 7. Proposed usability model.

In our proposed usability model, we have not considered Technical Accessibility (TA) as a usability attribute. TA refers to access to the system and content. Poor TA in a system is likely to impact the usability and UX. In future research, we will study TA in more detail to determine its impact on usability and UX.

V. User Experience Assessment Criteria for Satisfacion Usability Attribute

In Figure 7, the satisfaction usability attribute primarily focuses on aesthetics only. As discussed in section I and IV, the satisfaction attribute can be used beyond aesthetics and conventional satisfaction to provide a broad view of experience on satisfaction in use; that is, satisfaction in achieving pragmatic and hedonic goals. This section details how we derived assessment criteria for the satisfaction usability attribute. There are many definitions for the term aesthetics, such as visual appeal [27], beauty in appearance [30], a response or a judgment [10], [31] etc. A common viewpoint of these definitions is that aesthetics is related to pleasure and harmony, which human beings are capable of experiencing [5]. Accordingly, we consider *Visual appeal* and *Pleasure in interaction* as our first two assessment criteria. In Figure 3, we have shown that Expectations which affect a User's Internal State, contribute to the UX; hence we chose *Meeting expectations* as our third assessment criterion. According to Ketola and Roto [32], Frustration is a measure that could be used to assess UX obstacles in an interaction; therefore, *Less frustration* has been selected as an assessment criterion. Confusion or lack of understanding is considered as impacting on creating an overall positive user experience [33], hence we have included *Less confusing terminology* as an assessment criterion. Lastly, the assessment criterion *Overall experience of using the system* was included to receive a subjective opinion from the user on the overall experience of interaction.

VI. Complete User Experience Assessment Criteria

Table I shows the complete list of assessment criteria for the usability attributes in our proposed usability model shown in Figure 7. Particularly, based on our analysis given in section V, the satisfaction usability attribute examines six positive and negative UX aspects: visual appeal, pleasure in interaction, meeting expectations, less frustration, less confusing terminology, and overall experience of using the system.

TABLE I
UX ASSEESSMENT CRITERIA

SATISFACTION
Visual appeal
Pleasure in interaction
Meeting expectations
Less frustration
Less confusing terminology
Overall experience of using the system
FUNCTIONAL CORRECTNESS
Completing tasks correctly
Available facilities to meet user needs
Available information to make decisions
EFFICIENCY
Completing tasks quickly
Achieving expected outcome
Completing tasks easily
ERROR TOLARANCE
Causes fewer errors
Clear error messaging for invalid conditions
Error messages that inform which actions to take
MEMORABILITY
Easiness to remember task steps
Needing to memorise task steps
Needing to access Help documents
FLEXIBILITY
Alternative ways to perform tasks
Navigating back/forward between task steps
User ability to cancel an operation
LEARNABILITY
Ease of learning system operation
Clarity of system status
Knowing what to do next during navigation
SAFETY
Fewer keystrokes
Security measures to protect personal information
Security measures to protect user transactions

VII. PILOT STUDY

A comparative evaluation questionnaire was developed based on the assessment criteria in Table I. A pilot study was conducted with 32 library system users (participants) on two different online library systems (S1 and S2) that were already in use. The main objective of the study was to validate the UX assessment criteria and instrument. We conducted the UX assessment in two groups (G1 and G2). Participants in G1 first assessed system S1 followed by S2, while participants in G2 first assessed system S2 followed by S1. We followed this approach to minimise and balance any learning effect bias in the assessments. All participants used the same scenario to assess both systems S1 and S2. Finally participants filled out the comparative evaluation questionnaire to express their system preference (S1/S2 strongly preferred, S1/S2 moderately preferred, or No difference) in terms of each assessment criteria. A section of the questionnaire is shown in Figure 8.

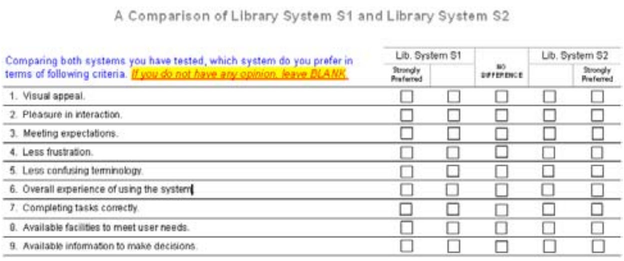

Fig. 8. A section of the comparative questionnaire.

Table II shows user responses from group G1 and G2 separately, as well as the total combined responses from both G1 and G2. According to Table II, group G1 preferred S2 over S1 with 88 strongly preferred scores for S2 against 12 for S1, and 107 moderately preferred scores for S2 over 23 for S1. Participants in G1 also identified that S1 is very similar to S2 with 161 no difference scores. A similar pattern of results was evident from group G2 which also preferred S2 over S1 with 88 strongly preferred scores for S2 against 6 for S1, and 70 moderately preferred scores for S2 over 34 for S1. Similar to G1, participants in G2 also identified that S1 is much similar to S2 with 202 no difference scores.

As a whole, the results clearly demonstrate that both the G1 and G2 groups preferred S2 against S1 with 176 strongly preferred scores for S2 over 18 for S1, and 177 moderately preferred scores for S2 against 57 for S1. Importantly, participants in both groups found that S1 and S2 were very similar for many assessment criteria with 363 no difference scores. This is not an unexpected result given the fact that both online library systems used in this pilot study were fully functional and in regular use in the public domain.

TABLE II
RESULTS

User Preference	Number of Responses **Group G1**	Number of Responses **Group G2**	Total Responses **(G1 + G2)**
S1 Strongly preferred	12	6	18
S1 Moderately preferred	23	34	57
S1=S2 (No Difference)	161	202	363
S2 Strongly preferred	88	88	176
S2 Moderately preferred	107	70	177

In this comparative user experience assessment study, the main emphasis was to highlight any differences between the systems and to determine if either system was preferred by the users. Accordingly, the evidence on the similarities between the systems was less significance. In this pilot study, we were interested in revealing that one of the systems was preferred as a whole by the user, in terms of the assessment criteria. Hence, we assigned weight factors in the order of importance; '0' (zero) to the user preference 'S1=S2 (No Difference)' to make it neutralised, '1' to the user preference 'S1 Moderately Preferred' and 'S2 Moderately Preferred', and '2' to the user preference 'S1 Strongly Preferred' and 'S2 Strongly Preferred'. Table III shows how we calculated the overall score for user preferences based on our weight factor assignment.

TABLE III
RESULTS

User Preference	Number of Responses **(R)**	Weight Factor **(W)**	Overall Score **(R*W)**
S1 Strongly preferred	18	2	36
S1 Moderately preferred	57	1	57
S1=S2 (No Difference)	363	0	0
S2 Strongly preferred	176	2	352
S2 Moderately preferred	177	1	177

Figure 9 shows the overall score of user preferences for both systems S1 and S2.

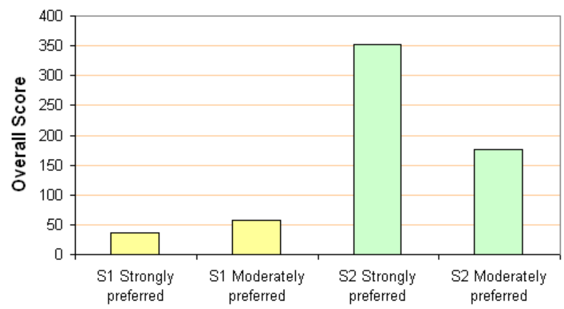

Fig. 9. A overall score of user preferences for both systems S1 and S2.

According to the results shown in Table III and Figure 9, users preferred the library system S2 over S1 in terms of UX assessment criteria, with 352 strongly preferred scores and 177 moderately preferred scores for S2 against

36 strongly preferred scores and 57 moderately preferred scores for S1.

VIII. CONCLUSIONS

In this paper, we have integrated and accommodated a number of approaches to UX modelling and derived a well-grounded assessment instrument that can be used to conduct an effective UX assessment in HMI. We also presented an approach to conduct a comparative UX assessment on two systems, and data analysis and results of a pilot study. The UX assessment criteria detailed in this paper also can be used for UX assessment on single/multi-systems or interfaces either in a qualitative or quantitative research setting.

The main objective of the pilot study was to validate the assessment criteria and the capability and suitability of the instrument for a research study that use two systems for comparative user experience assessments. These results clearly demonstrate that the assessment criteria and instrument were successful in generating results that highlighted the system differences.

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