Visualising Emotion in Support of Patient-Physician Communication: An empirical study

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10494 words

Abstract—Patient-physician communication is a crucial aspect of clinical diagnoses and treatments. However, there are barriers to effective empathic practices, including consciousness, busy working rhythms, and difficulties recognising patients' implicit emotional expressions. While previous research has attempted to support asynchronous medical conversations, this study has explored the use of emotion visualisation techniques for synchronous, face-to-face medical encounters. After interviewing doctors to understand user requirements, an emotion-visualisation prototype, EMVIS, was created. The prototype was evaluated in a study with 31 patients and 37 healthcare providers within different specialist groups using a contextualised Technology Acceptance Model (TAM) and follow-up interviews. The results indicated that patients and physicians were generally accepting of emotion visualisation for medical encounters. Patients were more interested in their physicians' attitudes and intentions, while physicians accepted the visualisation, but their requirements differed according to their skill levels and specialities. Hence, four supportive factors - emotional empathy, careful attention, human connection, and reflective conversation - elicited information on how EMVIS contributed to medical conversations. Five future opportunities for the emotion visualisation of medical conversations were discussed in respect of the human factors and potential requirements. These include communicating uncertainty, addressing user diversity, providing explanatory information, managing attention, and supporting negotiations.

Keywords—Information visualisation, Emotion visualisation, Patient-physician communication, Empathic communication

1 INTRODUCTION

In medical practice, communication between patients and clinicians or healthcare providers creates and forms the patient-physician relationship. Based on this communication, which integrates participants' own and others' experiences, shared decision-making can lead to an ethical and technical judgment of treatment [1, 2], as well as to an individualised plan of care [3].

The mutuality model of communication can support the medical dialogue [4, 5], in which both patient and physician can obtain the same power in the relationship, as per the models of "patient-centred care", "relationship-centred care", and "participatory decision making" [4, 6]. Hence, doctors need to listen attentively and understand patients' plights to enable them to open a path toward healing [7]. During the clinical encounter, a clinician, as both a close listener and a reflexive listener, should notice what patients feel and sense their shifts in mood to generate questions and hypotheses about what these subjective experiences might mean [8].

However, there are obstacles impeding clinicians' practice of empathy and reflection [9]. A greater specialisation of physician training leads to narrower practice, making it easier to lose a holistic view of patients [4]. The side of physicians' consciousness, including knowing, thinking, and feeling the meaning of clinical events when facing patients during conversations, is not addressed sufficiently in medical education [4]. Moreover, because of the busy pace of medical practice, increased workloads, and overloaded schedules, the lack of time impedes practitioners from listening closely and developing empathy in their practices [4, 9]. Additionally, patients often express their emotions indirectly, while implicitly communicating their experiences using emotional cues and hints [10]. Hence, physicians may have to deal with these unspoken symbols.

In recent years, researchers have explored visualisation solutions to support patient-physician communications. Visualisation studies have been conducted to support patients and physicians or providers to record and obtain valuable information, such as daily symptom tracking information, emotions, and feelings about diseases in life [11, 12]. They have also explored visualisations for risk communication for shared decision-making with patients [13, 14]. However, most of these works were based upon asynchronous communications, and they were all conducted on online platforms. Thus, any support was offered before, after or in-between patient-physician encounters, not during the encounters.

Of the limited prior research into synchronous communications in face-to-face medical dialogues between patients and doctors, work has improved students' consciousness of practising empathy in medical education. For example, visualisations for the transcripts of multi-party dialogues for the analysis of a medical team's communication [15], for summarising the quality of a clinical conversation and providing suggestions [16], and for presenting good/bad attitudes of medical students during simulated interviews [17]. However, few works have focused on conducting face-to-face conversations in clinical medical practices where doctors face insufficient time and difficulties identifying patients' indirect expressions of emotion.

The overall goals of this research are twofold. First, by developing the tool, EMVIS, to visualise emotion to support synchronous patient-physician communication; second, to examine the acceptance of EMVIS empirically and to understand the requirements of emotion visualisation support during medical conversations.

2. RELATED WORK

2.1 Emotional cues and concerns in medical conversations

During medical conversations, patients usually express their emotions indirectly [10, 18] through emotional cues [19]. In a model of empathic communication in medical interviews [18], the interactional sequences of an interview begin with a potential empathic opportunity (indirect cues). The subsequent response of the physician determines the following sequence, continuing and eliciting an empathic opportunity or terminating the same. Hence, to respond effectively, physicians firstly have to understand and decode patients' nonverbal emotional cues from their voice channel, body channel and face-present channel, which leads to patients' satisfaction with their medical care [19].

In general practitioners' consultations, they will often encounter patients with emotional problems. To further emphasise the importance of accurate emotional communication, Byng et al. defined patients' emotional problems in consultations as their "emotional concerns" [20], which can be categorised into three levels: mental health problems, subclinical low moods, stress or anxiety, and low moods, stress or anxiety attributed to difficult life circumstances. When a general practitioner (GP) encounters patients presenting emotional problems, positive GP-patient communication about emotional concerns has therapeutic value [20, 21]. It can reduce the patients' self-stigma and attenuate the effects of any such stigma [22, 23].

However, according to Byng et al., emotional concerns are challenging to disclose [20] because of patients' low self-worth, pessimism, feelings of guilt and stigma [24-26] , as well as worries about their ability to make themselves understood [27]. Meanwhile, a GP's lack of confidence, limited experience, stretched resources, and a lack of time and counselling services may also result in avoiding emotional concerns and preventing diagnosis [20, 28].

To effectively recognise emotions during medical appointments, surveys [29] or direct observation and feedback [30] may support measuring patients' emotions. However, there are inevitable recall biases in practice [31] , and these methods are time-consuming, expensive, and unfeasible [30, 32]. Recently, natural language processing (NLP) technologies have been applied to classify emotions by text-based lexical features in psychotherapy [33-35]. However, in medical visits, little work has automatically captured emotional content. Park et al. [32] explored the problem of how to train a machine learning model to automatically predict the emotional valence of patients and physicians from transcripts of medical conversations. They rated emotional valence at the utterance level, but did not include nonverbal cues, which are important in an effective medical conversation.

In the research of nonverbal emotion cues, recent work in expressive disorder decoding [36] explored an algorithm to estimate depressive disorder, through facial encoding and emotive analysis, because facial expressions, as one of the sources of nonverbal emotion cues, have been found to be associated with basic emotions. Furthermore, Liu et al. found that facial expressions can jointly represent specific emotion categories and dimensions [37]. Hence, in our research, the data-driven work is based on facial cues, while we consider other nonverbal emotional channels, such as the voice and the body, among others, as falling within the future scope of our work.

2.2 Visualisation for empathic medical conversations

Information Visualisation, the interactive visual representation of data [38], has been considered a promising approach for supporting practitioners and patients' communication in

better understanding and making sense of illnesses and health conditions [39, 40]. However, current studies into visualisation for empathic or patient-centred medical conversations or dialogues have focused mainly on medical education to improve students' empathic communication abilities.

Monologger is aimed at helping doctors to be more empathic. The engagement of doctor-patient conversations includes interruptions, questions, affirming speeches, monologues, and repeated words. The habit models of conversations are presented on a webpage, or printed on paper, to summarise and provide suggestions for improvement [16]. TeMoCo, a visualisation tool for multi-party dialogues in simulated clinical settings [15], analyses visually clinical team conversations and temporally shows team members' individual contributions to such conversations. Yatera, Nishiya et al. [17] developed a visualisation system of participants' facial expressions to present good/bad attitudes of medical students during simulated interviews and then provided them with feedback. Entendre is a synchronous visual feedback display of clinicians' empathy level during on-site patient-clinician communications, and this is used for training empathic nonverbal communication skills in education [41].

These works all visualise medical dialogues and conversations for medical education, help clinicians and students learn communication skills with patients, and learn how to present their empathy during any conversations. However, in medical practice, physicians have to face other obstacles and barriers to providing effective close and reflexive listening. These include a lack of time, a limited resource of service, and the difficulties of understanding emotional cues [4, 9, 10, 20, 28].

In this current work, we have explored whether visualisations could provide more support in on-site medical conversations when patients and physicians face the problems outlined above. Hence, a visualisation approach of a real-time presentation of patients' emotional shifts has been explored, while additional potential chances for the emotion visualisation of medical conversations have also been discussed.

3. STUDY 1 INITIAL DEMANDS EXPLORATION

3.1 Methods

A study was conducted to explore medical practitioners' responses to a description of the concept to explore the potential benefits of the visualisation of real-time patients' emotional shifts. The concept was described as: (1) collecting the instant valences of seven emotions from the facial expressions of patients (i.e., happiness, sadness, fear, surprise, anger, disgust, and neutrality), and (2) presenting this visually to physicians, to support their recognition of the transitions of patients' emotions. We invited physicians to participate in the initial interviews to identify the essential functions of the concept.

Participants

In Study 1, ten participants were recruited to attend the initial interviews. These included two physicians from the psychology department, two from paediatrics, four practitioners separately from cardiology, hepatology, gynaecology and emergency departments, and two campus doctors.

Procedure

First, the study's objectives were presented, and consent to participate was obtained. Subsequently, the visualisation concept was described, and semi-structured interviews were conducted featuring the following questions: (1) the stages that need emotional understanding during the medical conversation; (2) the illness that requires emotional attention; (3) the difficulties of noticing a patient's emotion-shifts; (4) the effects on the conversation-process of patients' emotion-shifts; and (5) the effects on doctors of patients' emotion-shifts. Following that, (6) their requirements for a visualisation system were collected. The study has been reviewed according to the ethical review processes at the University of Nottingham Ningbo and obtained ethical approval from the university's ethics committee.

3.2 Data analysis

All interview transcripts were transcribed into text, and the qualitative research was conducted by a Thematic Analysis (TA) [42, 43]. Following the phases of TA, participants' perspectives were coded around the six interview questions. After developing and refining the thematic map, the four themes were defined and named. The qualitative analysis methodology and progress were described in detail in **Table 1.** The main findings are presented in the following section.

TABLE 1 THE QUALITATIVE ANALYSIS METHODOLOGY AND PROGRESS OF STUDY 1 AND STUDY 3

Phase	**Description of Process**
1. Familiarising with the data	Transcribing the data of interviews to note down initial ideas; Read data to identify ideas;
2. Generating initial codes	**Study 1** Initial coding with a theoretical approach; Coding data around six specific questions: (1) Stages that need emotional understanding during the medical conversation; (Nine codes identified) (2) The illness that requires emotional attention; (Thirteen codes identified) (3) Difficulties of noticing patient's emotion-shifts; (Eight codes identified) (4) Effects on the conversation-process of patients' emotion-shifts (Eleven codes identified) (5) Effects on doctors of patients' emotion-shifts (One code identified) (6) Requirements for a visualisation system (Twelve codes identified)
	Study 3 Initial coding with a theoretical approach; Coding data based on thirteen interview questions; Distinguishing four groups of senior psychological physicians, young psychological physicians, other healthcare providers, and patients;
3. Searching for and reviewing themes	**Study 1** Thinking about the relationship between codes, themes, and levels of themes; Generating the initial, developed thematic map; Reviewing and refining the thematic map; Creating top-level themes and sub-level themes;
	Study 3 Thinking about the relationship between codes, themes, and levels of themes; Generating the four thematic maps for the four groups; Creating eight themes in the map (Active PU, Negative PU, Active PEOU, Negative PEOU, ATT, BI, Helpful information, and General impression)
4. Defining and naming themes	**Study 1** Defining and naming the four main themes and ten sub-themes; The four main themes: (1) The situations that require additional emotional attention; (2) The difficulties of noticing a patient's emotion-shifts; (3) The effects on doctors and conversations of patients' emotion-shifts; (4) The requirements of an emotional visualisation during medical conversations.
	Study 3

	Refining and naming ten themes (Attitude, Supportiveness, Ability improving, Workflow supporting, Emotional records, PU in tasks, PU in stages, PU in situations, PU of users, and PEOU); Generating the specific sub-themes about active or negative points and healthcare providers or patients in every theme.

3.3 Findings

The participants' perspectives were analysed in the following four themes.

F1: The situations that require additional attention to patients' emotions

All the participants reported that observation of emotions is vital during a medical conversation, especially in the period of problem presentation and physical examination (F11). In particular, if the symptoms may relate to mental health problems (F12) and patients present strong negative emotions, physicians may need to pay more attention to emotion-shifts (F13). Moreover, caring for and communicating with inpatients requires a constant perception of patients' emotion-shifts. (F14) Moreover, caring for and communicating with inpatients requires the persistent perception of patients' emotion-shift. (F15)

F2: The difficulties of noticing the moment of a patient's emotion-shifts

Although the participants had been trained to observe facial expressions and to recognise emotions, in practice it takes several years to master this specific skill. Hence, senior physicians are more skilled (F21). However, for intern students or young doctors in the initial stages of their practice, observing facial expressions and recognising emotions during conversations is not easy (F22). Sometimes, they may overlook important information stemming from an emotional shift (F23). Additionally, because of their professional background, healthcare providers who are not in the psychology department may focus inadequately on patients' emotion-shifts during their clinical conversations (F24). Of course, lack of time is the main objective difficulty (F25). However, some participants mentioned that their subjective consciousness of noticing emotions is not so strong when the patient's illness is mild (F26).

F3: The effects of patients' emotion-shifts on doctors and on their conversations with patients

The participants from the psychosomatic departments described how they always cared about patients' emotions, because these are related directly to the symptoms, diagnosis, and treatment of mental health problems (F31).

All the participants reported that patients' real-time emotion-shifts could affect a physician's behaviour during a primary care encounter (F32). Physicians reported responding differently to patients, depending upon the emotions presented. For example, physicians reported reflecting on their patients' emotions when they exhibited sadness, fear, anger, pain, etc. (F33) or were emotionally unsolid (F34). Participants from the other departments paid attention to patients' emotions when they met their "emotional concerns" [20] (F35).

Additionally, a record of the emotional transitions in the whole procedure of the medical conversation could be helpful in subsequent medical conversations with the same patient, as this could be compared to the emotions that can be recorded and presented to the patient (F36).

F4: The requirements of an emotion visualisation during medical conversations:

The requirements were classified into two categories: the real-time presentation of patients' emotion-shifts during the conversation and the presentation of whole emotional records after the conversation. Detailed requirements were listed in the Table 2.

TABLE 2 REPORTED REQUIREMENTS OF AN EMOTIONAL VISUALISATION

Categories	Requirements

About real-timely presenting emotion-shifts	Providing emotional transitions as additional information; Providing dynamic reminding; Integrating with workflow and presenting in a digitised method;
About the presentation of whole emotional records	Illustrating the whole emotional situation of a patient; Displaying the emotional records based on a timeline for reflection; Saving the whole emotional situation for long-term observations;

Following the above analysis of the various perspectives, we created the guidelines for the visualisation prototype design of **Study 2**: (**G1**) The system should present patients' emotion-shifts in real-time during face-to-face medical conversations. (**G2**) The system should visualise the emotional shift of the whole conversation after it has been concluded. Both G1 and G2 were implemented accordingly in the prototype Design.

Furthermore, we understood from the interviews that health providers with different practical levels (*Based on F21, F22*) and specialities (*Based on F24, F31, F35*) may have diverse demands for using emotion visualisation for medical conversations. Consequently, **Study 3** investigated responses from a range of participants' practical levels and specialities. The recruited participants came from different medical departments. This included psychological physicians (*Based on F12, F31*), and nurses who care for inpatients in the cardiology department (*Based on F15, F24*). Moreover, we recruited the different groups of senior and junior physicians.

4. Study 2 Visualisation prototype design

4.1 Basic Functions

Based on the interviews in Study 1, we designed the visualisation prototype, **EMVIS**, with two main functions. First, the **dynamic-emotion-bar** is a real-time presentation of a patient's emotional shifts during the medical conversation (according to **G1**). The second is an **emotion-stream-graph**, a visualisation of the emotions recorded during the whole process of the medical conversation (according to **G2**).

4.2 Visualisation Design

Function 1: Real-time emotion-shift visualisation (dynamic-emotion-bar)

EMVIS present patients' instant emotional shifts through the use of a dynamic-emotion-bar (Figure 1). It is designed to refresh the scene if there is a change in any valence of the seven emotions [37, 44]. It has two areas (upper and lower). Two areas display separately the valences, with six of the emotions (happiness, sadness, fear, surprise, anger, and disgust) in the upper area, while neutral emotions are shown in the lower area. These six emotions, (i.e., excluding neutral), are the primary targets that physicians need to observe. They are illustrated in the upper area, and are highlighted with pictographs and reshaped bars (Figure 1).

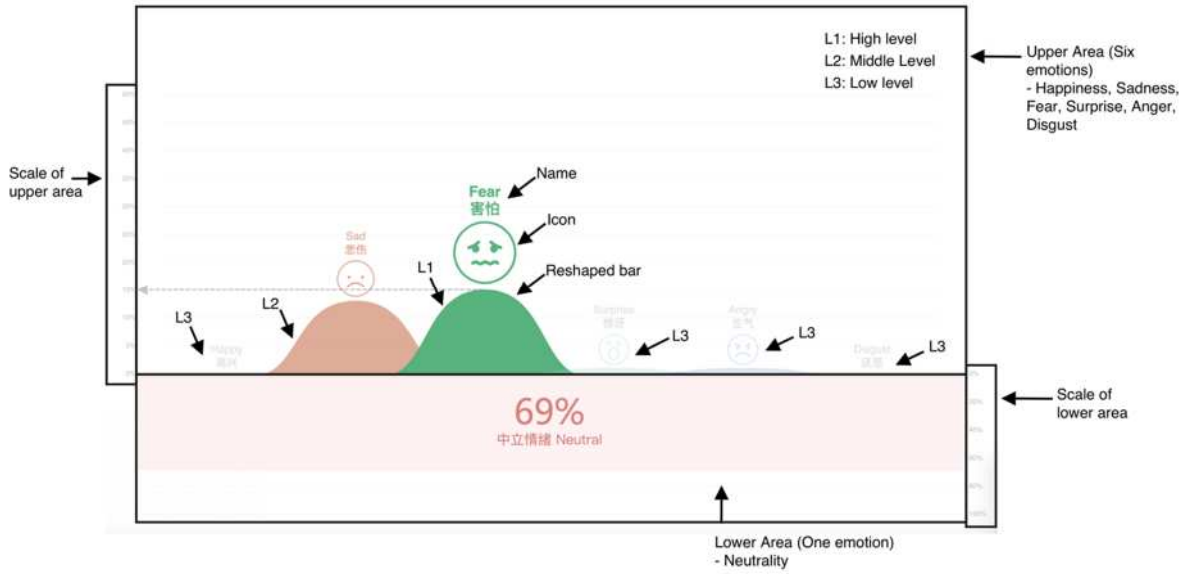

Figure 1. An example scene in the dynamic-emotion-bar

Within the upper area of the dynamic emotion bar, for every emotion (Figure 1), we use three elements to illustrate the immediate state of each. These are: (1) the label of the emotion, (2) an icon for the emotion, and (3) a reshaped bar. Each emotion in this area has a specific icon. The icons are based on those presented by [45]. The most appropriate icons were selected for each emotion through a survey (n=69) on the WJX platform, which was conducted to understand the strongest association between emotions and icons. The height of each reshaped bar indicates the valence of the particular emotion mapping onto the scale on the left. The value of the left scale ranges from 0% to 50%, which was a design decision taken after early prototypes showed that with an emotional scale of 0 to 100%, lower value emotions were difficult to perceive in the presence of a dominant emotion (e.g., 90% fear; 10% sadness). Thus, the dominant emotion is limited to 50% to enable users to perceive any secondary emotions.

TABLE 3 VISUAL ATTRIBUTES OF EMVIS

	L1 (High Level)	**L2 (Middle Level)**	**L3 (Low Level)**
Attention level	Focused attention	Divided attention	Inattention
Information slices of emotion-shifts	(**S1**) The highest of the six valences at one moment	(**S2**) The emotions with rising valence compared to the previous state	(**S3**) The emotions with stable/decreasing valence compared to the previous state
Visual attributes mapping	**(Group 1)** **Name:** -Opacity: 100% -Size: 21px **Icon:** -Opacity: 100% -Size: large **Bar:** -Opacity: 100% -Height: valence	**(Group 2)** **Name:** -Opacity: 85% -Size: 16px **Icon:** -Opacity: 85% -Size: small **Bar:** -Opacity: 85% -Height: valence	**(Group 3)** **Name:** -Opacity: 30% -Size: 16px **Icon:** -Opacity: 30% -Size: small **Bar:** -Opacity: 30% -Height: valence

We present three slices of information to convey patients' instant emotional shifts, S1, S2, and S3 (Table 3). According to the different levels of importance of the information slices, we separately assign different attention levels [46], from focused attention (the high level) to divided attention (the middle level) and inattention (the low level). The top valence of the six emotions at one moment is the most important and is assigned the high attention level. The

remaining two slices are the middle and low levels. The diverse information encoding mechanisms are arranged for each level with different visual attribute groups, including opacity and size of text, icon, and bar (Table 3). From Figure 1**,** the diverse information encoding mechanisms levels (L1, L2, L3) can be identified by the different visual attribute groups (Group 1, Group 2, Group3).

Additionally, the lower area in Figure 1 indicates the valence of patients' neutral emotions. The height of the lower area represents the valence of the neutral emotion valence, which maps onto the scale on the right. Hence, the rectangle's height will change with different valences, and its lower edge will float up and down simultaneously. We can compare the left and right parts of **Figure 2**, where the valence of neutral emotion in the left scene is 98% and 75% on the right, so the heights of the two lower rectangles are different. Meanwhile, the valences of the remaining six emotions in the upper area are changed.

Figure 2. Two scenes with different valences of emotions

Function 2: Emotion record visualisation (emotion-stream-graph)

According to the guidance G2 from Study 1, an **emotion-stream-graph** presents patients' emotion records after concluding the whole medical conversation. The emotion-stream-graph is a stacked area chart (Figure 3**)**, including the valence records of the seven emotions during the entire dialogue. The scale under the graph indicates the running time of the system in minutes.

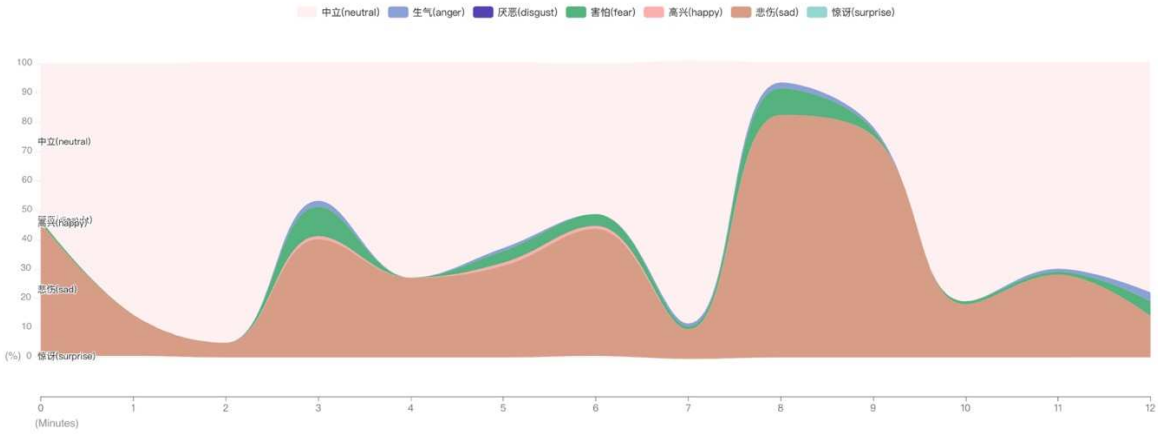

Figure 3. A view of the emotion-stream-graph

4.3 System Implementation

The EMVIS system was developed with Python 3.7, and is constructed with three parts: preparing emotional data, processing data for visualisation, and visualising emotions (Figure 4). First, using a camera, EMVIS captures patients' facial expressions on video as the emotional data source. Then, using OpenCV, images are read from the video frames and faces are detected based on the "Haar Cascade classifier". In the next step, to prepare the emotion data, Keras deep

learning API was used to make a model prediction based on a trained model to obtain the estimated emotions of the detected faces. As a result, EMVIS obtains the seven emotions' valence of every image (face). Before visualising emotions, EMVIS processes data separately for the Dynamic-Emotion-Bar and the Emotion-Stream-Graph. For the Dynamic-Emotion-Bar, the six basic emotions are classified into three different information slices (Table 3), and they map three groups of visual attributes. All the valences of the emotions are mapped to the height of six reshaped emotional bars (in the upper area) and the rectangle (in the lower area). The visualisation of the Dynamic-Emotion-Bar is refreshed once every two seconds. For the Emotion-Stream-Graph, EMVIS stores emotion data every 30 seconds and they are presented in a stacked area chart after the conversation. The whole visualisation uses the Echarts Library.

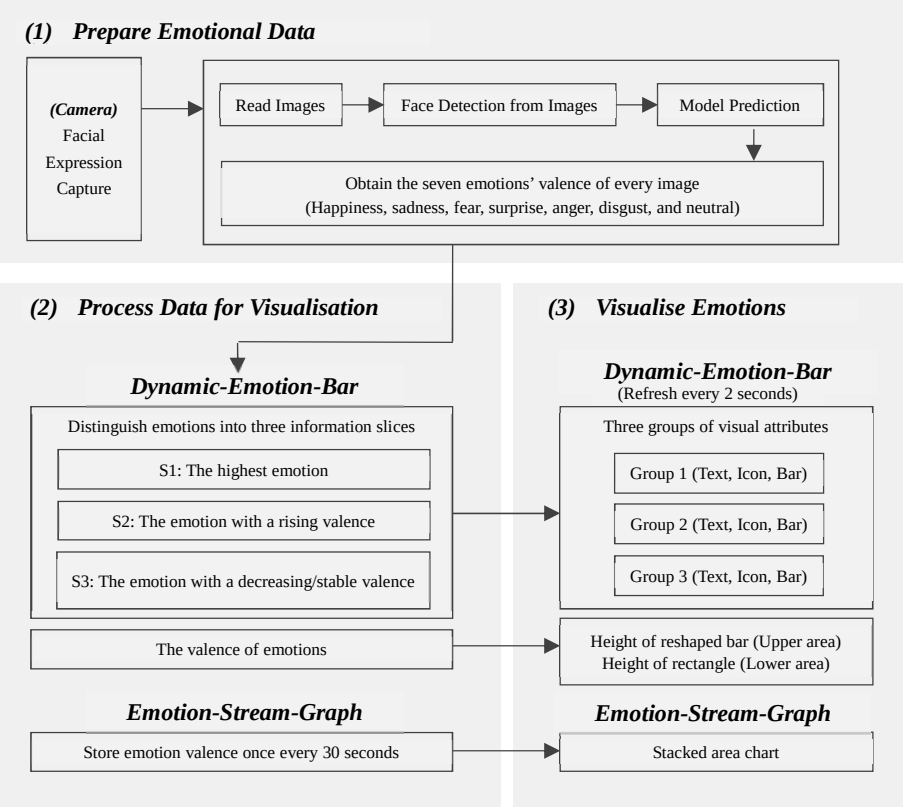

Figure 4. The system structure of EMVIS

The simulated system running environment is as illustrated in Figure 5. EMVIS was run on a laptop in front of physicians, and a Logitech HD camera was attached to the laptop to capture patients' facial expressions in real-time. In addition, an iPad placed in front of the patients was an extended and synchronous screen of the laptop. Hence, both practitioners and patients could see the same running performance of EMVIS. Although the primary beneficiaries of this system are likely to be the physicians, we took the opportunity to obtain feedback from patients, as they will also play an essential role in the success of the system and its adoption in medical practice.

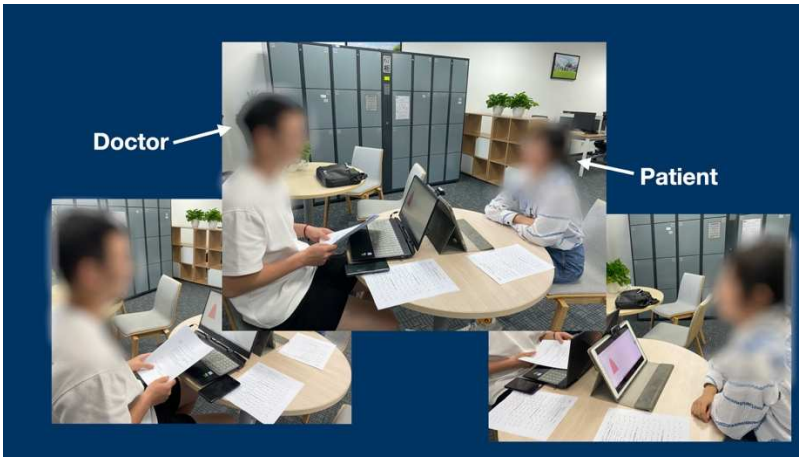

Figure 5. Setting of the simulated running environment

Furthermore, we considered how to protect patients' privacy, because the system used a digital camera to capture patients' facial expressions. No video or photographic material of the faces of the participants will be stored. Only the seven emotions' valences will be recorded and stored. Also, all the data will be stored on a computer with password protection, with access only available to members of the research team. Furthermore, all data will be anonymised after collection.

5. STUDY 3 EVALUATION

Focusing on the two objectives of this project, we organised the evaluations from two perspectives: (1) acceptance exploration, perceiving participants' acceptance of emotion visualisation support, and (2) requirements understanding, exploring the information requirements of both patients and practitioners.

5.2 Method

Based on the Technology Acceptance Model (TAM) [47], Holden et al. [48] suggested a contextualised TAM model in the practice of healthcare. This means using Health IT in a specific health care context setting, such as using a questionnaire for eliciting participants' beliefs about a specific medical behaviour and redefining perceived usefulness (PU), perceived ease of use (PEOU), attitude towards technology (ATT), and behavioural intention (BI) about the improvements to patient outcomes [48].

Firstly, we redefined the scales of the four aspects in the TAM model within the context of an empathic medical conversation. For example, after eliciting physicians' beliefs from the results of Study1, we utilised the specification descriptions related to physicians' tasks about empathic medical conversations to replace the general term of 'job' in physicians' scales (Table2). For example, physicians' tasks include recognising patients' emotion-shifts, understanding their conditions, and enhancing the effectiveness of their conversations. However, from the perspective of patients, their 'jobs' have different meanings compared to physicians. They aim to communicate effectively with doctors, and they expect to improve their physicians' attention to and understanding of their experiences and conditions [49]. Hence, these expectations are related to patients' PU scales (Table 4). Each scale has seven points with seven adjectives described from likely to unlikely end-points, corresponding to 1 to 7.

TABLE 4 MEASUREMENT SCALES FOR ACCEPTANCE EXPLORATION

Measurement Scales for Perceived Usefulness of EMVIS (For Doctors)	**Measurement Scales for Perceived Usefulness of EMVIS (For Patients)**
PU1: Using **EMVIS** would help me to recognise patients' emotion-shifts during medical conversations.	**PU1:** Using **EMVIS** would help me to recognise my emotion-shifts during a medical conversation.
PU2: Using **EMVIS** in my conversation would improve my understanding of patients' conditions.	**PU2:** Using **EMVIS** in my conversation would improve doctors' attention to me.
PU3: Using **EMVIS** would enhance my effectiveness in medical dialogue.	**PU3:** Using **EMVIS** would enhance the effectiveness of doctors' understanding of my emotional state.
PU4: I would find **EMVIS** useful in my medical conversation.	**PU4:** I would find **EMVIS** useful in my dialogues with my doctors.
Measurement Scales for Perceived Ease of Use of EMVIS	
PEOU1: Learning to use **EMVIS** in medical conversation would be easy.	
PEOU2: I find it easy to get **EMVIS** to present the emotional information that I need.	
PEOU3: It is clear for me to use **EMVIS** during medical conversations.	
PEOU4: I find **EMVIS** easy to use during medical conversations.	
Measurement Scales for Attitude Towards Use of EMVIS	
ATT1: Using **EMVIS** during medical conversations is a good idea.	
ATT2: Using **EMVIS** during medical conversations is unpleasant.	
ATT3: Using **EMVIS** during medical conversations is beneficial.	
Measurement Scales for Behavioural Intention of EMVIS	
BI1: I intend not to use **EMVIS** in medical conversations.	
BI2: I intend to use **EMVIS** in medical conversation as often as needed.	
BI3: I would use **EMVIS** in medical conversations frequently.	
Seven end-points of each scale	
Likely ( ) ( ) ( ) ( ) ( ) ( ) **Unlikely** **extremely quite slightly neither slightly quite extremely**	

Meanwhile, we organised the acceptance evaluation for the three groups of participants, namely the senior psychological physicians, the young psychological physicians, and other health care providers, to understand the various demands of the participants with diverse practical skill levels and specialities.

The **dynamic-emotion-bar** was presented during conversations. After their conversations, all the doctors and patients were shown the **emotion-stream-graph**. Afterwards, they took part in semi-structured interviews, during which they were first invited to complete measurement scales for PU, PEOU, ATT, and BI. Subsequently, the participants were asked to answer several related open-ended questions relating to their understanding, experience, visualisation attitudes, and information demands during their medical conversations.

5.2 Participants

A total of 37 healthcare providers and 31 patients participated in the study. Table 5 describes the sociodemographic characteristics of the participants. We recruited ten senior psychological physicians (27.03%), 13 young psychological physicians (35.14%), and 14 other healthcare providers (37.84%) including four campus doctors (10.81%) and ten nurses (27.03%). Most participants' patients (29) were less than 50 years old (93.5%).

TABLE 5 SOCIODEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Participants	Sociodemographic Characteristics	Frequency	(%)
Healthcare Providers (n=37)	**Gender**		
	Female	30	81.08
	Male	7	18.92
	Work experience		
	≤5 (young)	13	35.14
	6-10 (senior)	17	45.94
	>10 (senior)	7	18.92
	Profession		
	Psychological Physicians	23	62.16
	Campus Doctors	4	10.81
	Nurses	10	27.03
	Groups		
	Senior Psychological Physicians (Years of working >5)	10	27.03
	Young Psychological Physicians (Years of working <=5)	13	35.14
	Other healthcare providers *	14	37.84
Patients (n=31)	**Gender**		
	Female	20	64.52
	Male	11	35.48
	Ages		
	<20	11	35.38
	20-29	9	29.03
	30-39	7	22.58
	40-49	2	6.45
	>50	2	6.46
	Types of disease		
	Psychological illness	23	74.19
	Others	8	25.81

Note: * School Doctors 4; Nurses 10

5.3 Data collection and Analyses

Data from the measurement scales were collected using the WJX platform, and then exported into SPSSAU for descriptive analysis. Based on the different items in the four measurement aspects for the acceptance of EMVIS, we created four average values: PU, PEOU, ATT, and BI. Based on these four values, we observed the general opinions of participants, compared significant differences between the various groups, and discovered what factors had correlations with participants' behavioural intentions (BI).

To analyse the interview transcripts in **Study 3,** we transcribed the interviews' voice recordings and used Word, Excel, and Xmind software tools to code data and extract themes and relationships. The analysis process is illustrated in **Table 1**. The analysis results (**Appendix 1**) indicated whether participants intended to use EMVIS during medical conversations and why they thought like that.

In addition, to protect participants' privacy, although the information and data gained during the study may be published, all participants will remain anonymous, and their personal results will also remain confidential.

5.4 Findings

Acceptance Situation

The TAM measurement provided a 7 - Point Likert scale for each item. We obtained the medians and SD of the PU, PEOU, ATT, and BI based on the descriptive statistics. It should be noted that all four medians are between 2.0 and 3.0 (between quite likely and slightly likely). The results for the practitioners were: PEOU (2.25, 0.888), PU (2.5, 0.77), ATT (2.667, 0.815), and BI (3.00, 0.986), while those for the patients were: PEOU (2.25, 0.97), PU (2.5, 1.016),

ATT (2.667, 1.02), and BI (3.00, 0.929). The data indicate that all participants generally accepted the use of EMVIS during their medical conversations.

Significant Differences

(1) Senior and junior providers

A Mann Whitney test showed that senior or junior providers did not show any significant differences in BI, ATT, PEOU and PU. Hence, it has been proven that senior and junior providers have the same acceptance level.

(2) Providers with different specialities

When exploring differences between the psychological physicians versus the other healthcare providers, a significant difference was found for perceived usefulness (PU) of EMVIS (P =0.002<0.01), (see Table 6). Nurses perceived EMVIS to be much more useful when compared to psychological physicians and campus doctors. Campus doctors perceived a minor level of usefulness.

TABLE 6 NONPARAMETRIC TEST WITH PROVIDERS IN DIFFERENT SPECIALITIES

	Department Median (P_{25}, P_{75})			Kruskal-Wallis *H*	*p*
	Psychological physicians (*n*=23)	campus doctor (*n*=4)	nurse (*n*=10)		
BI	3.000(2.7,3.7)	3.833(3.4,5.5)	3.000(1.9,3.7)	4.598	0.100
ATT	2.333(2.0,3.7)	3.000(2.5,3.3)	2.500(1.8,3.3)	0.916	0.632
PEOU	2.250(2.0,2.8)	3.000(2.2,4.6)	2.000(1.2,2.3)	5.556	0.062
PU	2.750(2.3,3.0)	3.625(2.4,3.9)	2.000(1.6,2.0)	12.417	0.002**

* $p<0.05$ ** $p<0.01$

In summary, from the findings of the statistical analyses of the TAM measurements, the results show that: (1) the participants, both healthcare providers and patients, largely accepted an emotion visualisation supported conversation (ranging between quite likely and slightly likely); (2) Senior and junior providers had the same level of acceptance (with no significant differences); and (3) Healthcare providers with different specialities expressed diverse levels of perceived usefulness.

User acceptance

After analysing the voice recordings of the interviews, we deduced the following points from the user feedback. First, their attitudes, perceived usefulness, and ease of use were explored and classified (**Appendix 1**). With regard to attitudes, we collected six active points (AT1-AT6) and six negative points (NT1-NT6). In the case of perceived usefulness, we classified eight groups: supportiveness, improving ability, supporting workflow, emotional records, PU in tasks, PU in stages, PU in situations, and PU of users. Participants' active and negative viewpoints were collected separately for each of the eight groups. In addition, there were six items for the active views of the PEOU (APE1-APE6) and four items for the negatives (NPE1-NPE4). The resulting interview analyses supported our exploration of participants' opinions about using EMVIS.

In general, both providers and patients believed EMVIS was a good idea (AT2), and it was thought to be interesting (AT1), as well as helpful and supportive for on-site medical communication (AT3). Furthermore, providers with different work experiences and specialities expressed diverse demands for emotional visualisations, and different participants also had diverse viewpoints on acceptance, both active and negative.

(1) Patients' emotion-shift should be observed and presented during face-to-face medical conversations.

After using the dynamic-emotion-bar during the medical conversations, healthcare providers and patients discovered that enhancing the information visualisation of patients' emotions-shift can improve communication (AS8) and relationships (AS9). Patients felt that providers were more conscientious (AS4) and attached more importance to their emotions during their conversations (AS3). In addition, they were understood well during the communication (AS13). Providers believed they were enabled to think more about patients' emotions (AA1), and their emotional recognition ability was improved (AA4) because of the visualisation of patients' emotion-shift. Hence, information about patients' emotion-shift should be observed and presented during medical conversations.

(2) The emotion visualisation for the whole conversation procedure can be helpful.

The emotion-stream-graph illustrates the whole record of a patient's emotion-shifts during a conversation. Since the graph involves the time information (the time scale under the graph) relating to patients' emotional transitions, the providers thought it helped them to reflect on what they could not recall from memory after their conversations had concluded (AA11). These reflections can help improve their skills in asking questions and diagnosing problems (AA12). Meanwhile, the emotion-stream-graph presented patients' leading "emotional tone" [50] (AW2), and this can support physicians in knowing a patient's basic and normal emotional situation (AW3). Furthermore, comparing variations of the patients' leading "emotional tone" noted both during and before a conversation could help understand and analyse the situation of a patient's rehabilitation (AW4) (AW5). As a result, the emotional record is a new dimension of searching for patients' medical recoreds (AER2) and can be helpful for evaluations of therapy and rehabilitation (AS11). However, patients did not express a high demand for emotional records following their conversations, and they believed that they were more beneficial to providers than to patients (NA8).

(3) Senior and junior providers had diverse reasons for using emotional visualisation.

From the results of the data analyses, it is evident that senior and junior providers had the same level of acceptance. Nevertheless, whether or not they have diverse demands should be further explored. For example, junior providers need the dynamic-emotion-bar to help them recognise some negative emotions (AA1), including disgust, anger, and fear. Meanwhile, it was used to support the understanding of what causes illness (AA6) and guide them to discover any more noteworthy points (AA7) and the direction of future work (AA8). As a result, this can lead to more robust and more accurate diagnoses and treatments (AA10). Furthermore, the emotion-stream-graph can provide reference points and guide any subsequent medical conversations (AW7).

Senior providers, however, used EMVIS as an analysis tool for rehabilitation situations (AW5) and as a tool for the evaluation of treatments while also regarding it as reference information (AS11). Moreover, senior providers expected EMVIS to help them discover how patients influenced their own unconscious feelings, which is described as counter-transference [51, 52] , and which is essential for therapies, especially for relationships and interactions in psychological therapies [53, 54]. Hence, senior providers hoped for an additional camera to catch their own emotions during conversations, to present their own personal and unconscious feelings.

(4) Providers with different specialities focused on different requirements.

Providers with different specialities had diverse levels of perceived usefulness. We compared

the differences in their requirements to understand why this was the case.

Because the nurses did not specialise in psychology, they needed EMVIS to support them to gain a better understanding of their patient's emotions (AS7), especially when confronted with patients who cannot express themselves clearly (APU1). Meanwhile, nurses need to know the leading 'emotional tone' [50] of a patient from the emotion-stream-graph (AW3), from which they may discover what conditions a patient may not want to discuss (AW1). In addition, they need to share in-patients' emotional situations within the care team (including different doctors and nurses) (AER3). Hence, the nurse participants rated highest for the perceived usefulness of EMVIS, and they expected to experiment further with the system.

The psychological physicians would like to combine EMVIS, their specialities and their recognition of patients' emotions (AS1) to encourage them to be more self-confident in their communicating and more accurate in their diagnoses (AA10). In addition, they felt that the system would support them in gaining a more complete and more detailed understanding of their patients' emotions (AA5). When discussing emotions together with patients, they used the system as a rehabilitative channel for those who had limited abilities to recognise and distinguish their own emotions (APU6). The psychological physicians would like to integrate EMVIS into their current workflow during psychological conversations and thereby improve their treatments (AW1, AW6, AW7). As a result, they provided many suggestions about collecting additional information to be integrated into the system. Their suggestions will be outlined and explored in the Discussion section below.

The campus doctor participants had sufficient time to engage with their patients. They did not view patients' emotions as a necessary element of the whole process of their conversations, except when they carried out bodily checks, such as pressing patients' stomachs or raising their arms. Only at some particular moments during their conversations did they feel the need for the support of EMVIS. However, they did need the animations of the dynamic-emotion-bar to remind them to be aware of any emotions which may be overlooked while writing notes or operating their computers (AA3). They also need patients' emotional information to support them when judging whether symptoms may be caused by mental disease (AA13). Furthermore, a review of conversations based on the emotion-stream-graph may be used to improve their skills in asking questions during a dialogue (AA12). However, they complained about the existence of EMVIS, because they see it as an additional stuff between them during conversations, especially when they are unfamiliar with their patients (NPST1). Meanwhile, they were concerned about the disturbance of the dynamic effect of the dynamic-emotion-bar (NPE3). In addition to these points, when they need to judge whether or not students are not being truthful because they want to take sick leave (AS5), EMVIS provided some useful hints, although these were thought to be insufficient (NPT2).

6. DISCUSSION

Our findings indicate that EMVIS was supportive during on-site medical conversations. Based on the findings from Study 3, we have understood the results and have discussed the same from the three aspects of health providers' empathy motivation, empathy practising and empathy effect. Therefore, we have concluded four reasons for its perceived usefulness: evoking empathy, supporting careful attention, creating a human connection, and forming reflective conversations. "Evoking empathy" is concerned with motivation; "supporting careful attention" relates to empathy practising; and both "creating a human connection" and "forming reflective conversations" describe the empathy effect. Figure 6 illustrates the relationship between the study findings, themes, and elicited reasons. These reasons indicate how the visualisation process can support empathic medical communications.

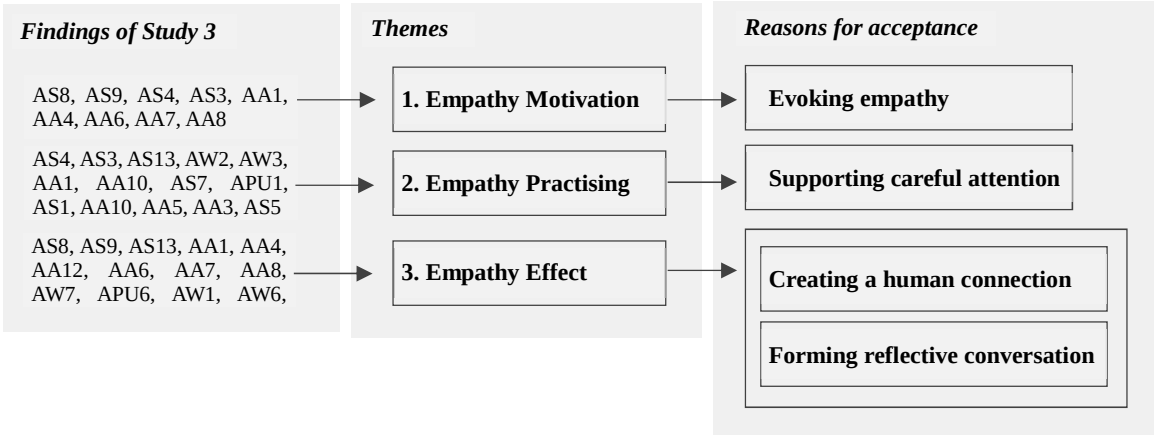

Figure 6. Relationship between the study findings, themes, and elicited reasons

6.1 The Four Reasons for Acceptance:

Evoking empathy

During the medical practice of an individual interview, being a "close listener" to pay attention to a patient's complicated stories, from the perspectives of both "content and form", is "the igniting act of humane healthcare" [8]. According to Charon, "mood or feeling" is one of the "forms" of a story. At the same time, Parker et al. asserted that emotions should be concerned and managed during GP-patient communications [20]. However, we have learnt that providers with different specialities show different levels of awareness about being close to patients in the channels of emotions. Despite such differences, the healthcare providers who participated in this study were motivated to know more about patients' emotions and to pay attention to their direct presentation. After the experiment, they perceived an enhancement in their emotional recognition ability, support for their understanding of what causes illness, and the discovery of the relationship between life events and emotions during real-time physician-patient encounters. Hence, the emotion visualisation could evoke providers' empathy for patients.

Supporting careful attention

Healthcare providers need to practice "careful attention" to understand what matters to patients and what has mattered to them over time, from which they can learn how a patient's mind works [8]. The emotional visualisation helped providers to notice emotions more fully and conscientiously. EMVIS helped providers to confirm what they had recognised from patients' facial expressions, and to discover the nuances between patients' emotions and their statements. The system displayed patients' usual "emotional tone" and reminded practitioners

to take notice of emotions that may have been overlooked during conversations. Meanwhile, the patients considered that it provided a more explicit expression of themselves, thereby helping healthcare providers to give fuller attention to their problems.

Creating a human connection

A human connection is achieved through the empathy and warmth that healthcare providers convey and patients achieve during their encounters. This human touch is essential for encouraging and allowing patients to talk about their concerns and discomfort, while at the same time it is intrinsically therapeutic [20]. Furthermore, the participating patients perceived their needs to have been well understood, and they experienced a good attitude being presented by their healthcare providers. Consequently, they became more familiar with these providers. This normal state is both a helpful and a safe space for patients [20], which can help to improve adherence to treatment recommendations [55, 56] and also helps patients to perceive a genuine human connection.

Forming reflective conversations

After recognising and explicitly acknowledging a patient's emotions, the next step is to identify how providers respond. The interactional model of empathic communication suggested catching empathic opportunities, responding as a "potential empathic opportunity continuer", and summarising and expressing empathic understanding [18]. In our experiment, after providers had adjusted the methods, speed, and content of their dialogues in real-time and in line with any emotional transitions, the visualisation can reflect the release of patients' negative emotions. This release is feedback and reflection on the effects of providers' adjustments and responses, which support effective empathic encounters. Meanwhile, patients could perceive physicians' positive attitudes towards them, such as offering comfort when they had negative emotions. Hence, the visualisation enhanced the interaction of empathic communication through reflective conversation.

These four reasons have described why emotion visualisation could support medical conversations. In the next section, along with the practice guidelines and the workflow of empathic medical communication [8, 18, 20], the potential opportunities in future work for emotion visualisation during medical conversations will be discussed from the perspective of human factors and requirements.

6.2 Future opportunities

Communicating uncertainty

The uncertainty of information visualisation is always present. It stems from users' different experiences with visualisations, and from their expertise and domain knowledge [57]. After they had become familiar with it, the participants had different experiences of using visualisation. Some senior psychologists were concerned about the "accuracy" of EMVIS. When the visualisation did not match their recognitions of patients' emotions, or sometimes when there was a delay in the display, they were concerned that this might cost them too much time and attention when judging and thinking about their subsequent actions. Such problems of uncertainty will affect their attitudes and behaviours. Hence, the emotional visualisation should

provide a channel for communicating uncertainty with users [58], where the system visualises from where any uncertainty comes, and users communicate their uncertainty to the system.

Addressing user diversity

It is critical to address patient diversity in visualisations when visualising health data in medicine, because it is highly patient-dependent [57]. Emotional visualisation is faced both by patients and by healthcare providers, so it should address the diversity of both sides. For example, it is suitable for patients who are open to new technologies or new things. However, other patients may be concerned about a camera catching their facial expressions and recording their emotions. In the opinions of some providers, visualising patients' emotions is helpful for those who would suppress and hide their own emotions (to prevent them from being recognised), and those who have limited ability to recognise and distinguish their own emotions and express themselves clearly. However, from the point of view of some patients, it may not be helpful to directly present them with their emotions, especially when their minds are in some state of distress, because they will not relax, which will further impede the expression of their emotions. For some physicians, the dynamic-emotion-bar acts as a helpful reminder. However, for those whose ability with regard to free-floating attention [59] is not sufficiently strong, or their level of experience is insufficient, the dynamic-emotion-bar could make them hurry and feel confused. Hence, it is necessary to consider whether or not patients' emotions should be presented to themselves, whether emotion bars or emotion streams should be displayed dynamically during encounters, or whether more natural and friendly settings should be utilised. Thus, the design of emotional visualisation needs to accommodate a diverse range of users according to their various characteristics and requirements.

Providing explanatory information

During medical encounters, the emotional visualisation encouraged the participants' engagement and improved understanding and communication, but they considered the information presented to be insufficient. Thus, additional information could be explored for patients' explanatory models [20, 60]. In practice, the visualisation may convey complex emotions outside of the seven basic emotions, such as confusion, grief, excitement, or other happy emotions, which may be inferred from a sarcastic smile. In addition, a patient's intonation, body language, and biological signals from the skin, the heart, and the brain, or even certain bodily odours, can help support understanding and communication. Hence, multiple channels of nonverbal emotional cues could be included in the further visualisation study, to support the understanding of more complex emotions and effective communication. Furthermore, the visualisation should synthesise other information, such as voice recordings of medical dialogues, keywords related to emotions, such as anger, pain, hatred, hints, and other specific events. Finally, patients' background information could lead to conversations taking a more accurate direction. This background information could include events that have affected them previously, such as their learning and working conditions, or their relationships with friends and family members. In addition, the information could include the aims of conversations, details of problems that need to be dealt with, any expectations for diagnoses, and their acceptance of treatments.

Managing attention

Information visualisation utilises salient cues to capture users' exogenous attention, and

organises appropriate information material to guide endogenous attention and minimise distracting information [61]. For example, some patients were worried about physicians spending too much time on EMVIS and their emotions, thereby ignoring their statements. This provides evidence that the emotion visualisation system caught the providers' attention during encounters, but sometimes this was excessive, leading to patients' worries. Hence, the emotion visualisation system should balance supportiveness and interference by reorganising any material and interactions to manage the appropriate attention level. For example, the visualisation form of the dynamic-emotion-bar could be adapted to try more minor animation effects and more intuitive representations, or to reset the system's environment, among others.

Supporting negotiations

Encouraging patient reflection was insufficient for negotiating the shared level of understanding between provider and patient, so further active approaches could be explored [20, 62]. The emotion visualisation motivated patient engagement and initiative, and some participants suggested visualising the interaction of dialogue to support understanding. For example, questions which should be addressed include: what caused a patient's emotional transition; on what should providers be focused; how have providers shaped and refined patients' accounts, and how have they highlighted or reflected these to patients, and how should patients' emotions be considered after any such reflection? The visualisation approach aims to support patients and providers to develop their understandings. Thus, thed exploration of visualisation for the joint understanding process is valuable for medical conversations.

6.3 Limitations

The limitations of this work relate to the characteristics of the recruited participants. From Table 5, it can be seen that there were 30 females (81.03%) in the group of participating healthcare providers. Women are more perceptive to sense-sensitive factors, such as those related to smell, taste, sight, touch and hearing[63]. In addition, females show greater sensitivity and responsiveness to stimuli [64] and sensory environments [63]. Hence, most of the participants' high perceptions of sensitivity may have affected the results of our study.

Moreover, while we had 23 psychological physicians, we only had ten nurses and four campus doctors. Thus, we failed to recruit general practitioners for clinic patients. Campus doctors face the same tasks of diagnosis and treatment as GPs, but they do not work in such busy environments. In future work, more general practitioners and more male care providers should be involved.

In addition, although the participants were not observed directly during their conversations, and they communicated independently, they were aware that they would be interviewed after their conversations, and patients were also made aware that their facial expressions were being captured during the experiments. Therefore, it was inevitable that they paid more attention to the visualisation system and behaved differently from usual. We analysed and discussed users' acceptance and requirements based on their different experiences compared to a normal situation. However, future experiments could be set in more unobtrusive environments. Further study could be conducted after both physicians and patients are more familiar with the support of the specific visualisation system.

7. CONCLUSION

Effective medical communication contributes to ethical and technical diagnoses and leads to individual treatments and care. Hence, the physician needs to be a close and reflexive listener, and thereby create a human connection with patients during a clinical encounter. However, physicians' insufficient levels of empathy and clinical practitioners' busy schedules impede their practices. Furthermore, a challenge faced by every physician is to recognise their patients' implicit and indirect expression of their experiences and emotions. Therefore, this work is focused on designing a real-time emotional visualisation system, EMVIS, as a potential solution for presenting patients' emotions, and to support face-to-face medical encounters. This potential solution has been evaluated in empirical studies, indicating that healthcare providers and patients would like to accept a conversation supported by an emotional visualisation. Senior and junior providers had the same level of acceptance, but their requirements were not the same. Furthermore, healthcare providers with different specialities had diverse levels of perceived usefulness, and expressed a variety of needs.

So, what are the main aspects that influence users' acceptance, and what are their requirements for the emotional visualisation of medical conversations? We learned from the study that four reasons led to users' acceptance of the emotional visualisation for empathic medical communications: evoking empathy, supporting careful attention, creating a human connection, and forming reflective conversations. Furthermore, we have discussed the potential opportunities for future work concerned with emotional visualisation during medical conversations. In the future, five potential aspects have been identified as worthy of further exploration: communicating uncertainty, addressing user diversity, providing explanatory information, managing attention, and supporting negotiations.

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