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ANALYZING THE SCOPE OF INTEGRATING ELECTRONIC MEDICAL RECORDS (EMR) AND ELECTRONIC HEALTH RECORDS (EHR) WITH MULTIMODAL HUMAN COMPUTER INTERACTION (MMHCI)

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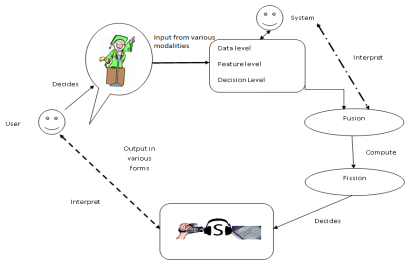
Graphical abstract



Abstract

Developing applications using Multi Modal Human Computer Interaction (MMHCI) remains a great challenge due to the advancement of technologies. Enhanced interaction applications and tools employed in medical records will help to improve the quality of patients' healthcare and it opens a variety of research challenges. Replacing a difficult system to store complex data related to medical history of patients through Electronic Medical Records (EMR)/Electronic Health Records (EHR) would offer several advantages that include confidentiality and patient details reliability along with the mechanisms for quick and flexible retrieval of data/information. The task of designing MMHCI applications for real time environment for EMR/EHR is thus complex. As the inputs to medical systems are heterogeneous, the associated issues grow up with the need for new system since the existing frameworks have many gaps and drawbacks. This paper attempts to discuss the possible guidelines, standards, tools and techniques involved in integrating MMHCI with EMR/EHR.

Keywords: Multimodal interaction, clinical data, interfaces, modality fission, fusion, context management, dialog management

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1.0 INTRODUCTION

In this proliferation world, diseases are increasing in different forms. Due to this, a need for inventions in the field of medicines increases day by day. This need not only stop with invention of drugs but it also needs computing resources to make jobs simple. Unfortunately, the facilities required to make job simple is not in a single location to attain this objective. The present Indian scenario states that it is not possible and feasible to treat all kinds of diseases from a single point of contact. A patient needs to carry his/her medical history along with them always whenever a new treatment is required from some specialist. During the process, there arises a chance of theft or loss of data. To avoid these issues, it is preferable to maintain the details in an electronic format which would reduce the burden of carrying information from one place to another. In order to do so, it is essential to record and maintain the details electronically which can also confirms the reduction of manual intervention. Further, the human intervention can be reduced if the electronically maintained details are emphasizing on less human

intervention with effective presentation of details to make the process very much usable.

The usability of any process may be improved by a suitable mechanism of interaction that would increase the understanding of the system. A better understanding can be brought by the different modes of presentation. One of the techniques that support the multiple views of presentation is the multimodal interaction. Especially in the field of medicine, this multimodal interaction is expected to deliver more natural way of communication through audio, video and images. This kind of demonstration would enhance the reliable and flexible communication. The effectiveness of this technique would be more provided the mode of interaction is convenient and understandable to the individual users. If the individuals' convenience and understandability is the major concern, then it is needed to comprehend the system with the cognitive capability of the users. Thus, to provide an effective mechanism for EMR/EHR handling, a multimodal based HCI incorporating cognitive theory would be preferable. Hence a quantitative review is performed to understand the fundamental view of multimodal interaction supported by the cognitive science to combine the modalities of medical records.

2.0 AN INSIGHT INTO MULTIMODAL INTERACTION

In general, MMHCI refers to "interaction with the virtual and physical environment through natural modes of communication" [Wikipedia]. According to Oviatt [14], Multimodal interfaces process two or more combined user input modes in a coordinated manner. These interfaces recognize naturally occurring forms of human language and behavior. Major features of multimodal processing and architectures are: *(a) merging different types of data (fusion) and (b) real-time data processing together with the constraints pertaining to temporal aspects*. The idea stated by Oviatt *et al*. [15] offer a modified class of interfaces that generally differs from a WIMP interfaces. A study on multimodal interfaces by Oviatt in 2008 has shown that applications involving multimodal interfaces could speed up the completion of task.

2.1 Philosophy behind Multimodal Interaction

The underlying principles of Multimodal interaction are discussed in various forms by Oviatt [15] and Norman [11]. Following Figure 1 depicts the multimodal interaction loop.

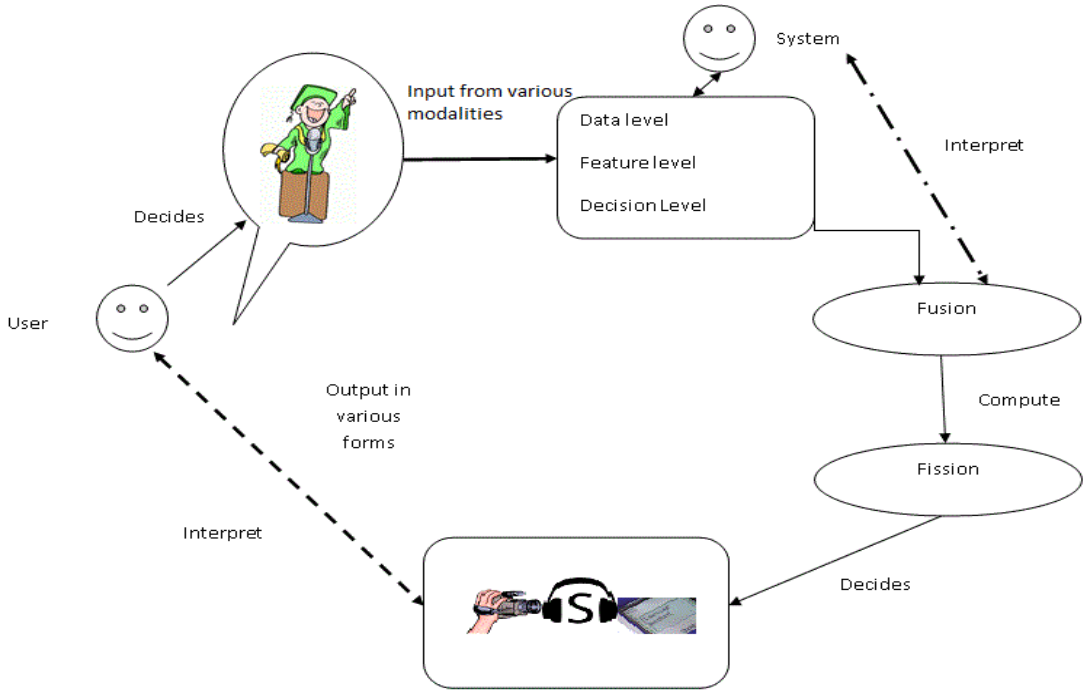

Figure 1 Multimodal Interaction Loop

User decides to communicate through any of the input modalities viz. speech, gestures. System will interpret the inputs from modalities at any one of the following levels: Data level, Feature level and Decision level. Then it is interpreted by the system which can be collectively termed as fusion that represents combining inputs from various modalities. System again will decide the modality through which the response can be given back. The modalities include: audio, video or text. System chooses the

modality for responses to be provided and the user interprets the results generated in any form. Given below Table 1 illustrates the role of users and machines in any multimodal applications.

Table 1 Various states in Multimodal interaction

States	Mode (input/output)	User's role	Machine's role
Decision state	Input	Intension Attention Emotion	-
Action State	Input / Output	Input (through any means)	Output (Modality determination)
Interpretation State	Input / Output	Output to be interpreted	Input to be recognized
Perception state	Input / Output	Perceive inputs	To decide the perception
Computation state	Output	-	Action to be taken against the received input and modalities

User decides the input modality by any means through intension, attention or emotion via keyboarding, speech or gestures respectively in decision state. Users having chosen their modality, give their input in action state whereas the machine determines the output modality to respond back to the input. In interpretation state, machine determines the users' input and users interpret the responses generated by the machine. In perception state, users recognize the mode and modality of response whereas the machine decides the channel among the existing alternatives to deliver the response. In computation state, machine interprets the users request and decides about the mechanism to generate the responses.

According to the study by Norman [11] and Oviatt [14], the key issues related with the multimodal interactions are:

- Integrating multimodal signal leading to the data fusion
- Planning for the responses using suitable modality of output
- Dialog Management
- Context Management
- Developing time sensitive architectures to include the above mentioned features

2.2 Guidelines for the Multimodal interfaces

Several research works highlighted the guidelines in developing applications using multimodal interfaces. According to Reeves *et al*. (2004) and Nicu Sebe [12] the guidelines prescribed are:

- Consideration of wide range of users to support multiple modalities and flexibility
- Concern on the security and privacy issues
- Integration of modalities using user's preferences and capabilities
- Care on personalization
- Design of the complimentary modalities to improve robustness and to reduce errors

According to Matthias Schneider *et al*. [10], and Sarter [13], the entire guidelines of multimodal interfaces have been synchronized into four major themes:

- Selection of modalities
- Mapping of modalities to task and information
- Combination, Synchronization and Integration of modalities
- Adaptation of modalities with respect to task context and circumstances

According to Lalanee *et al.* [4], multimodal interactions have been declared as a seven layer protocol model with three different combinations of layers such as conceptual, perceptual and physical. The layers addressed the issues such as operational goal, pragmatic concepts to achieve the goal, specific operations to implement the task towards the goal, sequencing of input and output information units, smallest information of interaction, physically coded information and primitive symbols.

Ultimately, the multimodal interfaces are expected to address issues related to performance such as adaptability, consistency, feedback, error handling, robustness and scalability.

2.3 Key Components of a Multimodal Interfaces

According to Oviatt *et al*. [15], major components of MMHCI include

- Fusion Engine
- Fission Module
- Dialog Manager
- Context Manager

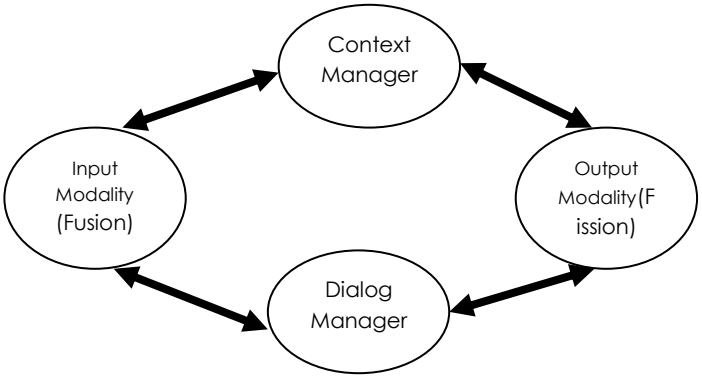

Figure 2 Major Components of MMHCI

The above Figure 2 shows the flow among the components that contributes to integration committee. Here, various recognizers are used to perceive various input modalities. They pass their output to fusion engine which gives a general interpretation of inputs. Dialog management module identifies the state of dialog (transition to be performed or action to be communicated). It in turn gives its result to fission management module that takes the responsibility of giving back responses to the input received that may be achieved through a single or combination of modalities that is mainly dependent on users and context which is supported by context management module. Recently, W3C has recommended different components of Multimodal Human Computer Interactions as:

Users *– Any users giving input to the system; interprets the responses given back.*

Input — Any interactive application shall use multiple modes for input including audio, keyboarding, handwriting, speech etc.

Output — Applications involving multimodal interaction may employ one or more modes of output say text, graphics, speech, audio files etc.

Interaction manager — Also referred as Integration committee by some authors is the logical component that manages and coordinates data execution / flow from all input and output modalities. It maintains the state together with the context so as to respond to the received inputs and changes in environment. Dialog manager in the fig. is responsible for this task.

Session component — it takes care of persistent and temporary session management in MMHCI applications there by providing an interface to the integration component. Context manager in the fig. takes care of this feature.

System and Environment component — it takes care of changes in environment and users capabilities with their preferences. Context manager in Fig represents the same.

3.0 EXISTING FRAMEWORKS FOR PROGRAMMING/MODELING MMHCI

Many studies attempted to program and model MM interaction before formalizing [16, 18]. Many frameworks have been evolving recently to support the multimodal interfaces. Unlike the traditional human computer interaction, MMHCI introduces the natural modalities such as facial expression, gestures, verbal and non-verbal cues. Krahnstoever *et al*. [8] designed a framework with gestures and speech to produce a natural interface by integrating video cues and audio. The framework was validated through various implementations. The authors suggested that adding speech recognizers to validate the speech in any noisy environment as well as identifying any individuals through their emotional speech as room for further improvement. Quickset, a framework developed by Cohen *et al*. [3] acted as test bed for many fusion methods as the authors proposed a novel integration strategy in their work. Quickset was implemented in US navy and army and validated thoroughly which gave room for incorporating speech recognizers in a heavily noisy environment and the same has been added in their next release. Flippo *et al*. [5] analyzed the direct integration of a framework into an application itself by using independent fusion technique in parallel applications by resolving ambiguities. Here, the architecture is based on agents and concept of frames was used for fusion. The authors suggested using fuzzy based approach and Bayesian networks toward implementing the same as their future enhancement. Bouchet *et al*. [1] ended with an approach based on CARE design space which is purely component-based referred as ICARE where components cover all the essential tasks where events were used to model component communications. The FACET system proved in reducing production costs and also verified ideas such as evolution, reusability (as ICARE is component based development) and maintainability when the system was implemented using ICARE framework. This inspired and laid the foundation for an open-source toolkit OpenInterface that was comprehensively used as a GUI toolkit for cross platform environments in 2008. OpenInterface uses normal WYSWYG (What You See is What You Get) kind of editors. Jai Shen *et al*. [6] in their study classified the existing frameworks as shown in the following Table 2: SDKs based on local/remote procedure call and middleware based on publish/subscribe (P/S) architecture.

Table 2 Frameworks classified by Jai Shen

Name of the framework	Inventor details	Purpose
Based on Local/remote procedure call		
DirectShow	Microsoft, March 1997	To perform various operations with media files or streams. It is the replacement for Microsoft's earlier Video for Windows technology.
Open Interface	Neuron Data, Released in March 1991.	Cross platform GUI toolkit with WYSIWYG editor.
Based on P/S architecture		
ActiveMQ	Apache, Initiated in July 2007 and stable release in October 2013	An open source message broker written in Java to provide Enterprise Features fostering the communication from more than one client or server.
Fleeble	OStatic,	Java based open-source tool; agent based complete framework with mobility, distributed and autonomy features.

Despite the fact that the existing frameworks scale well in developing traditional multimodal applications, much of the work has to be done in designing the frameworks for integrating electronic health records using multimodal human computer interaction.

4.0 MODELING MMHCI

Unlike the programming based approach, model driven software development emphasizing on models had a greater influence on MMHCI. Modeling at various levels of abstraction would be a beneficial one to the multimodal system. Rather than interaction specification through audio, video and gestures, modeling focuses on the abstract modality to define common characteristics of HCI modalities. Two formal models that exist for combining modalities are:

- CASE (Concurrent, Alternate, Synergistic and Exclusive) model in 1993 focused on possibilities of combining modality at fusion level.
- CARE (Complimentary, Assignment, Redundancy and Equivalence) model during 1995 focused at user level possibilities to combine modalities

According to a study by Zeljko Obrenovic and DusanStarcevic [19], modeling of HCI is generally performed based on the following: Expertise, Task and Efficiency, Task Success, User behavior and it is agreed by the researchers that the response of multimodal human computer interaction is modeled based on perceptual processing, immediate response and the unit task time. It is observed that most of the modeling techniques are based on the cognitive abilities that determine the user behavior. Figure 3 gives an idea about various cognitive concepts.

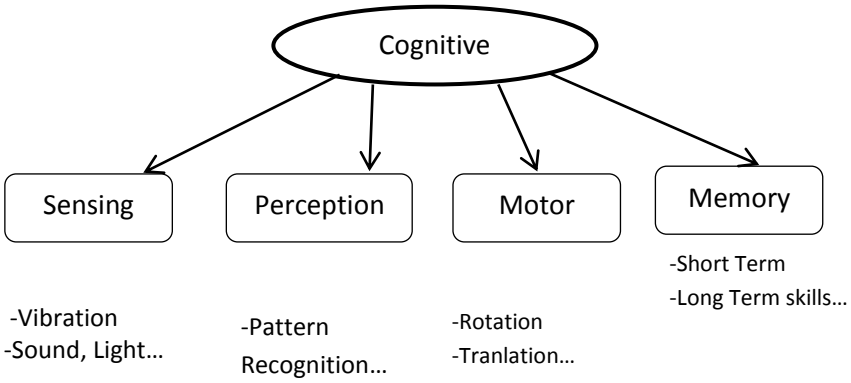

Figure 3 Cognitive Abilities of a user

Input modalities such as vibration, sound and light can be associated with sensing in cognitive science while pattern recognition in input modalities in multimodal interaction can be mapped to perception in cognitive concept. Identification of movement like rotation or translation employed in multimodal communications can be treated as motor skills required in cognitive theory. Memory and process related to memory such as short-term and long-term memory skills can be related to cognitive memory. As all the cognitive skills and concepts are well fit into multimodal human computer interaction, it is evident that cognitive theories shall be applied while designing applications involving MMHCI. Considering the principles of MMHCI and the ideas provided by existing frameworks and modeling tools, it is quite possible to introduce MMHCI in varieties of applications that act upon users input mostly. Especially in the field of medical applications, this kind of multimodal interaction would be a great support to reduce time, space and to improve decision making process among the physicians. Specifically, while dealing with EMR and EHR lot of user input is required which is submitted through either keyboard or mouse click. If the multimodal interface is provided, there can be a drastic improvement on the system usage and effectiveness. The existing features and frameworks do not incorporate the features of HCI to facilitate patient's interaction or usage of their electronic records. The frameworks concentrate only on maintaining the records, securing the patients' record. All the existing frameworks only deals from the perspectives of the service provider or the physicians like how the implementation can be made optimal or how the physicians can be given a more user friendly user interface. Considering the patients background and knowledge level, none of the contributions were made by incorporating the stated features like integrating audio with their record or making interfaces more user friendly. As a matter of fact, there are only a very few software systems in Indian medical scenario that only maintains the whole hospital information in their own local servers and none of them shares the information with other hospitals so as to effectively implement the concept of EHR. Even the cognitive abilities of the patients were not completely considered while designing the user interfaces for any medical systems in India. Only by the year 2013, Indian Government has initiated the process of Electronic Medical Records throughout the country so as to make effective sharing of information and easy traversal of patients' information across the physicians in the nation. Looking into MMHCI as a feature that would support easy operations of medical records by patients, no specific contributions were made in this scope thus by arising the need for more issues.

5.0 OVERVIEW OF EMR/EHR

According to Wikipedia, EHRs can be defined as "a systematic collection of electronic health information about individual patients or populations". The existing system based on paper need more space, time and physicians full attention in filling them. Even a small mistake can lead to misinterpretation and wrong decision making. Also, it may have its own restrictions in sharing the details between several healthcare units without transportation of medical record safely. These issues could be avoided if there is a viable method which can share EHRs/EMRs and requires less information to be filled in is available for use. Due to the basic nature of MMHCI, it is highly preferable to use such kind of interfaces in EMR/HER.

Some of the potential benefits and advantage of EHRs are mentioned below:

- Prepare Once; Employ Always
- Data maintenance through computers helps to produce proper records
- Enhanced Policy making
- Coordinating tasks at various levels
- Providing universal access minimizes redundancy
- Reduction in referral cost
- Consistency in data elements and standardization of information models enable the decision support implementation by semantic interoperability
- Prevention of adverse events
- Able to reduce the number and types of errors in treatment summaries.

Considering all the potential benefits as given, there has been a possible barrier in implementing HER systems. Some of the major barriers identified are:

i. No Standards
ii. Difficult to determine the exact cost
iii. Operators inability
iv. Time to change in the existing clinical activities
v. Whom to trust
vi. Safety of patients data

From the above stated implementation constraints, it is noted that EMR and EHR have greater challenges in improving the quality of healthcare which is to be delivered on time with accuracy.

5.1 EMR/EHR with MMHCI

Some of the earlier work towards this direction is presented as follows:

Chen & Shih [2] proposed an EMR system which is portable considering the increased occurrence of accidents and sickness that may occur while travelling with a web-based interface. They suggested streaming and integrating media techniques with EMR so as to enhance referrals, communicate with lab and notification of diseases among hospitals. They concluded that adding medical images still remains a major concern with streaming. Krist and Woolf [9] in their article idealize that whenever the patients can access their information and involve themselves, health records become patient-centered as most patients now-a-days are using computers and smart phones to access their personal information. Stroemann *et al*. [7] also discussed in a study strongly advised that all the patients should start accessing their medical details with the existing facilities so as to improve better communication between patients and physicians. They suggested that when a patient starts using multimodal tools to manage and involve themselves in health status, better communication and results could be achieved by which patients with complex diseases can monitor their observations to act accordingly. Charissis *et al*. [17] proposed a study to analyze and evaluate user-centered interface designed for medical training environment based on virtual reality. It supported the exchange of medical images in 3Dimensional view. Their study concluded that 2D/3D communication for information exchange is to be developed for supporting the decision making procedure more evident. Whenever the patients involve directly themselves in handling their data, chances for improving their skills and knowledge lead to familiarize themselves with their present status thus by getting improved experiences with their electronic records. When the experience of using electronic records would be made easier by including MMHCI features, any novice users would interact with computers and physicians. For example, integrating speech features into a patients' electronic record can assist them to improve their interaction with their physicians irrespective of their competency level. In general, use of multimodal interfaces in healthcare research to improve patients care has several open issues to be addressed. Some of them are:

- Ways to access medical images are not adequate.
- Control over the existing medical image data is limited.
- Data transfers and Management Process are not consistent as they need to be customized.
- Administration of these systems using multimodal interfaces for EMR should consider how to manage the clinical data with their quality and security.
- Mechanisms for uploading and storing of records need more optimization techniques.
- CBIR (Content Based Image Retrieval) mechanisms may be employed to improve clinical decision process.
- Open issues pertaining to general image processing techniques will also fit in this aspect.
- Fundamental aim of improved User Experience and Optimized workflow in HCI opens widely major issues.
- Managing medical image and data by providing layered security (authentication, authorization, access control and full audit trail) still remains a great challenge.
- Options for reviewing multiple images and data whenever needed it need more mechanisms and ways to improve the ways of retrieving the same.

Hence, the existing frameworks and tools lack complete support in integrating multimodal interaction approach in electronic health records that give way to invent new framework and tool to enhance the existing approaches so as to improve the quality of patients'. A proposed idea of integrating MMHCI and EHR is depicted in the following Figure 4.

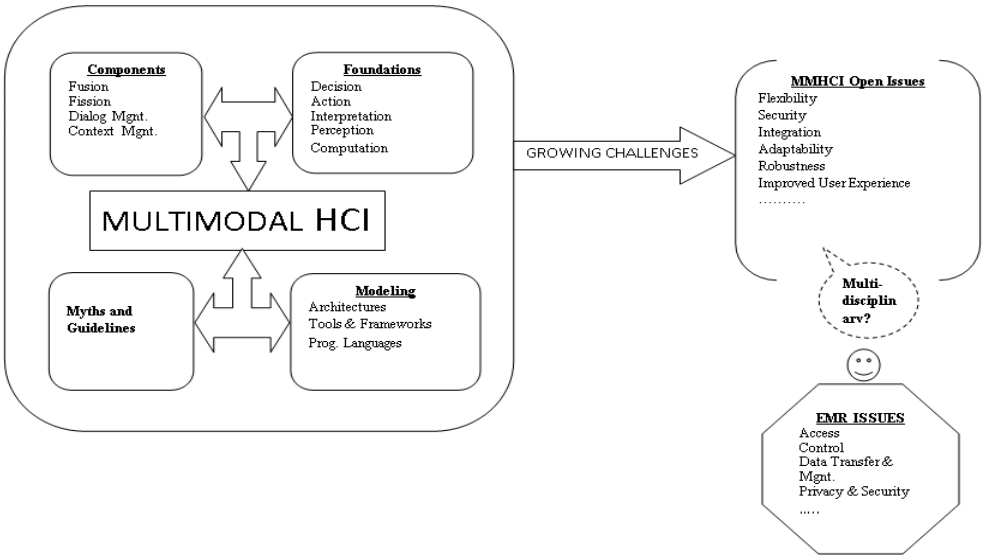

Figure 4 Applicability of MMHCI into EMR/EHR

As shown in the above Figure 4, multimodal human computer interaction has its strong foundations with various components supported by several guidelines dealing with various input modalities and output modalities. Many techniques are available for integrating the modalities with different components viz fusion, fission, context management and dialog management. Researchers have proposed their own frameworks and modeling multimodal interaction in their own ways and the same has been validated after implementation in real time. Stronger guidelines were accepted as rule of thumb in multimodal applications as suggested in various studies. ACM has also recognized ten myths for multimodal interaction which serves as a platform for new application design. Following Table 3 summarizes the issues associated with integrating EMR/EHR with existing MMHCI due to which they still remains within active research scope.

Table 3 Summary of issues associated with EMR in MMHCI

MMHCI Characteristics	Integration with EMR/EHR
Flexibility	√
Security	√
Access control	√
Integration	√
Adaptability	√
Robustness	√
Privacy issues	√
Improved user experience	√
Myths and Guidelines	√
Data transfer	√
Data management	√
Data structures	√
Architectures	√
Modeling tools	√

6.0 CONCLUSION

This study did not consider all the existing techniques of multi modal human computer interaction. Considering the existing Indian medical scenario and feasibilities, this study identified that we can integrate the features of MMHCI into electronic medical records in order to make efficient utilization of the patients' history. This study tried to generalize the aspects of medical records irrespective of their category (image or text). From this study, it is evident that applications using Electronic Medical Records and Electronic Health Records can be integrated with multimodal interfaces to enhance the quality of patients care and improve clinical decision making process by enabling practitioners to access the records when they needed in any form through ease of storage/retrieval of the same. More focus is to be given for medical images as the same can be combined with existing practice of using EMR. Remarkable improvements can be achieved only after implementing the systems with proposed ideas of integrating the HCI features into the existing medical records so as to facilitate the patients' to involve themselves in their personal care. The process can be evaluated only after completely implementing the same all over the nation by the way of measuring user satisfaction. Once implemented, patients are free from carrying their own medical details from one place to another place. Physicians would also find it useful for referring across the nations as pointed out already. Thus, this study concludes that the features of HCI with multiple modalities can be integrated into the existing systems of medical records of the patients.

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