Usability evaluation of a comprehensive national health information system: A heuristic evaluation

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ARTICLE INFO

ABSTRACT

Aim: to evaluate the usability of a comprehensive national health information system by the heuristic method.
Introduction: Presently, information systems are widely being used in healthcare settings.
Methods: Five independent evaluators assessed the user interface design of this system in terms of its compliance with a set of predetermined standard principles, also known as Jakob Nielsen's 10 general principles. Problems were reassessed in the presence of all evaluators, and similar cases were merged and a single list of unique problems was prepared. After a second assessment, the evaluators determined and categorized problem severity in five domains, including: the absence of a problem (zero point), a cosmetic problem (1 point), a minor problem (2 points), a major problem (3 points) and a catastrophic problem (4 points). Data were then analyzed in a spreadsheet using descriptive statistical tests.
Results: The "recognition rather than recall" principle with 13 problems (21.3% of all cases) had the greatest frequency among all problems, while the "match between system and the real world" and "help and documentation" principles with 1 problem (1.6% of all cases) had the least frequency. Moreover, principles such as "help users recognize, diagnose and recover from errors", "error prevention", and "help and documentation" had a mean severity of 2.8, 2.8, and 3.4, respectively. Consequently, they were considered as catastrophic and major problems.
Conclusions: Based on the viewpoint of evaluation experts, a large portion of problems in this system were classified into major and catastrophic categories, which primarily indicates the poor usability of this system. Therefore, it is highly recommended that authorities be notified of the issues in writing in order to resolve them in a future update. Finally, special consideration should be given to the meticulous evaluation of these systems during preliminary stages of design and development, so as to encounter fewer issues on a national level at the time of implementation.

1. Introduction

Currently, information systems are widely used in various healthcare settings. These systems have an important role in providing safe, on-time, effective, and efficient healthcare services [1,2]. However, studies have revealed that a number of information systems are not fully accepted by their users; thus, they may not be able to achieve their predetermined targets [3]. Reasons for the low acceptance rate include the development of new errors, a low ease-of-use score, and usability problems associated with the user interface quality [4–6]. Generally,

usability can be regarded as one of the key features of information system quality. Usability can be defined by ease-of-use and the extent to which a product is utilized with effectiveness, efficiency, and satisfaction by specific users for various goals [7]. Furthermore, a poor usability score causes a decline in the efficiency of users and an overall dissatisfaction with respect to the system [8–10]. Systems with usability problems increase the chance of error and may lead to a disaster [11,12]. On the other hand, systems with a high usability score aid users to rapidly and easily carry out their tasks with the least amount of mental effort [13]. Therefore, it is highly recommended that the system usability be

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regularly evaluated in order to identify and resolve any unforeseen problems [3,14,15].

Different methods exist for the usability evaluation of information systems, including the heuristic evaluation method [11]. In this method, experts evaluate the compliance of the user interface design in terms of a series of predetermined standard principles [11,16,17]. Due to numerous advantages of this method, including low cost, easy to implement and learn, high efficiency, implementation under limited time and resources, and rapid feedback response, this method is probably the most-used usability evaluation method for user interface design [11,18,19]. In addition, a large number of studies have successfully applied heuristic evaluation for the usability evaluation of healthcare information systems. For instance, commercially-available dental computer-based patient record systems [15] and computer-based patient training programs [20] were evaluated by the heuristic method. The results indicated that numerous severe usability problems exist in the investigated systems. Moreover, in a study by Thyvalikakath et al. [21], it was indicated that on average, 50% of usability problems are identified by the heuristic evaluation method.

Based on Iran's healthcare system reform plan in 2014 [22], the Integrated Health System (SIB in Persian) was founded in 2015 with the aim of providing integrated healthcare services to the public, offering special requirements for the successful implementation of the referral system, accessing the archived reports of the general population healthcare state, and finally, promoting the quality of healthcare services. From the very beginning until the end of 2017, this system had registered electronic health records for more than 70 million people in Iran. On the other hand, more than one hundred thousand users, including physicians, psychologists, nutritionists, healthcare providers, and paramedics are providing valuable services in more than thirty thousand centers in Iran. Therefore, due to the prevalent use of the integrated health system across the country and its critical role in providing healthcare services, its usability should have been carefully evaluated prior to its widespread use. However, to our best knowledge, no study has been carried out yet that evaluates the usability of the integrated health system [23]. Thus, this study was conducted in order to evaluate the usability of the national integrated health system at health centers and homes affiliated with the Kashan University of Medical Sciences using the heuristic method.

2. Methods

2.1. General description of system under study and research setting

This descriptive cross-sectional study was conducted in 2017 at health centers and homes affiliated with the Kashan University of Medical Sciences. Based on a survey of users, the system was mainly used to enter and register data related to pediatric cases. Therefore, the usability evaluation of user interface was investigated for pediatric cases. The system was operational in 96 health centers of Kashan and 535 users were interacting with it on a daily basis. Since the system was used in health centers and homes similarly, heuristic evaluation was conducted solely in terms of the user interface design in order to identify any usability problems. Furthermore, it should be mentioned that various types of data entered into the systems in different centers were not considered in this study. Thus, it can be concluded that the usability evaluation was not affected by the research setting and the same results can be obtained if the usability evaluation is repeated for other health centers.

2.2. Evaluation method

The heuristic evaluation method is one of the most well-known methods for usability evaluation of the user interface of a system without involving users [11]. In this method, 3–5 evaluators assess the user interface in terms of compliance with a set of predetermined

standard principles (Jakob Nielsen's 10 general principles) [9]. After identifying the problems, their severity and finally, their future consequences for the users may be determined [17].

2.3. Usability evaluators

The present study was conducted by 5 experts in heuristic evaluation. An expert with a Ph.D. in Health Information Management and 20 years of experience in teaching health information management, an expert with a Ph.D. in medical informatics, two Ph.D. candidates of Health Information Management holding master's degrees in health information technology, who had experience in working with different health information systems, and a M.Sc. student of Health Information Technology familiar with health information systems were among our participating experts. Moreover, evaluators had previously participated in one or more usability evaluation studies and were consequently familiar with heuristics evaluation methods and SIB.

2.4. Data collection method

This study was conducted in 4 stages:

First stage: evaluators investigated the user interface and SIB structure in order to become familiar with the system.
Second stage: Experts independently evaluated the user interface of the system in terms of compliance with the Jakob Nielsen's 10 general principles and entered the usability problems in a data collection form. This form consisted of a 4-column table, including problem title, problem description, problem location, and conflict with usability principles.
Third stage: Evaluators reviewed five lists of identified problems, where similar issues were discarded from the list and a single list of unique problems was finally prepared. Moreover, any disagreement over the problems was discussed, and any dispute regarding their assignment to the Jakob Nielsen's 10 general principles was resolved.
Fourth stage: evaluators determined the severity of problems by an independent second assessment of the user interface based on the following criteria [24].

- **Frequency** of exposure to risk: whether the problem occurs frequently or rarely.
- **Impact** of the problem on the user experience: whether the problem is easy to overcome.
- **Persistence of the problem:** whether the problem is solved on the first attempt, whether its recurrence causes any problems.

Thereafter, the mean severity of problems is extracted based on Table 1. Provided that one of the principles was absent in the system, the principle is considered as catastrophic and scored only once. Finally, data were analyzed in an Excel sheet using descriptive statistics.

3. Results

Five evaluators carried out the Heuristic evaluation for the SIB, where 116 usability problems were identified. Since duplicate data were excluded, 61 unique problems remained. Consequently, our analysis was

Table 1
Rating scale used to rate the severity of usability problems [25].

Problem	Severity	Description
No problem	0	I don't agree that this is a usability problem at all
Cosmetic	1	Need not be fixed unless extra time is available on project
Minor	2	Fixing this should be given low priority
Major	3	Important to fix, so should be given high priority
Catastrophe	4	Imperative to fix this before product can be released

performed based on these unique problems.

Results revealed that 24 (39.4%) out of the 61 unique problems, were, in fact, minor problems, 34 (55.7%) of them were major problems, and only 3 (4.9%) were considered as catastrophic problems. The "recognition rather than recall" principle was mentioned 13 times (21.3%) and had the most frequency with a mean severity score of 2.4, which categorized this issue as a major problem (Table 2).

The "match between the system and the real world" and "help and documentation" principles were each mentioned once (1.6%) and had the least frequency with mean severity scores of 2.6 and 3.4, respectively, which categorized them as major and catastrophic problems, respectively. The "help users recognize, diagnose and recover from errors", "error prevention", and "help and documentation" principles with mean severity scores of 2.8, 2.8, and 3.4, respectively, were considered as the most severe problems. Moreover, 50% of the problems were associated with 8 principles (1, 2, 3, 5, 6, 7, 8, and 10) and were considered as major and catastrophic problems. In addition, other usability problems, including "consistency and standards" and "aesthetic and minimalist design" were placed in the minor problem category. Whereas, 61% of problems related to other heuristics (37 out of 61 in total) were considered as major and catastrophic problems (Fig. 1).

Identified problems based on the heuristic evaluation:

1 **Visibility of system status:** 12 problems (19.7%) were incompliant with respect to this principle, where the mean severity score was 2.5. A number of mentioned problems were as follows:
   - Vague messages displayed by the system.
   - Scanned book pages as the system user guide.
   - Vague system performance, for instance, the patient's referral window still remains active after registration is completed.
2 **Match between system and the real world:** 1 problem (1.6%) was incompliant with regard to this principle where the mean severity score was 2.6. A problem of this type:
   - Mismatch between the function and symbol of icons.
3 **User control and freedom:** 5 problems (8.2%) were incompliant with regard to this principle where the mean severity score was 2.5. A number of mentioned problems were as follows:
   - Lack of the back button to the previous page.
4 **Consistency and standards:** 9 problem (14.7%) were incompliant with regard to this principle where the mean severity score was 1.8. Frequently mentioned problems were as follows:
   - Checkbox was used for multiple-choice questions instead of a radio button as the preferred method.
   - Units, number fonts, date, and texts were all in English (Fig. 2).
5 **Help users recognize, diagnose and recover from errors:** 4 problems (6.6%) were incompliant with regard to this principle where the mean severity score was 2.8. Frequently mentioned problems were as follows:
   - Unclear process of data correction after their confirmation.

   - Inability to cancel or revise the entered data.
   - Inability to open error feedback in a separate window.
6 **Error prevention:** 4 problems (6.6%) were incompliant with regard to this principle where the mean severity score was 2.8. Frequently mentioned problems were as follows:
   - No confirmation message after a process is completed.
   - System performance failure, for instance, clicking the confirmation button in the event of a lack of referral results in a displayed message regarding this issue, however, clicking the cancel button and then the confirmation button causes a system failure.
   - Upper and lower range limit values were not mentioned.
7 **Recognition rather than recall:** 13 problems (21.3%) were incompliant with regard to this principle where the mean severity score was 2.4. Frequently mentioned problems were as follows:
   - Questions were displayed in multiple pages.
   - Inappropriate visual feedback.
   - The user manual did not offer very useful content.
8 **Flexibility and efficiency of use:** 2 problems (3.3%) were incompliant with regard to this principle, where the mean severity score was 2.3. The frequently mentioned problems were as follows:
   - Existence of long phrases in pages.
   - Inability of the combo box in the referral page to search by more than two first letters of a word.
9 **Aesthetic and minimalist design:** 10 problems (16.4%) were incompliant with regard to this principle, where the mean severity score was 2.0. The frequently mentioned problems were as follows:
   - A similar color was used for the title, confirm, and register buttons (Fig. 3).
   - Unnecessary usage of pages for a single process.
   - Similar fonts and sizes for all letters.
10 **Help and documentation:** The system lacked any feature related to this principle; thus, it was considered as a catastrophic problem, with a mean severity score of 3.4.

4. Discussion

Among a total of 61 identified unique problems, 24 (39.4%) were considered as minor problems, 34 (55.7%) were regarded as major problems, and 3 (4.9%) of them were catastrophic problems. The "recognition rather than recall" principle with 13 problems (21.3% of all cases) had the most frequency among problems, with a mean severity score of 2.4, which categorized this issue as a major problem. The "match between system and the real world" and "help and documentation" principles with 1 problem each (1.6% of all cases) had the least frequency, with mean severity scores of 2.6 and 3.4, respectively, which categorized them as major and catastrophic problems, respectively.

Table 2
The frequency of severity of problems based on the principles of heuristic evaluation.

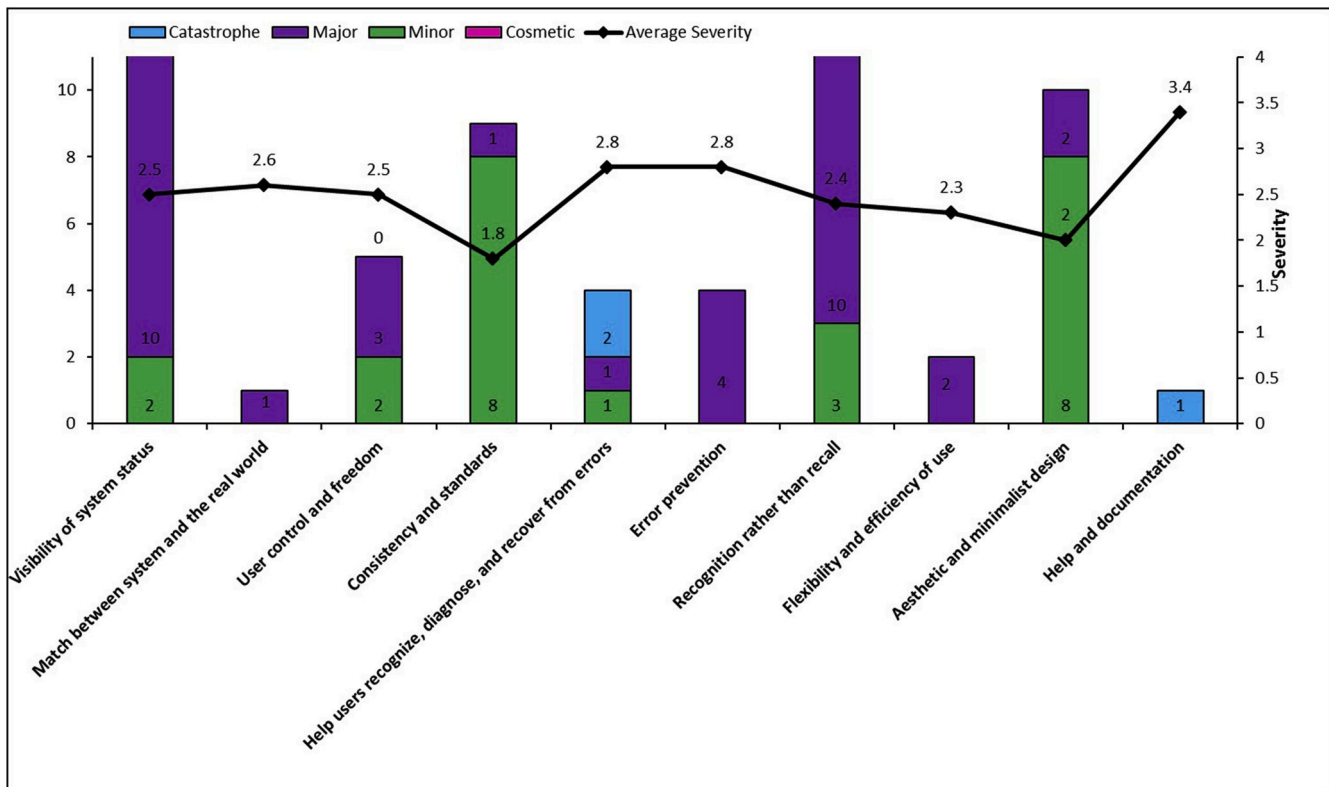| Heuristic evaluation principles	Average severity	Severity				Total	
		Cosmetic	Minor	Major	Catastrophe	Frequency	%
Visibility of system status	2.5	0	2	10	0	12	19.7
Match between system and the real world	2.6	0	0	1	0	1	1.6
User control and freedom	2.5	0	2	3	0	5	8.2
Consistency and standards	1.8	0	8	1	0	9	14.7
Help users recognize, diagnose, and recover from errors	2.8	0	1	1	2	4	6.6
Error prevention	2.8	0	0	4	0	4	6.6
Recognition rather than recall	2.4	0	3	10	0	13	21.3
Flexibility and efficiency of use	2.3	0	0	2	0	2	3.3
Aesthetic and minimalist design	2	0	8	2	0	10	16.4
Help and documentation	3.4	0	0	0	1	1	1.6
Total	2.51	0	24	34	3	61	100
		%0	39.4%	55.7%	4.9%	100	

Fig. 1. Comparison between frequency and severity of the problems from the principles of heuristic evaluation.

Fig. 2. Heuristic violations of consistency and standards.

Furthermore, the findings of this study revealed that the "help and documentation" principle had the most severe usability problem with a mean score of 3.4 and subsequently was considered as catastrophic. Similar to the present study, other studies carried out by Khajouiei, Atashi and Mirabootalebi [17,26,27] addressed a lack of "help and documentation" section in the system. Moreover, other researchers reported problems associated with this principle as catastrophic [9,13] and major [3,28–31]. Finally, in all of these studies, the problems associated with "help and documentation" were considered to be major; thus, the findings of the present study are consistent with the results mentioned in previous studies.

However, in other studies [32,33], the severity of problems associated with this principle were classified as minor, which was inconsistent with the findings of the present study. In addition, most of the investigated systems lack a "help and documentation" section while in those that have provided one, numerous design flaws and major problems were identified. In the present study, the low number of problems in this principle was due to the fact that the integrated health system lacked any information in this regard. Therefore, no usability problem was identified for this principle. In other words, a user cannot receive help in the event of a problem. Moreover, previously conducted studies revealed that the "help and documentation" section is underdeveloped in other investigated systems where a need for improvement can be clearly observed. Based on the viewpoint of evaluators in terms of improving the quality of user interface and system performance, it is highly recommended that a "help and documentation" section be added

Fig. 3. Heuristic violations of Aesthetic and minimalist design.

to software in order to witness a usability improvement in this information system.

The problems associated with the "help users recognize, diagnose and recover from errors" principle, with a frequency of 4 and a mean severity score of 2.8, were also regarded as major. In separate studies [26,28] the problems in this principle were considered as catastrophic. In other studies [9,17,20,30,32] the problems in this principle were considered as a major problem. The findings of this study are consistent with that of the mentioned studies. However, in the studies [29,31,33, 34] the problems in this principle were classified as minor, which was inconsistent with the obtained results in this study. Based on this principle, error messages must be stated in a simple language, the problem must be shown clearly, and a possible resolution must be provided for the mentioned problem. However, a number of issues were found in the system under investigation, including lack of clarity in data correction after initial confirmation, and inability to edit or remove information after initial entry. Since SIB is widely used on a national level where an appropriate resolution in the event of a problem and avoiding misunderstanding are paramount for the users, authorities should heavily focus on resolving any issues regarding this section.

Problems related to the "errors prevention" principle was considered major with a mean severity score of 2.8. In other studies conducted [9, 26], which were similar to the present study, the highest severity score was considered as a catastrophic problem despite having a low number of problems. In other studies [17,20,30,32], the problems in this principle were considered as a major problem. Our findings are consistent with that of the mentioned studies. However, elsewhere [28,29,31] the problems in this principle were considered as a minor problem. Moreover, the study of Toribo-Guzman [34] estimated a low severity score for this principle. In a study by Choi [33], the two principles of "errors prevention", with 5 problems and a mean severity score of 1.7 and "help and documentation", with 7 problems and a mean severity score of 1.7 had the lowest severity score as compared to other principles. They were categorized as minor problems, which is inconsistent with the results obtained in this study. This principle addresses the ability of a system to prevent the occurrence of problems, as well as displaying an appropriate message in the event of an error. Our current system fails to display a completion notification which may lead to user confusion. Since the occurrence of an error could be time-consuming and may hinder the user, developers should heavily focus on resolving any problems in this regard.

Different methods were used to carry out heuristic evaluation in the studies, with results that were both consistent and inconsistent with that of this study. In a study by Abedi [29], the evaluation was performed by

three experts and the categorization of problem severity was also different from our study. In the Toribo-Guzman study [34], 11 principles were investigated by an expert and the problem severity was categorized in three levels (low, medium, high). In another study by Choi [33], three evaluators were used for data collection, which as compared to the present study, the number of experts was lower. Moreover, Choi used open structure forms, similar to the present study. It should be noted that Choi also recorded the voice of participating evaluators. Since three evaluators were used for problem identification in the studies with similar results to that of the current study, a different method was used for the categorization of problems severity in Lilholt's study [28], a different number of principles were evaluated in the Guo's study [32] (14 principles) as compared to the present study, and systems investigated in similar studies were considered local. Therefore, it cannot be stated with certainty that the difference between problem severity in various studies is due to the number of participating evaluators or that the systems are being used locally or on a national level. However, the present study is different from the inconsistent studies in terms of the categorization of problem severity. Hence, inconsistency in findings could be attributed to the different sets of categorization of problem severity, as well as the type of the system being investigated. Since a number of studies consider 3–5 participating evaluators as sufficient to identify problems, it is recommended that the effect of the number of participating evaluators be further investigated.

4.1. Practical Recommendations

1. The most important recommendations in terms of the "help and documentation" principle are as follows:
   - Addition of a comprehensive user guide (help) in the system.
   - The most important items and necessary notes should be placed as one document so as to achieve a favorable experience with the system.
2. The most crucial recommendations in terms of the "visibility of system status" principle are as follows:
   - The displayed messages should be improved in terms of clarity.
   - Scanned book pages such as the system user guide should be replaced with brief written documents.
   - The patient referral option should be inactivated once the patient referral process is complete, so as to avoid any confusion.
3. The most crucial recommendation in terms of the "match between system and the real world" principle is as follows:
   - The symbol of icons should convey information about their functions.

4 The most crucial recommendations in terms of the "user control and freedom" principle are as follows:
  - Back, Undo and Redo icons should be defined for the system.
  - Since it is possible that a child with unusual conditions is admitted, the system must refrain from display an error when entering abnormal ranges.

5 The most important recommendations in terms of the "consistency and standards" principle are as follows:
  - Persian language should be used all across the system.
  - Radio Button should be used for multiple-choice questions.

6 The most important recommendations in terms of the "help users recognize, diagnose and recover from errors" principle are as follows:
  - The process of data correcting should be clear after initial confirmation.
  - Ability to cancel or revise the entered data all across the system.
  - A separate window should be used for error notification.

7 The most important recommendations in terms of the "error prevention" principle are as follows:
  - Completion notification should be displayed once the data entry process is finished.
  - Range of data entry should be mentioned.

8 The most important recommendations in terms of the "recognition rather than recall" principle are as follows:
  - Appropriate visual feedback should be designed.
  - The number of pages should be as few as possible, containing the highest number of questions.
  - Units of measurements should be added for a number of values.

9 The most important recommendation in terms of the "flexibility and efficiency of use" principle is as follows:
  - Ability of the combo box in the referral page to search by more than two first letters of a word.

10 The most important recommendations in terms of the "aesthetic and minimalist design" principle are as follows:
  - Using a similar color for titles and buttons.
  - Using fewer pages for a process.
  - Using different fonts in various parts.

5. Conclusion

Based on the viewpoint of evaluation experts, a large portion of problems in this system were classified in the major and catastrophic categories, which primarily indicates the poor usability of the user interface in registering the information related to pediatrics cases. Therefore, it is highly recommended that authorities be notified of the issues in writing in order to resolve them in a future update. Finally, special consideration should be given to meticulous evaluation of these systems during preliminary stages of design and development so as to face fewer issues at the time of implementation on a national level.

Authors' contributions

All authors made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all have critically reviewed its content and have approved the final version submitted for publication.

Funding

Ethical statement

I testify on behalf of all co-authors that our article submitted to *Informatics in Medicine- Unlocked* meets all institutional ethical guidelines.

Declaration of competing interest

The authors have no conflict of interests to declare.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.imu.2020.100332.

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