User Preferences for Adaptive User Interfaces in Health Information Systems

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Abstract

Purpose: An adaptive user interface requires identification of user requirements. Interface designers and engineers must understand end-user interaction with the system to improve user interface design.

Methods: A combination of interviews and observations are applied for user requirement analysis in health information systems (HIS). Then user preferences are categorized in this paper as either data entry, language and vocabulary, information presentation, or help, warning and feedback. The user preferences in these categories were evaluated using the focus group method.

Result: Focus group sessions with different types of HIS users comprising medical staff (with and without computer skills) and system administrators identified each user group's preferences for initial adaptation of the HIS user interface.

Conclusions: User needs and requirements must be identified to adapt the interface to users during data entry into the system. System designers must understand user interactions with the system to identify their needs and preferences. Without this, interface design cannot be adapted to users and users will not be comfortable using the system and eventually abandon its use.

Keywords: Adaptive user interface, Focus group, Health information systems, Usability, User preferences

1. INTRODUCTION

Information technology (IT) facilitates the recording, maintenance, retrieval and management of information. With the development of IT and the transition from traditional information systems to electronic ones, users are directed to utilize digital user interfaces (UIs). UIs are interfaces between the end user and the system and can be either static or dynamic. Static interface does not change and has the same look and feel for all users, while a dynamic interface changes in response to user behavior during his/her interaction with the system [1]. Dynamic interfaces can be categorized as adaptable, adaptive or a combination of the two. If adaptation of the interface is managed by the user, it is called an adaptable interface. Adaptive user interfaces (AUIs) automatically adjust their displays and actions to current user goals and abilities. AUIs assist users in accomplishing tasks in an application [1, 2].

The purpose of adaptation in UI is content, navigation and presentation adaptation [3, 4]. For content adaptation, the system adapts the content of a page to user characteristics. The system provides navigation adaptation by management of hyperlinks (hiding, sorting, annotating, removing, and adding) during a user navigation session. The goal of adaptive navigation is to help users find the path to accomplish a specific goal in the application. Adaptive presentation focuses on text positioning, graphics, multimedia inclusion/exclusion, background and GUI interfaces. The combination of adaptable and adaptive interface can be adaptable with system support or adaptive with user control. All of these categories are different scales of personalized user interfaces [5, 2].

The accurate design of a user interface is an essential part of application design process. A software system can only deliver its full potential if it is consistent with the skills, experiences and expectations of its users [6]. Lack of good user interface has been a major barrier to the acceptance and routine use of HISs [7].

Designing user interfaces that fit user preferences and needs is a challenge of the design of HIS. The existence of a well-designed and friendly usable user interface in healthcare is so important that can have a direct impact on patient health. A poorly-designed user interface leads to incorrect usage of the system or increased user error. As a consequence, the system may be abandoned. Users with different abilities, skills and needs use the system; therefore, it is necessary to adapt the interface according to user needs. For an adaptive user interface design in HIS, the users and their needs must be known and understood and to design the interface according to user needs.

There are various principles for the design of user interfaces. Effective UIs should be easy to learn, easy to remember, easy to use, have predictable behavior and keep the user in control [8, 9]. User interface design is derived from the principles of human-computer interaction (HCI) [10-12]. Toolkits for HCI research can be used to assess user needs in user interface design. Some toolkits that can be used to identify user needs in HIS are the think-aloud method [7, 13, 14], ethnographic studies [15], cognitive task analysis [16, 17], participatory design [18], heuristic evaluation and usability testing [14, 19, 17, 20, 21]. Previous studies have addressed user interfaces for healthcare environments [10, 22, 17], and evaluation of health UIs [20]. Some research has focused on the effect of user interface on doctor-patient communication [23], while others study design principles and compare alternative designs [24] and develop UIs [25-28]. Researchers have proposed a variety of guidelines to improve UIs for HISs [29-31, 28, 32, 17].

These studies either consider design guidelines for specific health applications [26-28] or design guidelines for one specific group of users such as general practitioners (GPs) [11] or nurses [25] or the elderly [30]. One study proposed a framework to redesign healthcare UIs [17], but differences between HIS users were not considered. Because users of HIS are diverse and have different needs and requirements, there is a need for adaptive user interfaces for different user groups.

An adaptive user interface improves user interaction with systems by facilitating user performance, minimizing user need to request assistance, helping users deal with complex systems and avoid cognitive overload [5]. Ramachandran [4] explored two major techniques to create adaptive interfaces: adaptive presentation and adaptive navigation. He provided examples of each in healthcare applications. Chen [33] used USHER's predictive ability to design intelligent user interface adaptations to improve data entry accuracy and efficiency. He then evaluated these mechanisms with professional data entry clerks working with real patient data. The USHER model gives a subset of answers for a form and accurately predicts values for unanswered questions. The results show that these adaptations have the potential to reduce error with limited effect on entry time. Findlater and Grenere [34] evaluated the impact of screen size on performance, awareness, and user satisfaction with adaptive graphical user interfaces. Additional examples exist about adaptive user interfaces and techniques for adaptation [2-4, 35-37]. Nguyen and Sobecki constructed user profiles based on consensus for adaptive development of user interfaces in multimodal web-based systems [38].

To summarize the state of the art, while some research projects studied user interface issues in health care [7, 10, 11, 17- 20, 24-28, 30] and other studies examined adaptive UIs [2-5, 35-37], few studies have examined adaptive UI design issues, especially for health settings [39], and none considered different user groups in HIS. Shakshuki, Reid and Sheltami [39] offered a multi-agent system with learning techniques to construct adaptive UIs for each patient. Other HIS users were not considered in this study.

The contribution of the present study beyond the state of the art is that it takes the first step in the design of an adaptive user interface, which is understanding and analyzing user needs when interacting with HIS. It also presents adaptive interface design requirements with a combinational view to individual and group adaptation. To evaluate the proposed requirements, the focus group method [40] was applied as a qualitative evaluation method along with a questionnaire. The focus group is a valuable tool for understanding the needs and concerns of users in human-computer interaction studies. Meetings with different groups of HIS end users were held to discuss their requirements. The focus group discussions were then analyzed as qualitative information. Participants also filled out a questionnaire which was analyzed to gain quantitative results for this study. To the best of the authors' knowledge, the current paper is one of the very few research studies that examine user requirements to design user interfaces for HIS especially tailored to different user groups in health settings.

2. METHODOLOGICAL FRAMEWORK

2.1. Eliciting user requirements

In any service adaptation including user interface adaptation, there are two tasks to be carried out; one is the adaptation of content or service, and the other is knowing the user and identification of user needs and preferences. Identifying the needs of users is like exploring an ancient castle; the more we work, the more we discover and the more we discover, the more we realize that there remains a lot to explore [41]. In addition to scientific literature, methods such as interviews with users, ethnography and observation of user interactions with the system were applied. Dialogue with users, their behavior and speech, and how they interact with the system during interviews and observations were recorded and employed. The main requirements for user interface design were then identified. Some identified requirements were the use of simple and quick data entry devices for HIS [22], considering multiple methods for data entry and search (e.g., text entry fields, A-Z lists) [8, 31], using feedback requiring minimal attention, such as light and sound [23, 22], using general as well as specialized terminology for different users, designing mobile devices with semi-transparent screens, making pocket-sized devices [23], removing or hiding unnecessary information from the screen, showing confirmation to user for recorded data [31], using understandable icons and figures instead of just text in screen (form factor) [18].

2.2. Requirement Classification

For a more detailed study of user preferences, it was necessary to classify the requirements derived from previous studies and observations. This allowed classification of user preferences about HIS interfaces into the categories of data entry devices, system language and vocabulary, information presentation and help, warning and feedback as shown in Figure 1.

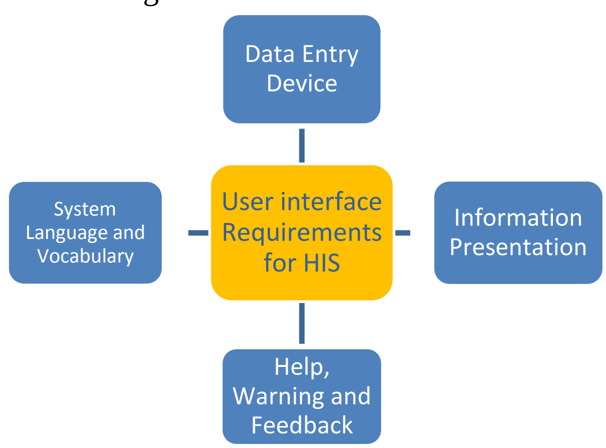

Figure 1. Proposed user interface requirements for HIS

2.3. User Classification

Age, sex, physical ability, education level, computer skills, medical knowledge, goals and motivations are the set of variables and aspects that impact end-user preferences. Vasilyeva et al. [3] pointed to "medical knowledge" as the main criterion for grouping users for user interface adaptation.

Ramachandran [4] found that healthcare users range from having little computer knowledge to having expert computer knowledge. The observation of users interacting with HIS in the current study indicates that these two factors clearly influence user needs and preferences and how users interact with the system. It can be concluded both from literature and observation of HIS usage in clinics that there are two important aspects that distinguish end users, computer literacy and medical knowledge. Based on these two criteria, end users can be clustered in four groups: medical staff with computer skills (MSCS), medical staff without computer skills (MS), system administrators (SA) and clerks who are employed to work with HIS. The fourth user group comprises users without computer literacy and medical knowledge. Because this last group of users is very rare in clinical settings, they have not been included in this study. MS and MSCS groups can interact with information systems directly at the patient's bedside to view, record and search information related to the patient. The SA group transfers information from paper chart to electronic information systems.

3. EVALUATION METHOD

User requirements extracted from the first stage of research were evaluated using a qualitative method (focus group) and a quantitative method (questionnaire); hence, both qualitative and quantitative results were obtained.

3.1. Qualitative Analysis by Focus Group

Three focus group sessions were held with end users of HIS at three hospitals in Tehran, Iran. Sixteen persons from the different hospitals were invited to attend. The first meeting was held with eight users from the SA group. Four persons from the MS group attended the second session and four physicians from the MSCS group were invited to the third session. The mean age of participants was 33.7 years and the average work experience was on average 7 years. The educational level of the participants comprised 12% associate degrees, 50% undergraduates, 31.25% general physicians and 12.5% specialist physicians.

User requirements were identified for initial adaptation of the user interface. To achieve this, unstructured and semi-structured questions were developed based on the requirements (section 3.2). Discussions in each session began with opening and introductory questions so that participants could gain insight into the topic and express their opinions. The agenda was the same for all three focus groups. All sessions lasted for approximately two hours. During each session, topics were accompanied by a visual display in Microsoft PowerPoint. Each session was recorded for later transcription and analysis. In addition, all statements, comments and gestures of the participants were recorded by an assistant. The researcher noted the key points as the meeting facilitator.

3.2. Quantitative Analysis by Questionnaire

Two questionnaires were developed. The first questionnaire was given to participants at the beginning of the session and covered areas such as demographic data, work experience and consent to participate in the session. The second questionnaire contained structured questions about the main topics of research. It was validated by 10 experts in user interfaces design and HCI. Experts commented on the relevancy, simplicity, clarity and necessity of items in accordance with the recommended range. The final questionnaire with 42 questions was designed using a five-point Likert scale. This questionnaire was completed by participants and delivered to the meeting facilitator at the end of the focus groups session.

4. RESULTS

The results of the focus groups and questionnaires were made available for qualitative and quantitative analysis, respectively, for each group of requirements discussed below. Comments from participants are shown in italics.

4.1. Data Entry Device

Data entry device selection was one of the topics discussed with end users. The keyboard, mouse, barcode reader, digital pen, touch technology, voice and radio frequency identification (RFID) are data entry types used for HIS that were introduced to the users. The SA group suggested different criteria for selecting the type of data entry device, because they worked in different parts of the hospitals. For example, reception and operation ward users considered use of the barcode reader to facilitate data entry to be suitable; however, a user with many years of work experience stated that a mouse and keyboard are the best devices for data entry. Clinic secretaries prefer touch technology for recording patient visits because it is less tiring compared to long hours of working with a keyboard and mouse.

One physician in the MS group remarked that the keyboard is the hardest data entry device. On the other hand, the best tool for data entry, according to the physicians, are voice and digital pens. Physicians in the MSCS group considered RFID as a necessary and appropriate technology at bedside to automate and facilitate the process of entering patient records. One participant stated that input through voice, especially in large patient referral centers, significantly reduces mistakes during data entry.

In addition to the qualitative survey, a questionnaire was also made available to participants that showed willingness to use different types of input devices on a scale ranging from of *strongly agree* to *strongly disagree*. Figure 2 compares the group preferences for choice of data entry device. The mean responder score for each type of data entry device was calculated. Table 1 shows the priority data entry device by group based on the average rating of participant responses.

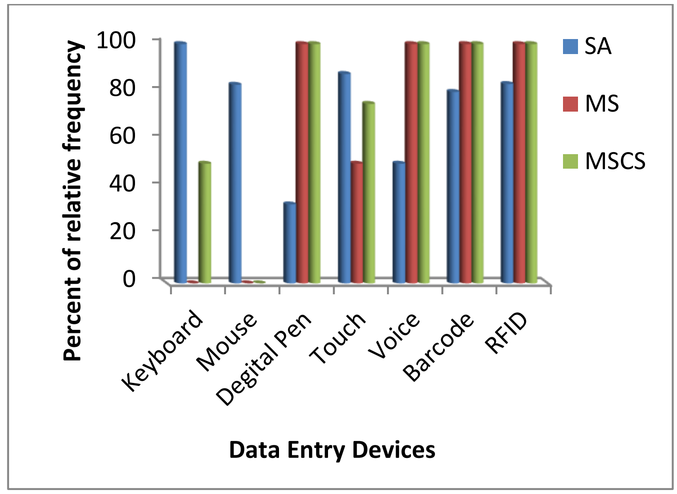

Figure 2. Comparison of group tendency to choose data entry technology, data entry device/percent of relative frequency
SA: System administrator, MS: Medical staff without computer skills, MSCS: Medical staff with computer skills

Table 1: Priority choice of data entry device in groups based on the average rating of the participants' answers.

SA	MS	MSCS
Keyboard (3.37)	Voice (4.00)	RFID (4.00)
Barcode reader (3.20)	RFID (3.60)	Voice (3.75)
Touch (3.12)	Digital Pen (3.60)	Digital Pen (3.00)
Mouse (3.00)	Barcode reader (3.50)	Barcode reader (3.00)
Voice (2.66)	Touch (2.50)	Touch (2.75)
Digital Pen (2.50)		Keyboard (2.50)

SA: System administrator, MS: Medical staff without computer skills, MSCS: Medical staff with computer skills

4.2. System Language and Vocabulary

Another example of adaptation is the ability to choose between the languages used to explain the elements on a page. Each user can select the desired language (Persian or English) with which to interact with the system. The selection of a particular choice several times by a user will result in automatic selection of that choice by the system; however, users can manually change the system language during interaction if desired. All participants agreed to a combination of Persian and English with the ability to change the language.

The vocabulary used in the system is different for the different user groups. The reason for the difference in vocabulary is that words used by different user groups differ in terms of users' knowledge and experience and should be adapted to the target users. The use of scientific vocabulary, standard codes, abbreviations and non-academic words in the content of HIS was discussed. Doctors and nurses sometimes use non-academic vocabulary for drug names or required actions at the bedside when recording clinical data in paper charts. The SA group's preference is to provide non-academic words along with scientific words to transfer data to the electronic system. They believe it can be done easily and quickly. One participant from the MS group stated "*the use of abbreviations will increase the speed of data entry*". In contrast, some MSCS and MS group participants were opposed to the use of abbreviations. Lack of standardization and several possible meanings for an abbreviation were mentioned as reasons for opposing this idea. They insisted on the use of full scientific terms to preserve high accuracy in the system.

The use of standard codes was also a matter of disagreement. One participant said: "*The probability of error due to the conversion of a disease to a standard code is high*". An opponent of the use of standard codes stated: "*Not all codes assigned to all diseases, diagnoses or actions are unique. Sometimes we are forced to use codes having the greatest similarity to the diagnosis, which it is not accurate enough and could be much generalized and not include sufficient detail*".

4.3. Information Presentation

Adaptive presentation can be implemented to hide some of the content on the page or provide different information and links on a particular page based on the user's knowledge of related concepts. Adaptive presentation techniques must focus on multimedia items such as images, videos, and audio in addition to text for each page. For example, for a complete patient record, if the user is a medical staff member from the MS or MSCS groups, the user interface can display advanced medical details that can be entered or obtained from the patient. If the user is in the SA group and has limited medical knowledge, those fields can be hidden and later displayed to medical staff for complete details.

The management of icons and objects in the interface by the software is an example of an automatic adaptive user interface. Re-arranging or highlighting user interface objects and icons based on user activity is another type of adaptation in a user interface. This was discussed with participants. Some believed that reordering may confuse users and that consistency is better because users learn the places of objects on pages and operate according to what they have learned to more easily select them.

Object manipulation on pages by users was also discussed. Some of the medical staff (MS/MSCS groups) liked this idea, while others believed that consistency is better. All participants of the SA group agreed and knew that this is a step towards customization. Table 2 compares the response frequency to information presentation of the groups.

4.4. Help, Warning and Feedback

Help can be provided differently to the different user groups or individuals. Novice users need more guidance while expert users may not require guidance. Helps can be designed for beginner users and then adapted for expert ones [8].

Participants in all three sessions agreed to guidance and alarms in the system to help users and reduce errors in data entry. Users without computer skills and the MS group need a multimedia form of help because they are unable to work the system correctly and need more guidance. One participant from the MS group pointed out that "*help that requires us to read text to work with the system is not interesting and it is better to have guidance in ways other than reading text*". For users of the MSCS and SA groups, shortcut keys for help are sufficient; when they need it, they can click a button.

While recording incorrect, duplicate or irrelevant information, the system should give good tips in addition to alerts. Guidance to users should be given upon request, even if information is properly recorded. For example, tips including information on dosage and time of medication use are embedded on the same page for the user when recording patient prescriptions. The interface should show the consequence of an act to the user and state whether or not an action has been done successfully by use of indicators [8, 31]. Feedback should be informative for the user. Changing in the color, text, light, vibration or sound are examples of system feedback for different devices. In medicine, feedback requiring minimal attention, such as light and voice [23, 22] are recommended.

All participants of the MSCS group believed that system feedback to physicians' mistakes in interaction with the system, using text and color changes is sufficient and that light, voice or any other type of feedback that draws a patient's attention can endanger the perception of the physician and have serious negative effects on patient confidence in the medical staff. Some MS work group participants prefer system feedback that draws less attention to the interface and a combination of multiple feedbacks including text with color changes, voice and light.

Table 2: Comparison of frequency of response to information presentation between groups

	User Group	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Total
Ability to manipulate objects in interface by user	SA	3	4	0	0	0	7
	MS	0	2	1	1	0	4
	MSCS	0	2	0	1	1	4
	Total	**3**	**8**	**1**	**2**	**1**	**15**
Ability to show relevant information to each user group and hide the rest (e.g. according to the user's level of knowledge)	SA	0	0	0	0	0	0
	MS	2	2	0	0	0	4
	MSCS	2	2	0	0	0	4
	Total	**4**	**4**	**0**	**0**	**0**	**8**
Automatic link management (activating, inactivating, deleting or reordering a link)	SA	0	0	0	0	0	0
	MS	2	1	0	1	0	4
	MSCS	0	2	0	2	0	4
	Total	**2**	**3**	**0**	**3**	**0**	**8**

Differences in the total amount of data occur because of missing data

Table3: Comparison of frequency of response to help, warning and feedback

	User Group	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Total
Provide the key to Help to be used if needed (Such as F1)	SA	7	1	0	0	0	**8**
	MS	2	2	0	0	0	**4**
	MSCS	1	2	1	0	0	**4**
	Total	**10**	**5**	**1**	**0**	**0**	**16**
Provide guidance when registering false, duplicate or irrelevant information in addition to warnings.	SA	4	4	0	0	0	**8**
	MS	3	1	0	0	0	**4**
	MSCS	2	1	1	0	0	**4**
	Total	**9**	**6**	**1**	**0**	**0**	**16**
Embedded help on the same page when recording information (show help for information on medicine for nurses on medical record page)	SA	3	5	0	0	0	**8**
	MS	2	1	0	0	0	**3**
	MSCS	1	2	1	0	0	**4**
	Total	**6**	**8**	**1**	**0**	**0**	**15**
A combination of above features	SA	7	1	0	0	0	**8**
	MS	3	0	0	0	0	**3**
	MSCS	3	1	0	0	0	**4**
	Total	**13**	**2**	**0**	**0**	**0**	**15**

Differences in the total amount of data occur because of missing data

In the SA work group, some participants preferred voice feedback and others preferred feedback with text, color and images. One preferred images for better understanding of feedback. Another said that it is better to first attract the attention of the user with a color change, then open text boxes to express the details. The opinions of the majority of participants indicated that, because the attention of an SA group user is on the information system monitor for data entry, using text, color and image feedback is most effective. Table 3 compares the response frequency for help, warning and feedback.

5. CONCLUSION AND FUTURE WORK

In order to adapt the interface to users during data entry into the system, user needs and requirements must first be identified. System designers must understand user interactions with the system and identify their needs and preferences. Interface design cannot be adapted to users otherwise; as a result, they will not be comfortable with the system, will avoid using it and the system will eventually be abandoned or underused.

The present study observed user interactions, interviewed users about their interactions with HIS and studied resources about user interface design principles. It was concluded that a data entry device has a significant impact on user interactions with the system. The medical staff preferred data entry devices that do not require typing. The lack of such devices in medical settings is a major obstacle to medical staff interactions with HIS; however, data entry by typing is not difficult for system administrators. The differences in the features desired and preferences of the various user groups are crucial to usability and user interface design.

To ensure the accuracy of identification of user requirements, several focus group sessions were held with users of the HIS to discuss user preferences when interacting with the system. Sixteen end users from different hospitals that have worked with HIS attended three focus groups. They ranged in age from 25 to 47 years and recorded average work experience of 7 years on average. In addition to open-ended questions about user preferences in interface design, a questionnaire was also designed for detailed analysis. The questionnaire focused on participant preferences expressed using a Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

The results obtained from the discussions with users were expected in some cases and unexpected in others, or conflicting with results of previous studies. Most users chose a combination of Persian and English for system language, which was predicted. The use of light and sound feedback was advocated for HIS in the literature, though the medical staff participants in the current study were opposed to the use of sound and light. It was possible to identify the features and preferences of different groups of users from the results. These can be applied for HIS interface design so that during user interaction with HIS, the interface is in accordance with user requirements, needs and preferences.

The novelty of this research is that end users of HIS were involved in the first step of the design and their requirements were evaluated using both qualitative and quantitative methods. User preferences were obtained in accordance with the user group to which they belong. This study provides guidelines based on UI requirements gathered from focus groups. Designers can benefit from these guidelines for adaptive HIS interface design. This is a major contribution to the field of user interface design in HIS settings.

This research study has several implications. First, the results indicate different preferences for different HIS user groups. Preference difference, even without considering the priority list of preferences obtained by this specific study, is a confirmation of the necessity for adaptive user interfaces in health settings. Adaptive user interfaces can provide better usability and user experiences for each user group.

A second important implication of the study is that it derives from the findings on priority choices of data entry devices, information presentation, help, warning, feedback, system language and vocabulary in three groups of HIS users. Adaptive interface design for three groups of users will become possible by considering the identified user requirements for each group. Users will become more comfortable using an adaptive interface and a major obstacle to the acceptance and routine use of HISs will be removed.

As an example, priority choices for data entry devices in groups based on the average rating of the participants' answers indicates a similarity of choices by medical staff with or without computer skills and a difference with the system administrator group. This means that two sets of devices are sufficient for all three HIS user groups. This is a valuable piece of information for choosing and buying devices for different user groups in HIS settings. There is no need for adaptation in the form of providing help and multimedia help is interesting. Help content can be adapted based on users' domain knowledge. Different choices for information presentation emphasize the necessity for adaptation, however user groups are not decisive in such matters and it is better to give more control to each user rather than implement automatic adaptation by the software.

The third important implication of this study is that some interface design choices have direct impact on patient health and at times on the physician-patient relationship. The choice of language and vocabulary, including use of standard codes, influences the probability of error and consequently will have a direct impact on patient health. In some cases, such as feedback about physicians' mistakes when interacting with the system, voice or any other type of feedback that draws a patient's attention can endanger patient perceptions about the physician and have serious negative effects on patient confidence in the medical staff.

Directions for future research include the design evaluation of an adaptive user interface for HIS based on the results of this study. It is also possible to use the results of this study to improve user experience about existing user interfaces in HIS. In addition, another method can be used to gather user requirements and compare requirements obtained by applying different research methods. The design guidelines resulting from this study can also be tested and evaluated one-by one in HIS.

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