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Task-specific usability requirements of electronic medical records systems: Lessons learned from a national survey of end-users

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ABSTRACT

Background: There are various approaches to evaluating the usability of electronic medical record (EMR) systems. User perspectives are an integral part of evaluation. Usability evaluations efficiently and effectively contribute to user-centered design and supports tasks and increase user satisfaction. This study determined the main usability requirements for EMRs by means of an end-user survey. *Method*: A mixed-method strategy was conducted in three phases. A qualitative approach was employed to collect and formulate EMR usability requirements using the focus group method and the modified Delphi technique. Classic Delphi technique was used to evaluate the proposed requirements among 380 end-users in Iran. *Results*: The final list of EMR usability requirements was verified and included 163 requirements divided into nine groups. The highest rates of end-user agreement relate to EMR visual clarity (3.65 ± 0.61), fault tolerance (3.58 ± 0.56), and suitability for learning (3.55 ± 0.54). The lowest end-user agreement was for auditory presentation (3.18 ± 0.69). *Conclusion*: The highest and lowest agreement among end-users was for visual clarity and auditory presentation by EMRs, respectively. This suggests that user priorities in determination of EMR usability and their understanding of the importance of the types of individual tasks and context characteristics differ.

KEYWORDS

Computer systems; Delphi technique; electronic health records; personal satisfaction

Introduction

Electronic medical record (EMR) systems contain a wide spectrum of clinical and demographic information to support clinical and administrative processes. These include records of diagnoses, visits, laboratory tests, prescriptions, and physical examinations (1). EMR is an preliminary example of electronic health records (EHR). These are records that capture medical information and include information related to lifestyle, self-care, caregiver-provided behavioral information, immunization status, and even sound and image (CT images) data (2). Despite the benefits of adopting health information technology tools, studies show that designing EMRs and EHRs has been delayed in some countries, and adoption of such designs has been resisted by doctors in health centers (3). Studies show that usability problems associated with an interruption in the work flow have led to user dissatisfaction (4–6), have undermined the efficiency of such systems, and form the major obstacles to their adoption (7–9).

The International Organization for Standardization (ISO) defines usability as "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" (6). Nielsen introduced the features of ease of learning,

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efficiency, ability to remember, prevention, protection from errors, and satisfaction to describe the usability of these systems (10). Rogers stated that being effective, efficient, and safe for use and ease of learning and recall are usability targets (11).

Studies have demonstrated that usability problems increase user frustration and inefficiency, have adverse effects on patient care (5,7), and create obstacles to workflow and execution of simple tasks (12). Evaluation of usability is an effective strategy to coordinate between system design and user needs and tasks (13,14), in quality assessment of clinical information technology (15) and helps to identify information system strengths and weaknesses (16,17). In fact, the purpose of a system usability assessment is to discover, understand, reduce, and prevent usability problems (12).

There are numerous ways to evaluate EMRs, among which usability survey from the user perspective is integral (18,19). Appropriate usability supports user-centered design and guarantees that users are able to perform their tasks efficiently, effectively, and with a high degree of satisfaction (5). The present study determined the main requirements for the usability of EMRs.

History of Iranian healthcare systems and electronic health records

The planning, monitoring, and supervision of health-related activities for the public and private sectors are under supervision of The Ministry of Health and Medical Education (MOHME) in Iran. A considerable portion of secondary and tertiary health services is provided by the public sector through a nationwide network. Healthcare funding in Iran is supported by the general government budget, health insurance reimbursement, and individual out-of-pocket expenses (20,21). The overall adoption of EHRs in Iran is still in its infancy and is limited to electronic hospital medical records (22). Ghazisaeidi (23) found that, of all public teaching hospitals affiliated with Tehran University of Medical Sciences, an estimated 28.6% are ready for pre-implementation of EHR (23). Most Iranian EHR systems are commercially sold instead of internally developed; however, the Information Technology Center of MOHME has developed an evaluation framework for these systems.

Material and methods

Setting

The three phases of the study were implemented using the focus group method, modified Delphi technique and classic Delphi technique. Details of each phase will be discussed below.

Phase I: Designing a focus group to develop usability requirements

Recruiting focus group discussion participants

The focus group discussion (FGD) pursued two objectives: identifying the most important usability requirements based on the opinions of an expert panel and clarification of all problematic areas reported by user groups (physicians, nurses, administrators, and managers) about the usability of EMRs. The research team believes that homogeneity of participants has a synergistic effect on group function. Ten information technology (IT) specialists were purposefully selected based on significant homogeneous characteristics. The researcher assumed that IT specialists would be best qualified for an expert panel group. The characteristics used to select the experts were ability to recognize user group EMR issues that affect system usability, background in different user-group EMR usability obstacles, work experience as an EMR troubleshooter, and expertise on system usability and end-user requirements in the area of EMR usability.

The expert panel group had two main inclusion criteria: IT specialists who work as IT administrators for hospitals and those who have more than 7 years of work experience. The following tasks were undertaken:

- Developing multidiciplinary team for information systems (IS) selection
- Creation and submission of a request for proposal based on user requirements
- Preparation of an IS vendor on-site demonstration and clinic-led evaluation session (user evaluation)
- Ranking of vendors and deciding on organization objectives and user needs
- Implementation, evaluation, and maintenance of information systems
- Troubleshooting end-user computer problems (at computer service office)

A list of qualified participants was developed, and their interest and availability were confirmed by phone call. Five days before the scheduled meeting, a confirmation letter stating the title and purpose of the study, members of group, date, time, and place of meeting were sent to all participants.

Conducting FGD

The FGD trained moderator (researcher) explained the aim of the study and the non-evaluative environment of the FGD. The moderator then asked for the expert panel to express their opinions without concern for other participants' judgments. The FGD moderator has the following responsibilities: (1) address all areas of inquiry within the allocated timeframe; encourage all respondents to actively participate; summarize and extract the main ideas from lengthy and imprecise comments.

The assistant moderator (recorder) was responsible for recording the discussion, observing the FGD, and taking notes. Examples of questions used to guide the expert panel during the FGD include:

- What is IS usability?
- How do you describe the importance of usability of an IS?
- How do you evaluate the abilities of current information systems, for example EMR?
- What are major usability problems with EMR?
- What are major end-user usability problems with EMR?
- Of the calls by users for computer help to customer service, how many were related to EMR usability?
- What were the types of usability problem? Can you name them?
- Have end-users you have contacted suggested improvements for EMR usability?
- During EMR selection, what usability requirements were emphasized by end-users?
- What are major usability requirements for EMR?
- Do you know of any frameworks or models for standard usability requirements?

Data analysis

In the first session of the FGD, a wide spectrum of IS usability requirements compelled participants to organize their comments based on the unified accepted model. The most widely accepted usability requirements, Software Usability Measurement Inventory, Questionnaire for User Interface Satisfaction, Purdue Usability Testing Questionnaire, and ISO 9241 (Part 10) were extracted (17,24–27). ISO 9241 (Part 10) IsoMetric usability dimensions were accepted as the core theme, and it was decided that the requirements proposed by experts would be added to IsoMetric usability dimensions based on their definitions. If the proposed requirement was similar to one of the ISO usability criteria, it was grouped with the related theme, and otherwise a new theme was developed.

Two 4-hour meetings were held under moderator supervision in which the participants enjoyed the freedom to present new ideas about EMR usability requirements. During the first 4-hour round, seven core themes were addressed. These were suitability of the task, self-descriptiveness, controllability, conformity with user expectations, fault tolerance, suitability of individualization, and suitability of learning. At the end of the second 4-hour round, new ideas were finalized, and two

additional themes (visual clarity, auditory presentation) were added. Preliminary EMR usability was developed in terms of the nine main dimensions and 160 requirements selected.

Phase II: Reaching consensus on EMR usability requirements through FGD

The modified Delphi technique was used to reach consensus on EMR usability requirements. The modified Delphi serves as a group decision-making technique to obtain consensus on the opinions of experts through a series of structured questionnaires (referred to as rounds). It is an iterative multistage process which continues until group consensus is achieved. The approach is commonly employed in medical, nursing, and health services research, and many differing forms are now available.

The modified Delphi technique is an open-ended Delphi round conducted through focus groups or one-to-one interviews (28). At the end of the FGD, the preliminary EMR usability requirements were formatted in terms of a questionnaire on a five-point Likert scale (0 = strongly disagree to 4 = strongly agree). Each EMR usability requirement was reviewed separately by experts who then rated each item. Requirements with mean final scores of ≥3 were confirmed, and those with mean final scores of <2 were omitted. Those with final mean scores of 2–3 were presented to experts for further analysis until they were either confirmed or omitted from the questionnaire.

Experts were encouraged to present new ideas about EMR usability requirements. They reached agreement after six FGD rounds to provide the set of final questions on EMR usability requirements. Prior to each round, the experts provided a summary of the means and median ratings from previous rounds. The final nine categories (155 items) of EMR usability requirements were accepted with a minimum score of 3.02. Five items with mean final scores <2 were omitted from the 160 preliminary EMR usability requirements during data analysis.

Phase III: EMR usability requirements based on end-user perspectives

In this phase, the 155 confirmed requirements in phase II were distributed among 380 end-users comprising physicians, nurses, and other healthcare providers from all over Iran in the form of a questionnaire. This questionnaire included demographic information, the 255 close-ended questions and one open-ended question to allow presentation of additional requirements by end-users.

All participants had 5 years of experience using EMRs. At all stages of the Delphi technique, anonymity when providing feedback to participants was observed. To support all classic Delphi characteristics (anonymity and feedback), different focal points (research contributors) were identified in the surveyed hospitals throughout the country. The focal points were responsible for orienting end-users toward the research objectives and give feedback on the data in each round. The scaling system used was 0 = strongly disagree, 1 = disagree, 2= no comment, 3 = agree, and 4 = strongly agree. The mean final score of each requirement was then calculated.

During collection of end-user comments during the first Delphi round, 15 requirements were proposed by end-users in the open-ended question. The modified questionnaire comprising 170 EMR usability requirements included the 15 newly proposed requirements by end-users were distributed in the second Delphi round. Requirements with mean final scores of ≥3 were approved, those with mean final scores of <2 were omitted, and those with mean final scores of 2–3 were presented to end-users to be considered for assessment in the second phase of the Delphi technique to reach consensus on rejection or acceptance. Seven of the 170 usability requirements failed to achieve mean scores >3 and were rejected. Detailed information about the definition and numbers of requirements in each dimension for EMR usability is presented in Table 1.

Table 1. Final EMR usability requirements.

Theme	Definition	Requirements (no. of items)
1. Suitability of task	A system is suitable if it supports the user to realize his tasks effectively and efficiently. Only those parts of the software are presented which are necessary to fulfill the task (17).	24 items
2. Self-descriptiveness	A system is self-descriptive if every step is understandable in an intuitive way or, in case of error, supported by immediate feedback. Adequate support should be offered on demand (17).	22 items
3. Controllability	A system is controllable if the user is able to start the sequence and influence its direction and speed until he has reached his aim (17).	19 items
4. Conformity with user expectations	A system is congruent with user expectations if it is consistent, complies with characteristics of the user, takes into account the knowledge of the user in the area under study, and accounts for education, experience, and generally acknowledged conventions (17).	25 items
5. Fault tolerance	A system is error tolerant if the intended deliverable is reached with little or no effort despite obvious faulty steering or wrong input (17).	21 items
6. Suitability of individualization	A system is suitable for individualization if it allows customization according to the task, individual capabilities, and preferences of a user (17).	7 items
7. Suitability of learning	A system supports the suitability of learning if the user is accompanied through the learning process and the effort expended to learn is as low as possible (17).	19 items
8. Visual clarity	Refers to how clearly the system displays information (29) on the screen clearly in a well organized, unambiguous, and easy-to-read manner (30).	18 items
9. Auditory presentation	The use of sound to communicate information about the state of a computing device to a user (31).	8 items
Total		**163**

Ethical considerations

Ethical considerations for the current research were discussed as part of the focus group discussions and presented in the survey of end-users. Using the mixed method, the ethical considerations for current research were discussed as parts of the focus group discussion and in a survey of end-users about EMR usability requirements. Before starting the FGD round, all participants signed informed consent forms which described the research founder, goals of the study, non-critical and unbiased climate of the meeting, voluntary nature of participation, and assured the confidentiality of the information. The research participants were informed about the purpose of the study prior to completion of the questionnaire. The voluntary nature of participation was explained, and they were assured of anonymity and the confidentiality of the responses. Informed consent was implied by their returning the completed questionnaires.

Statistical analysis

SPSS software, version 18, was used to analyze the data. Descriptive statistics of mean and standard deviation (SD) were used.

Results

The final list of EMR usability requirements was approved and totaled 163 requirements in nine groups (Table 2). As the results indicate, the highest rates of end-user agreement related to "visual clarity" (3.65 ± 0.61), "error tolerance" (3.58 ± 0.56), and "suitability for learning" (3.55 ± 0.54). The findings show that the lowest end-user agreement related to "auditory presentation" (3.18 ± 0.69).

Table 2. EMR usability requirements

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
Suitability of task							
1. Focuses on user tasks related to actual work	225 (67.1)	118 (31.1)	7 (1.8)	–	–	380 (100)	3.65 ± 0.51
2. Completes entire work routines	121 (31.8)	205 (53.9)	47 (12.4)	7 (1.8)	–	380 (100)	3.15 ± 0.7
3. Supports user in performing task	266 (70)	110 (28.9)	4 (1.1)	–	–	380 (100)	3.68 ± 0.48
4. Takes fewest steps possible to accomplish task at hand	259 (68.2)	121 (31.8)	–	–	–	380 (100)	3.68 ± 0.46
5. Decreases work needed for accomplishing the task	291 (76.6)	89 (23.4)	–	–	–	380 (100)	3.76 ± 0.42
6. Breaks long task sequences into appropriate subsequences	229 (50.3)	104 (27.4)	47 (12.4)	–	–	380 (100)	3.47 ± 0.7
7. Follows logical steps to complete a task.	241 (63.4)	139 (36.6)	–	–	–	380 (100)	3.63 ± 0.48
8. Arranges fields sensibly on-screen	221 (58.2)	156 (41.1)	3 (0.8)	–	–	380 (100)	3.57 ± 0.51
9. Organizes information on screen logically	241 (63.4)	139 (36.6)	–	–	–	380 (100)	3.63 ± 0.48
10. Easily retrieves information about entry field	274 (72.1)	103 (27.1)	3 (0.8)	–	–	380 (100)	3.71 ± 0.47
11. Helps user easily find required information on screen	289 (76.1)	91 (23.9)	–	–	–	380 (100)	3.76 ± 0.42
12. Helps user easily find all information needed on screen	229 (60.3)	77 (20.3)	57 (15)	10 (2.6)	7 (1.8)	380 (100)	3.34 ± 0.95
13. Properly presents the information to support user work.	242 (63.7)	127 (33.4)	11 (2.9)	–	–	380 (100)	3.6 ± 0.54
14. Repeats function for work steps that must be performed several times in succession	241 (63.4)	99 (26.1)	34 (8.9)	6 (1.6)	–	380 (100)	3.51 ± 0.72
15. Helps the user easily find important commands required to perform task	175 (46.1)	148 (38.9)	46 (12.1)	11 (2.9)	–	380 (100)	3.28 ± 0.78
16. Defines task-specific jargon and terminology in first step	178 (46.8)	145 (38.2)	44 (11.6)	13 (3.4)	–	380 (100)	3.28 ± 0.8
17. Creates compatibility between terminology and work environment	256 (67.4)	84 (22.1)	36 (9.5)	4 (1.1)	–	380 (100)	3.55 ± 0.7
18. Helps users enter required data only once	254 (66.8)	107 (28.2)	13 (3.4)	6 (1.6)	–	380 (100)	3.6 ± 0.63

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
19. Suits the way in which data is entered to task at hand	188 (49.5)	154 (40.5)	38 (10)	–	–	380 (100)	3.39 ± 0.66
20. Supports all information media (text, sound, picture and video)	220 (57.9)	133 (35)	27 (7.1)	–	–	380 (100)	3.5 ± 0.62
21. Supports different approaches for data entry (voice recognition, touch screen, mouse and keyboard)	195 (57.9)	133 (35)	27 (7.1)	–	–	380 (100)	3.44 ± 0.62
22. Gives options suited to task at hand for selecting output	259 (68.2)	103 (27.1)	18 (4.7)	–	–	380 (100)	3.63 ± 0.57
23. Adjusts presentation of results (on screen, to printer)	225 (59.2)	129 (33.9)	18 (4.7)	8 (2.1)	–	380 (100)	3.5 ± 0.68
24. Easily adapts the software for performing new tasks.	235 (61.8)	119 (31.3)	26 (6.8)	–	–	380 (100)	3.55 ± 0.62
Total	**5584 (61.2)**	**2958 (32.4)**	**506 (5.5)**	**65 (0.7)**	**7 (0.1)**	**9120 (100)**	**3.54 ± 0.56**
Self-descriptiveness							
1. Provides specific explanations for the use of the system.	226 (59.5)	146 (38.4)	8 (2.1)	–	–	380 (100)	3.57 ± 0.53
2. uses clear and unambiguous terms and concepts.	259 (68.2)	121 (31.8)	–	–	–	380 (100)	3.68 ± 0.46
3. Graphically displays what is compatible with user's view.	246 (64.7)	116 (30.5)	18 (4.7)	–	–	380 (100)	3.6 ± 0.57
4. Features clear shortcuts (abbreviations, hidden commands).	226 (59.5)	146 (38.4)	8 (2.1)	–	–	380 (100)	3.57 ± 0.53
5. features easily understandable messages.	289 (76.1)	91 (23.9)	–	–	–	380 (100)	3.76 ± 0.42
6. features concise and positive instructions and massages.	278 (73.2)	102 (26.8)	–	–	–	380 (100)	3.73 ± 0.44
7. Features relevant instructions and massages.	227 (59.7)	136 (35.8)	17 (4.5)	–	–	380 (100)	3.55 ± 0.58
8. Features informative and accurate status messages (what the system is doing or has just been done)	246 (64.7)	116 (30.5)	18 (4.7)	–	–	380 (100)	3.6 ± 0.57
9. Easily distinguishes differences among feedback messages, requests to commands, warnings and error messages	216 (56.8)	147 (38.7)	17 (4.5)	–	–	380 (100)	3.52 ± 0.58

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
10. Distinguishes between selected and unselected icons.	138 (36.3)	224 (58.9)	18 (4.7)	–	–	380 (100)	3.31 ± 0.55
11. Informs users of menu items	183 (48.2)	170 (44.7)	20 (5.3)	7 (1.8)	–	380 (100)	3.39 ± 0.67
12. Begins every display with a title that describes screen contents	235 (61.8)	120 (31.6)	25 (6.6)	–	–	380 (100)	3.55 ± 0.61
13. Displays general explanations and concrete examples	179 (47.1)	126 (33.2)	59 (15.5)	16 (4.2)	–	380 (100)	3.23 ± 0.86
14. Provides clear explanations which refer to the specific situations	169 (44.5)	184 (48.4)	16 (4.2)	11 (2.9)	–	380 (100)	3.34 ± 0.69
15. Displays basic information about conceptual aspects of the program	201 (52.9)	97 (25.5)	70 (18.4)	129 (3.2)	–	380 (100)	3.28 ± 0.87
16. Provides enough information about permitted entries	217 (57.1)	88 (23.2)	64 (16.8)	11 (2.9)	–	380 (100)	3/34 ± 0.85
17. Provides default values	210 (55.3)	81 (21.3)	77 (20.3)	12 (3.2)	–	380 (100)	3.28 ± 0.89
18. Promptly informs the user of any delays	264 (69.5)	111 (29.2)	5 (1.3)	–	–	380 (100)	3.68 ± 0.49
19. Clearly informs the user of task completion	276 (72.6)	99 (26.1)	5 (1.3)	–	–	380 (100)	3.71 ± 0.48
20. Provides appropriate feedback for the task at hand	259 (68.2)	82 (21.6)	29 (7.6)	10 (2.6)	–	380 (100)	3.55 ± 0.74
21. Clear reports on error correction	278 (73.2)	102 (26.8)	–	–	–	380 (100)	3.73 ± 0.44
22. Provides appropriate content of tutorial and help menu	202 (53.2)	138 (36.3)	40 (10.5)	–	–	380 (100)	3.42 ± 0.67
Total	**5024 (60.1)**	**2743 (32.8)**	**514 (61.1)**	**79 (1)**	–	**8360 (100)**	**3.52 ± 0.42**
Controllability							
1. Provides adequate amount of help	250 (65.8)	121 (31.8)	9 (2.4)	–	–	380 (100)	3.63 ± 0.52
2. Provides easy access to system procedures necessary for task completion	227 (59.7)	144 (37.9)	9 (2.4)	–	–	380 (100)	3.57 ± 0.54
3. Provides adequate possibilities for navigating within the software	219 (57.6)	151 (39.7)	10 (2.6)	–	–	380 (100)	3.55 ± 0.54
4. Switches between different menu levels	242 (63.7)	138 (36.3)	–	–	–	380 (100)	3.63 ± 0.48
5. Moves back and forth between different screens	292 (76.8)	88 (23.2)	–	–	–	380 (100)	3.76 ± 0.42

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
6. Returns directly to main menu from any screen	257 (67.6)	113 (29.7)	10 (2.6)	–	–	380 (100)	3.65 ± 0.52
7. Directly accesses a particular screen in a sequence of screens	229 (60.3)	132 (34.7)	19 (5)	–	–	380 (100)	3.55 ± 0.59
8. Allows users to enter different parts of system	231 (60.8)	127 (33.4)	22 (5.8)	–	–	380 (100)	3.55 ± 0.6
9. Requires user to perform a fixed sequence of steps	185 (48.7)	127 (33.4)	40 (10.5)	19 (5)	9 (2.4)	380 (100)	3.21 ± 0.98
10. Provides an easy way to undo an action and step back to a previous stage.	228 (60)	141 (37.1)	11 (2.9)	–	–	380 (100)	3.57 ± 0.55
11. Can interrupt any dialog at any time	194 (51.1)	112 (29.5)	74 (19.5)	–	–	380 (100)	3.31 ± 0.77
12. Can abort a running procedure manually	169 (44.5)	118 (31.1)	75 (19.7)	18 (4.7)	–	380 (100)	3.15 ± 0.9
13. Directly enters a letter or command code when selecting menu items	226 (59.5)	105 (27.6)	40 (10.5)	9 (2.4)	–	380 (100)	3.44 ± 0.77
14. Easily reverses user actions	193 (50.8)	93 (24.5)	84 (22.1)	10 (2.6)	–	380 (100)	3.23 ± 0.88
15. Provides possibility for undoing or redoing an operation	218 (57.4)	123 (32.4)	39 (10.3)	–	–	380 (100)	3.47 ± 0.67
16. Provides availability of shortcuts	242 (63.7)	129 (33.9)	9 (2.4)	–	–	380 (100)	3.61 ± 0.53
17. Chooses rate at which information is presented	169 (44.5)	122 (32.1)	67 (17.6)	22 (5.8)	–	380 (100)	3.15 ± 0.91
18. Provides an opportunity to review action sequences in backward and forward processes	217 (57.1)	114 (30)	49 (12.9)	–	–	380 (100)	3.44 ± 0.71
19. Features default commands for repetitive data entry	229 (60.3)	130 (34.2)	11 (2.9)	10 (2.6)	–	380 (100)	3.52 ± 0.68
Total	**4217 (58.4)**	**2328 (32.3)**	**578 (8)**	**88 (1.2)**	**9 (0.1)**	**7220 (100)**	**3.47 ± 0.62**
Conformity with user expectations							
1. is consistent while moving within and between different parts of software	235 (61.8)	89 (23.4)	56 (14.7)	–	–	380 (100)	3.47 ± 0.73
2. Features standard procedures for similar, related operations (updating and deleting information, starting and finishing transactions)	252 (66.3)	116 (30.5)	12 (3.2)	–	–	380 (100)	3.63 ± 0.54

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
3. is capable of anticipating next screen in processing sequence	134 (35.3)	163 (42.9)	83 (21.8)	–	–	380 (100)	3.13 ± 0.74
4. Is capable of predicting results of functions	157 (41.3)	135 (35.5)	88 (23.2)	–	–	380 (100)	3.18 ± 0.78
5. Can predict time needed to perform a given task	188 (49.5)	153 (40.3)	28 (7.4)	11 (2.9)	–	380 (100)	3.36 ± 0.74
6. Uses consistent designations in all parts of software	210 (55.3)	139 (36.6)	31 (8.2)	–	–	380 (100)	3.47 ± 0.64
7. Uses consistent icons, symbols, graphical representations and other pictorial information	241 (63.4)	98 (25.8)	20 (5.3)	21 (5.5)	–	380 (100)	3.47 ± 0.82
8. Uses same function keys throughout program for same function	243 (63.9)	126 (33.2)	11 (2.9)	–	–	380 (100)	3.61 ± 0.54
Conformity with user expectations							
9. Provides consistent use of colors throughout system.	258 (67.9)	82 (21.6)	32 (8.4)	8 (2.1)	–	380 (100)	3.55 ± 0.73
10. Features consistent and standard format in all screens within a system.	249 (65.5)	89 (23.4)	33 (8.7)	9 (2.4)	–	380 (100)	3.52 ± 0.75
11. Uses same screen location for messages output by software	249 (65.5)	70 (18.4)	52 (13.7)	9 (2.4)	–	380 (100)	3.47 ± 0.81
12. Provides same type of information displayed in same location on e screen	253 (66.6)	63 (16.6)	55 (14.5)	9 (2.4)	–	380 (100)	3.47 ± 0.82
13. Provides same format for entering particular types of information throughout system.	265 (69.7)	97 (25.5)	18 (4.7)	–	–	380 (100)	3.65 ± 0.56
14. Uses a consistent method of entering information throughout system.	237 (62.4)	116 (30.5)	27 (7.1)	–	–	380 (100)	3.55 ± 0.62
15. Ensures that the way tor select items is consistent throughout system	241 (63.4)	96 (25.3)	43 (11.3)	–	–	380 (100)	3.52 ± 0.69
16. Uses same keys for same functions throughout system (when keyboard is used)	220 (57.9)	139 (36.6)	21 (5.5)	–	–	380 (100)	3.52 ± 0.6
17. Uses consistent actions to move cursor around screen throughout system	229 (60.3)	140 (36.8)	11 (2.9)	–	–	380 (100)	3.57 ± 0.55

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
18. Features a cursor which appears in same initial position on displays of a similar type	199 (52.4)	121 (31.8)	51 (13.4)	9 (2.4)	–	380 (100)	3.34 ± 0.79
19. Uses consistent actions to move cursor for data entry throughout system	258 (67.9)	94 (24.7)	28 (7.4)	–	–	380 (100)	3.6 ± 0.62
20. Assigns colors according to conventional associations where these are important (e.g. red = alarm, stop)	269 (70.8)	89 (23.4)	22 (5.8)	–	–	380 (100)	3.65 ± 0.58
21. Follows conventions for using abbreviations, acronyms, codes and other alphanumeric information displayed	268 (70.5)	92 (24.2)	20 (5.3)	–	–	380 (100)	3.65 ± 0.57
22. Features compatibility between formats of displayed information with form in which it is entered into system	278 (73.2)	84 (22.1)	18 (4.7)	–	–	380 (100)	3.68 ± 0.55
23. Features compatibility between format and sequence in which information is printed with way it is displayed on screen	248 (65.3)	102 (26.8)	30 (7.9)	–	–	380 (100)	3.57 ± 0.63
24. Presents and analyzes information in units with normal user work (e.g. batches, kilos, dollars, pixels)	239 (62.9)	120 (31.6)	21 (5.5)	–	–	380 (100)	3.57 ± 0.59
25. Provides control actions compatible with other systems	243 (63.9)	104 (27.4)	33 (8.7)	–	–	380 (100)	3.55 ± 0.64
Total	**5863 (61.7)**	**2717 (28.6)**	**844 (8.9)**	**76 (0.8)**	–	**9500 (100)**	**3.51 ± 0.58**
Fault tolerance							
1. Warns users about potential problems	278 (73.2)	84 (22.1)	18 (4.7)	–	–	380 (100)	3.68 ± 0.55
2. Prevents users from unauthorized actions	247 (65)	115 (30.3)	18 (4.7)	–	–	380 (100)	3.6 ± 0.57
3. Prevents users from action causing software error (e.g. system/program crash or an undefined dialog state)	243 (63.9)	103 (27.1)	34 (8.9)	–	–	380 (100)	3.55 ± 0.65
4. Provides safety features to help prevent unintended actions (e.g. critical keys spaced apart, clear designations)	258 (67.9)	94 (24.7)	28 (7.4)	–	–	380 (100)	3.6 ± 0.62
5. Guarantees that no system errors (e.g. crashes) occur while working with software	241 (63.4)	91 (23.9)	48 (12.6)	–	–	380 (100)	3.5 ± 0.7

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
6. Prevents serious consequences when mistakes occur	249 (65.5)	70 (18.4)	52 (13.7)	9 (2.4)	–	380 (100)	3.47 ± 0.81
7. Can try out possible actions (e.g. using a simulation facility) without causing problems	202 (53.2)	95 (25)	83 (21.8)	–	–	380 (100)	3.31 ± 0.8
8. Checks for correctness before further processing when making entries	256 (67.4)	115 (30.3)	9 (2.4)	–	–	380 (100)	3.65 ± 0.52
9. Ensures that user corrects all detected errors before input is processed	271 (71.3)	109 (28.7)	–	–	–	380 (100)	3.71 ± 0.45
10. Requests confirmation of action when user attempts to perform a destructive operation (e.g. deletion of data)	279 (73.4)	82 (21.6)	19 (5)	–	–	380 (100)	3.68 ± 0.56
11. Presents some form of cancellation (or undo) key for user to reverse an error	79 (47.1)	177 (46.6)	18 (4.7)	6 (1.6)	–	380 (100)	3.39 ± 0.65
12. Clearly and promptly informs user when it detects an error	277 (27.9)	86 (22.6)	17 (4.5)	–	–	380 (100)	3.68 ± 0.55
13. Informs user when amount of information entered exceeds space available	222 (58.4)	135 (35.5)	23 (6.1)	–	–	380 (100)	3.52 ± 0.6
14. Provides useful information on how to recover from error situations.	239 (62.9)	120 (31.6)	21 (5.5)	–	–	380 (100)	3.57 ± 0.59
15. Provides useful error messages	246 (64.7)	117 (30.8)	17 (4.5)	–		380 (100)	3.6 ± 0.57
16. Provides clear and unambiguous error messages	279 (73.4)	101 (26.6)	–	–		380 (100)	3.73 ± 0.44
17. Corrects mistakes with minimum effort.	259 (68.2)	121 (31.8)	–	–		380 (100)	3.68 ± 0.46
Fault tolerance							
18. Can easily undo last operation when a mistake occurs	272 (71.6)	108 (28.4)	–	–		380 (100)	3.71 ± 0.45
19. Keeps original data even after it has been changed	217 (57.1)	106 (27.9)	57 (15)	–		380 (100)	0.42 ± 0.73
20. Preserves information even if user makes a mistake	235 (61.8)	120 (31.6)	25 (6.6)	–		380 (100)	3.55 ± 0.61
21. Easily restores everything to its previous state (in case of error)	242 (63.7)	113 (29.7)	25 (6.6)	–		380 (100)	3.57 ± 0.61
Total	**5191 (65.1)**	**2262 (28.3)**	**512 (6.4)**	–		**7980 (100)**	**3.58 ± 0.56**

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
Suitability for individualization							
1. Is easily adapted to suit user level of knowledge and skill	224 (58.9)	31 (34.5)	25 (6.6)	–	–	380 (100)	3.52 ± 0.61
2. Allows user adaptation of forms, screens and menus to suit individual preferences	158 (41.6)	162 (42.6)	51 (31.4)	9 (2.4)	–	380 (100)	3.23 ± 0.76
3. Can change names of commands, objects and actions to suit user personal vocabulary	127 (33.4)	180 (47.4)	57 (15)	16 (4.2)	–	380 (100)	3.1 ± 0.8
4. Provides options for entering information either manually or automatically	168 (44.2)	139 (36.6)	59 (15.5)	14 (3.7)	–	380 (100)	3.21 ± 0.83
5. Adjusts attributes (e.g. speed) of input devices (e.g. mouse, keyboard) to suit individual user needs	230 (60.5)	99 (26.1)	40 (10.5)	11 (2.9)	–	380 (100)	3.44 ± 0.79
6. Can adjust amount of information (data, text, graphics, etc.) displayed on-screen to user needs	210 (55.3)	101 (26.6)	58 (15.3)	11 (2.9)	–	380 (100)	3.34 ± 0.84
7. Adjusts software response times to working speed	215 (56.6)	117 (30.8)	30 (7.9)	18 (4.7)	–	380 (100)	3.39 ± 0.82
Total	**1332 (50.1)**	**929 (34.9)**	**320 (12)**	**79 (3)**	–	**2660 (100)**	**3.32 ± 0.74**
Suitability for learning							
1. Provides fluent and simple language	220 (57.9)	131 (34.5)	29 (7.6)	–	–	380 (100)	3.5 ± 0.63
2. Is easy to learn to work with	259 (68.2)	121 (31.8)				380 (100)	3.68 ± 0.46
3. User can increase skill from explanations provided in help menu	271 (71.3)	109 (28.7)	–	–	–	380 (100)	3.71 ± 0.45
4. Rules for communication (i.e. data entry) are easy to learn	231 (60.8)	149 (39.4)	–	–	–	380 (100)	3.6 ± 0.48
5. Can be used without asking co-workers for help	271 (71.3)	109 (28.7)	–	–	–	380 (100)	3.71 ± 0.45
6. Encourages users to try system functions by trial and error	191 (50.3)	136 (35.8)	53 (13.9)	–	–	380 (100)	3.36 ± 0.71
7. Provides no-penalty learning	225 (59.2)	109 (28.7)	35 (9.2)	11 (2.9)	–	380 (100)	3.44 ± 0.77
8. Creates need to remember a great deal of detail	232 (61.1)	108 (28.2)	40 (10.5)	–	–	380 (100)	3.5 ± 0.67
9. Has easy-to-use commands	259 (68.2)	121 (31.8)	–	–	–	380 (100)	3.68 ± 0.46

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
10. Remembers specific rules about entering commands	250 (65.8)	109 (28.7)	21 (5.5)	–	–	380 (100)	3.6 ± 0.59
11. Is easy to get help (or guidance) easily regarding any points in the system.	261 (68.7)	98 (25.8)	21 (5.5)	–	–	380 (100)	3.63 ± 0.58
12. Explains possible action when user requests help	235 (61.8)	120 (31.6)	25 (6.6)	–	–	380 (100)	3.55 ± 0.61
13. Helps find relevant information directly without looking through unnecessary information	259 (68.2)	102 (26.8)	19 (5)	–	–	380 (100)	3.63 ± 0.57
14. Provides information through help menu	248 (65.3)	115 (30.3)	17 (4.5)	–	–	380 (100)	3.6 ± 0.57
15. Provides in-depth, comprehensive descriptions covering all aspects of system	216 (56.8)	140 (36.8)	24 (6.3)	–	–	380 (100)	3.5 ± 0.61
16. Ease of finding required section (information) in hard-copy documentation	218 (57.4)	137 (36.1)	25 (6.6)	–	–	380 (100)	3.5 ± 0.61
17. Provides user guidance and support related to user tasks	226 (59.5)	137 (36.1)	17 (4.5)	–	–	380 (100)	3.55 ± 0.58
18. Provides up-to-date user guidance and support	208 (54.7)	144 (37.9)	28 (7.4)	–	–	380 (100)	3.47 ± 0.63
19. Implements and maintains systems without vendor support	157 (41.3)	147 (45.8)	41 (10.8)	–	–	380 (100)	3.26 ± 0.73
Total	**4437 (61.5)**	**2369 (32.8)**	**395 (5.5)**	**19 (0.3)**	–	**7220 (100)**	**3.55 ± 0.54**
Visual clarity							
1. Proves salient visual cues to identify active window	278 (73.2)	102 (26.8)	–	–	–	380 (100)	3.73 ± 0.44
2. Information on screen is easy to see and read	278 (73.2)	102 (26.8)	–	–	–	380 (100)	3.73 ± 0.44
3. Provides clear and easily-read fonts on screen	259 (68.2)	102 (26.8)	19 (5)	–	–	380 (100)	3.63 ± 0.57
4. Has proper font size	251 (66.1)	118 (31.1)	11 (2.9)	–	–	380 (100)	3.63 ± 0.53
5. Has image of characters (fuzzy or sharp)	271 (71.3)	109 (28.7)	–	–	–	380 (100)	3.71 ± 0.45
6. Clearly separates different types of information	229 (60.3)	140 (36.8)	11 (2.9)	–	–	380 (100)	3.57 ± 0.55
7. Highlights important information on screen	270 (71.1)	87 (22.9)	23 (6.1)	–	–	380 (100)	3.65 ± 0.59
8. Defines prescribed area for data entry	267 (70.3)	93 (24.5)	20 (5.3)	–	–	380 (100)	3.65 ± 0.57

(*Continued*)

Table 2. (Continued).

Requirements \ Users viewpoints	strongly agree	agree	no comments	disagree	strongly disagree	Total	Mean of score out of 4
9. Defines the information format for entry.	259 (68.2)	121 (31.8)	–	–	–	380 (100)	3.68 ± 0.46
10. Distinguishes between old and updated input	241 (63.4)	128 (33.7)	11 (2.9)	–	–	380 (100)	3.6 ± 0.54
11. Makes clutter screens appear	271 (71.3)	109 (28.7)	–	–	–	380 (100)	3.71 ± 0.45
12. Contains clearly aligned columns of information	267 (70.3)	93 (24.5)	20 (5.3)	–	–	380 (100)	3.65 ± 0.57
Visual clarity							
13. Provides clear schematic and pictorial displays (e.g. figures and diagrams)	239 (62.9)	112 (29.5)	29 (7.6)	–	–	380 (100)	3.55 ± 0.63
14. Guarantees that all aspects of display are easy to see if used on a monochrome or low resolution screen, or if the user is color blind.	229 (60.3)	151 (39.7)	–	–	–	380 (100)	3.6 ± 0.49
15. Provides high contrast between text and background.	239 (62.9)	111 (29.2)	30 (7.9)	–	–	380 (100)	3.55 ± 0.63
16. Provides reasonable screen density.	248 (65.3)	93 (24.5)	39 (10.3)		–	380 (100)	3.55 ± 0.67
17. Uses high-value, high- chrome colors to attract attention.	248 (65.3)	114 (30)	18 (4.7)	–	–	380 (100)	3.6 ± 0.57
18. Provides easily distinguished colors.	275 (72.4)	77 (20.3)	28 (7.4)	–	–	380 (100)	3.65 ± 0.61
Total	**4619 (67.5)**	**1962 (28.7)**	**259 (3.8)**	–	–	**6840 (100)**	**3.64 ± 0.51**
Auditory presentation							
1. Uses commentary to assist user	151 (39.7	169 (44.5)	39 (10.3)	21 (5.5)	–	380 (100)	3.18 ± 0.83
2. Uses music to enhance presentation of information	138 (36.3)	192 (50.5)	50 (13.2)	–	–	380 (100)	3.23 ± 0.66
3. Presents voice commentary in sequence synchronously with information on screen	169 (44.5)	180 (47.4)	31 (8.2)	–	–	380 (100)	3.36 ± 0.62
4. Uses concise and understandable vocabulary	114 (30)	176 (46.3)	87 (22.9)	3 (0.8)	–	380 (100)	3.05 ± 0.74
5. Can record auditory data	124 (32.6)	159 (41.8)	97 (25.5)	–	–	380 (100)	3.07 ± 0.76
6. Informs user when requested action is completed (successfully or unsuccessfully)	117 (30.8)	162 (42.6)	96 (25.3)	5 (1.3)	–	380 (100)	3.02 ± 0.78
7. Tailors aspects of auditory presentation (e. g. adjusting volume, speed)	147 (38.7)	149 (39.2)	79 (20.8)	5 (1.3)	–	380 (100)	3.15 ± 0.79
8. Stops commentary and replay it	191 (50.3)	136 (35.8)	53 (13.9)	–	–	380 (100)	3.36 ± 0.71
Total	**1151 (37.9)**	**1323 (43.5)**	**532 (17.5)**	**34 (1.1)**	–	**3040 (100)**	**3.18 ± 0.69**

The highest score for "suitability for the task" was given to "ease of finding the required information on the screen" (3.78 ± 0.41). Other cases having the high rates of EMR usability were, in order:

(a) "decreases the amount of work needed to accomplish the job" from "suitability of task" (3.76 ± 0.42);
(b) "moved back and forth between screens" from "controllability" (3.76 ± 0.42);
(c) "concise and positive instructions and messages" from "self-descriptiveness" (3.73 ± 0.44);
(d) "clear statement about error correction" from "self-descriptiveness" (3.73 ± 0.44);
(e) "clear and unambiguous error messages" from "error tolerance" (3.73 ± 0.44);
(f) "clarity of active window in the software" from "visual clarity requirements" (3.73 ± 0.44);
(g) "easy-to-read information on the screen" from "visual clarity" (3.73 ± 0.44).

From among the requirements adopted, the lowest score was given to "informs the user when a requested action is completed" from "auditory presentation" (3.02 ± 0.78).

Discussion

This study determined EMR usability requirements based on end-user needs. The results revealed that the highest and lowest rates of agreement related to "visual clarity" and "auditory presentation," respectively. Visual clarity means that the information shown on the screen is clear, well-organized, unambiguous, and easy to read (29, 30). Many medical fields are visually oriented (32, 33). Studies show that an ecological interface design reduces user cognitive workload and improves work processes using "object" and "graphical display" (34, 35). The visual capabilities of EMRs enhance user perceptual abilities (36) and achievement of usability goals of IT tools for effectiveness, efficiency, and satisfaction (37). In an investigation comparing knowledge about changes in a patient's condition using an integrated graphical information display (IGID) and tabular intensive care unit (ICU), patient information display between ICU nurses found that nurse recognition of abnormal values in IGID was better than in a tabular display (38).

Wachter (39) reviewed the opinions of physicians, respiratory therapists, and nurses in an ICU and found that pulmonary graphical display provides an accurate representation of respiratory variables. Drew (40) reviewed the role of data display in anesthesiologist performance and concluded that a graphical display improves anesthesiologist awareness. Blike (41) evaluated the effect of a graphical object on the speed and accuracy of anesthesiologist diagnostic tasks and found that it reduced diagnostic errors of anesthesiologists who used an object display format and increased their diagnostic speed of shock states. Agutter (42) compared the effects of a graphic cardiovascular display between anesthesiologist groups and showed that myocardial ischemia detection by the group who used a graphic display was two minutes faster than in the other group.

The use of object and visual graphics increases work efficiency and improves user satisfaction (35). In an investigation measuring the effects of bar graph and ecological displays on treatment efficiency, cognitive workload and user satisfaction, Effken (35) reported greater satisfaction in nurses for ecological display (35). It appears that most healthcare professionals rely on visual characteristics; thus, understanding user tasks and context characteristics is critical for EMR usability. Zhang (2011) developed a unified framework of EHR usability and found that evaluating "the functionality of the EHR system in the context of user-meaningful operations" as a crucial task for EHR usability design and evaluation (6).

Findings of the present study revealed that the highest rate of EMR usability related to "ease of finding the required information on the screen" as an aspect of suitability of task performance. Holbrooka (43) noted that the speed and flexibility of electronic medical records were success factors of such systems. Horsky (44) introduced usability principles of such systems, including consistent use of color and language, a minimalist approach toward the layout of information, appropriate use of fonts to change information, and visual prominence as aspects affecting their speed and accuracy.

Rose (45) noted that the contrast between foreground text and background an affects quick information retrieval (45) and that the density of information also affects easy data recovery on the screen. Creating a balance between user informational needs with limited screen size is a challenge to EMR user interface design (45). Rose reported that physicians believe that a crowded screen disrupts task performance speed, causing an increase in medical errors (45). Other studies mention consistency of design concepts across systems, visual representation of clinical data, and use of controlled terminology as influential factors facilitating user information access (46).

The results of the present study indicate that the lowest agreement among end-users related to "auditory presentation" requirements, although its quality is of particular importance in devices that work with sound technology, such as speech recognition (47,48). Moreover, EMR system capability relies on tools such as alerts and reminders that have been designed for real-time notification of errors, potential hazards, or omissions related to interactive events and usually act in the form of an alarm (46). A poor design can cause alert fatigue among users by creating distracting noises which are gradually ignored and increase mistrust of alarms (49,50). This can have an adverse effect on patient safety. One survey found that therapists cancel drug safety alerts in 49% to 96% of cases (50). To reduce notification interruptions, it is essential to provide users with configurable individualized alerts. They require the ability to switch alerts on or off if needed or adjust them to suit patient needs (49).

Because this investigation was conducted as a survey among users, lack of complete understanding of the research questions was considered to be a weakness. Unlike the cognitive walkthrough or think-aloud methods that objectively focus on creation of a real environment and direct interaction between the user and system, a questionnaire-based usability test is subjective and relies on user perceptions. In a cognitive walkthrough approach, the ease of user activity can be assessed. In the think-aloud method, a user evaluates the defects of a user-centered design in a simulated environment of a real workplace.

All items relevant to EMR usability requirements were dealt with by all users regardless of field of work and tasks; this could cause bias in setting priorities for EMR usability requirements. Determination of major EMR usability requirements by the users in the form of a questionnaire can provide an avenue for creation of standard questionnaires in this area. Furthermore, the incorporation of user and expert feedback to determine EMR usability requirements is another strong point of this study.

Implications for practice, education, and research

The adoption and usage of EMRs are often hampered by their poor design and usability. Managers, policymakers, and vendors must be aware of user requirements and expert concerns. A small number of previous studies have provided comprehensive and objective requirements based on expert and user needs. This is triangulation of strategy that incorporates user and expert perspectives and the best testing methods (ISO 9241; Part 10: IsoMetric usability) to develop usability requirements.

The findings of the current study suggest a need for greater efforts on the use of EMR systems based on user task analysis and context of use. It is recommended that future studies focus more on the role of task-specific usability requirements for end-user tasks and job analysis of physicians, anesthetics, surgeons, clinical nursing, ICU nursing, laboratory, and radiology.

Conclusion

The results of the present research reveal that the highest and lowest agreement among end-users relates to the "visual clarity" and "auditory presentation" requirements of EMRs, respectively. These findings suggest that user priorities for determining EMR usability requirements and their understanding of the importance of the types of individual tasks and context characteristics differ. Therefore, user task analysis and context of use should be incorporated into the design of these

systems. Because the model was designed with the aid of expert and user perspectives in this study, EMR usability requirements were taken into account in detail. It is recommended that the items offered by this model be employed in other usability testing methods that evaluate a real environment by incorporating heuristic, cognitive walkthrough, and think-aloud approaches. Usability assessment according to the requirements set by users and experts in a real environment will provide a more comprehensive perspective.

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Declaration of interest

The authors declare that they have no competing interests.

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Notes on contributor

Mehrdad Farzandipour and Zahra Meidani made substantial contributions to the conception, design and acquisition of funding. Monireh Sadeqi Jabali participated in data collection and performed the statistical analysis. Zahra Meidani and Hossein Riazi contributed to manuscript drafting, revision, and approval, and Mehrdad Farzandipour was responsible for the general supervision of the research group.

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