The MAUI Project: Building MultiModal Affective User Interfaces for Everyone

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Abstract

We address some of the current challenges in intelligent interfaces for universal access and present the design of an intelligent interface which is aimed at 1) input processing the user's sensory modalities (or modes) via various media, 2) building (or encoding) a model of the user's emotions (MOUE) and 3) adapting its multimedia output to provide the user with an easier and more natural technology access and interaction. We identify key research issues relating to one particularly rich application of MOUE, namely home health care provided via telemedicine.

Home Health Care

In 1995, there were approximately 1.5 million patients receiving nursing services in their homes accounting for approximately 3% of United States national health care spending (Allen, Roman, & et al. 1996), (Whitten, Mair, & Collins 1997). Since this time, the level of acuity required of home health care providers and the number of referrals for home health care have been escalating exponentially (Johnston *et al.* 2000). Hence, is it not surprising that home care is currently "the fastest-growing section of the health care market in the United States" and is also experiencing rapid growth in other venues such as the United Kingdom (Darkins & Carey 2000). Home health care seeks to fulfill two general purposes.

First, home health care can provide patients with the *comforts and emotional support of a home environment*, which can positively impact their mental and physical state. A facilitated home environment may be especially enriching in the case of chronic conditions by providing a potential quality of life that is not available in ambulatory or nursing home facilities.

Additionally, transporting a patient to a medical facility for care may be challenging and disruptive. The disruption may be particularly inflated in the case of ultimately unnecessary and unscheduled visits to physician's offices or emergency rooms. The challenges a patient may face to readily accessing medical care may include distance, physical immobility, and emotional strain associated with the transport experience and doctor visit. The emotional challenges of transport may be especially real for patients with emotional disorders, such as depression, anxiety disorders, or post-traumatic stress disorder.

Second, home health care is aimed at *reducing medical costs* such as in-hospital care days, days in ambulatory facilities and visits to outpatient clinics or doctor's offices. Home care providers (often non-physician health professionals) are called upon to assess the patient's physical state and mental state relative to medical condition and to administer treatments or evoke medical intercessions by various medical team members, as deemed necessary.

In addition to replacing a hospital day or doctor visit with a less expensive home care interaction, the home health care environment may facilitate a focus on wellness by facilitating early intervention or prevention of medical complexities through recurring clinician interaction and engaging the patient in early symptom detection and health maintenance (Siwicki 1996). Though the home health care concept has facilitated the reduction of medical care cost in some ways, managing home health care logistics introduces a cost efficiency challenge. Distance causes a loss in valuable care time as nurses and other professional caregivers commute between patient sites. Staffing shortages expound the effects of these logistic issues as home health providers seek to maximize resources.

On average, non-chronic patients "require home care for three months, often needing more than two visits per week" (Siwicki, 1996). Daily or frequent visits may be the ideal, but not efficient or feasible due to health care reimbursement constraints and competing patient requirements for visit time, except in acute care situations. This requires health care professionals to make sometimes difficult decisions regarding the desired versus feasible frequency of on-site visits. Potentially, longer durations between communications may impede the open flow of relevant physical and mental health information (both verbal and non-verbal) between the home health care professional and patient, which may impact patient health.

Tele-home Health Care

In response, telecommunications began to establish a viable presence in the home health care industry in the 1990's in the form of telehealth. Tele-home health care is purported to cut on-site visit home health care costs and provide better health care through increased monitoring (Siwicki, 1996). Factors such as the reduction of driving time, allow "a home nurse to care for 15 to 22 patients per day compared to 5 per day using conventional home visiting" (Darkins & Carey 2000). One hospice study reports a savings of 33%-50% in replacing in-home visits with tele-home care for palliative care (Doolittle 1997).

Tele-home health provides communication options between the medical professional and patient when hands-on care is not required. For example, tele-home health interventions may be used to collect vital signs data remotely, verify compliance with medicine regimes, improve diet compliance, assess mental or emotional status, and check blood sugar levels (Allen, Roman, & et al. 1996) (Warner 1997). Tele-home health is often used as a means of communicating with patients diagnosed as having heart failure, chronic lung disease, stroke, AIDS, asthma, cancer, infections, diabetes, cerebral vascular accident, depression, and anxiety disorders (Johnston et al., 2000; Mahmud, 1995). Advocates of telehealth in home health care contend that this means of interacting is patient-centered and promotes patient autonomy through education and improved communications (Warner, 1997).

The means of telehealth communication for home health care purposes and can occur in a myriad of forms and include an array of peripheral devices. Tele-home health systems transmit three basic types of information - text data, audio, and images (Crist, Kaufman, & Crampton 1996). Telehome health possibilities include telephone reminder systems, wireless personal emergency response systems, vital sign monitoring devices, video conferencing, medication reminder systems, and web-based systems (Crist, Kaufman, & Crampton 1996). Interactive communications may be either synchronous or asynchronous and occur using telephone, video, scripted input devices, and the Internet. Patient medical needs and to a lesser degree, cost factors dictate the type of system recommended.

Three common forms of interactive communication include:

1) Video Telehealth System: consists of a videophone, telephone with speakerphone, and electronic peripheral devices including a blood pressure cuff and pulse monitor, stethoscope-sending unit, and thermometer. Telecommunication is facilitated using the "plain old telephone system" (POTS) or ISDN. The device can be used for assessing blood pressure, blood glucose levels and interactive triage videoconferencing with the consultant at the central workstation.

The camera can also be used to transmit pictures of external afflictions, like scars or wounds. A typical system equipped that includes a 2-1/2 inch screen and a tiny camera in the monitor's bezel would deliver color video at 7-10 frames/second. These types of systems are much slower than standard interactive-video mediated telehealth applications, which typically runs at a minimum of 15 frames/second with 256 lines of resolution.

2) Health Chat Line: the patient logs into a private Internet site from their home computer at a designated time for private synchronous communication with a clinician. Certain home health care programs may also support asynchronous communication. Telecommunication is facilitated using POTS, cable, or other standard forms of Internet connection. Internet communication is used in instances when free-form communication is preferred than scripted communication (see next paragraph) and when the patient possesses the appropriate computer skills. Internet communication is often used for mental health patients and is particularly well suited to patients who prefer a degree of isolation in their current health status (e.g. post tramatic stress disorder patients) and who do not want direct contact with a medical institution until they are in deep crisis.

3) In Home Messaging Device: connect to a patient's existing home telephone line (uses POTS) and allows patients to view questions and reminders from their healthcare provider on a brightly lit, high contrast LCD screen. The device provides asynchronous two-way dialog by allowing patients to respond to scripted "clinical dialogs" (vs. free-form communication) sent to them by their healthcare provider by pressing buttons on the device.

The device prompts the patient with specific objective questions and uploads the answers to the Internet site; a nurse reads the answers and determines the gravity of the patient's state based upon patient responses (noting trends) and calls the patient if deemed necessary. Patient responses often given on a daily basis, update patient records, which allow clinicians to systematically review all caseload information. This device is generally used in clinically stable situations where monitoring is a goal and when appropriate clinical dialogs are available. This type of device may also be employed in instances when the patient is not savvy in using more complex forms of technology.

The Need for Affective Computing in Home Health Care

Though on-site presence may not be mandated, the home health care provider must still exhibit cognitive and observational skills to assess patient status from a distance while using tele-home health tools. Vital sign readings and medicine reminders may be effectively communicated through current telehealth home heath care mediums, but affective state assessment may prove more challenging. Current feasibility issues may not permit home health care professionals to consider factors such as communication flow and affective assessment (aside from mental health situations) when assessing required on-site visit frequency. Hence, the computer mediated computer paradox is a relevant factor in the tele-home health care setting. As we decrease the modes of communication and freedom for expression, fewer affective clues pass through the communication process. This may hamper affective assessment.

System Capabilities: The first challenge involves limitations in the system capabilities. None of the devices support the multi-modal richness of face-to-face communication, which provides "body language", voice inflection, facial expression, and contextual clues to someone's affective state. As stated by Picard (1995), "...emotional states may be subtle in their modulation of expression... When affect communication is most important, then person-to-person contact carries the most information; email presently carries the least".

The personal information appliances provide the richest range of modality such as audio, video, and possibly kinesthetic if one feels that blood pressure level can provide a clue to emotional state. However, the quality of the visual and audio representation may hamper communication. Internet-based synchronous and asynchronous communication is more restrictive than the personal information appliances (video), since free-form text is the only means of signaling emotional states. Literature indicates that emotional states may be conveyed through voice, facial expression and other physiological representations (Lisetti & Schiano 2000). As we lose these modes, affective assessment may be subject to misinterpretation of meaning as well as deceptive intent (patient trying to hide their emotional state via inaccurate textual representation). In addition to losing modality, the scripted personal information appliance shrinks the vehicle of communication down to objective text-based responses, which limits expressive freedom.

Provider Cognitive Load: Cognitive load may also present challenges as the health care provider must visually scan/audio interpret and cognitively absorb comprehensive patient data (history, condition, etc...) provided to them by system output of patient communication, physiological readings and trend analysis. As well, the health care provider may be required to simultaneously provide patient interaction and system input. Given the multitude of presentation items requiring health care provider attention, it is possible that subtle affective clues from the patient may be lost in the process.

Patient Emotional "Fluency": A third CMC challenge is that patients may not be fluent in communicating their emotional states vocally or in text form. Affective articulation may be further hampered when communication is mediated by technology. Computer medicated communication theories indicate text-only communication, though well suited for conveying task-dimensional content may be limited in its ability to convey socio-emotional content. Users may adapt to a synthetic, "business-like" form and inhibit emotive text (Lisetti, Douglas, & LeRouge 2001).

Though multi-modal, even the Personal Telehealth System may not fully address this problem as patients may still adopt a task-oriented approach. "Studies show that as bandwidth narrowed, media allows less 'social presence,' and communication tends to be less friendly, emotional, and personal; communication is more [...] task oriented" (Lisetti, Douglas, & LeRouge 2001). Moreover, patients may become desensitized to routine and frequent inquiries about their emotional state and adopt a mechanized, standard response that does not provide accurate or complete information needed for assessment.

In summary, it can be argued that the three mediums of interactive tele-home healthcare introduced, (a) videoconferencing, (b) synchronous/ asynchronous Internet-based communication, and (c) specific objective scripted responses provide a progressively decreasing range of affective signals from which the health care professional can assess the patient's emotional state.

Affective computing has the potential to facilitate the assessment of a patient's emotional state and mood in a home health care context and provide needed affective information to home health care professionals.

MAUI: Multimodal Affective User Interfaces for Everyone

We now describe the MAUI project which focusses on building Multimodal Affective User Interfaces for all. Our project is based on the notion that affect and emotions can be recognized, adapted to and monitored by:

- building adaptive affective user interfaces that will truly be available to all, particularly to novices and elderly who might be intimidated with technology, but be reassured by a socially intelligent interface
- building models of user's emotions (MOUE) (Lisetti in press) to keep track of patient's affective patterns,
- providing to health-care providers previously unavailable affective information about tele-home health care patients which might be timely sensitive for depressed patients

Our MAUI project uses a multimodal framework which can take as input both mental and physiological components associated with a particular emotion. It is illustrated in Figure 1.

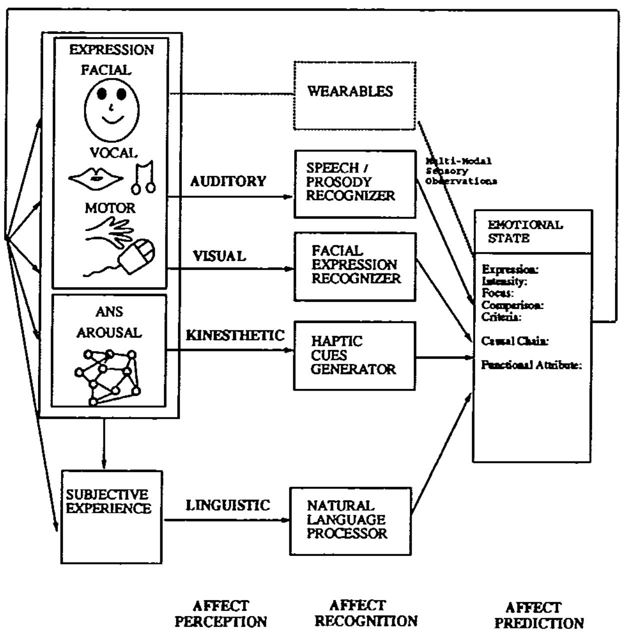

Figure 1: MAUI Overall Multimodal Paradigm (**V, K, A, L**)

Using the same terminology as Maybury and Wahlster (Maybury & Wahlster 1998), physiological components are to be identified and collected from observing the user via receiving sensors or medium: camera, mouse, microphone through the human senses employed to express emotion, i.e. the different modalities or modes which refer to: Visual, Kinesthetic, and Auditory (V, K, A). The system is also intended to receive input from Linguistic tools (L) in the form of linguistic terms for emotion concepts, which describe the subjective experience associated with a particular emotion.

The output of the system (shown in Figure 2 is given in the form of a synthesis for the most likely emotion concept corresponding to the sensory observations. This synthesis constitutes a descriptive feedback to the user about his and her current state, derived from the user's ongoing video stream, and a selected sequence of still images. The system is extensible by providing appropriate multi-modal feedback to the user depending upon his/her current state. Feedback adjustments involve varying aspects of the interface artificial agent, the avatar. Variations may be made to voice intonation, voice speed and pitch, face skin color, gender and facial expression (via animation).

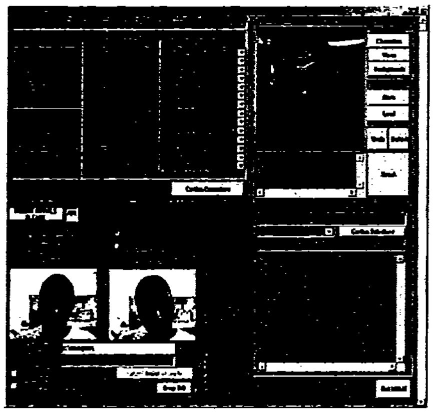

Figure 2: Avatar Mirroring Sad User

Figure 2 shows the MOUE interface which displays:

- the ongoing *Video* (lower left corner);
- the captured *Still Image* of the user;
- MOUE interface *Avatar* to be animated in the future (upper right corner);
- the *Perceptual Affective State System Output* (upper left corner).

We represent and express the interpretation by MOUE of the user's emotion via semantic descriptions of emotion concepts. Indeed MOUE not only aims at labeling the user's current emotional state with a labeling word, say "sad", but also MOUE aims at describing to the user what it understands the label "sad" to refer to. Each label refers to the inner components that the state is composed of, the generic causal chain of events that most probably caused it, and the action tendency that the state points to (i.e. what message that specific emotion is carrying with it).

In addition, as described in (Lisetti & Bianchi-Berthouze 2002), the MOUE interface allows the user to:

- *Confirm* the system's interpretation (confirm button), or
- *Correct* the system's interpretation by selecting different values in the *Perceptual Affective State User Corrections* panel.

The architecture of our system is described in (Lisetti in press), and we are in the process of adding modalities to our current system.

Socio-Technical Research Questions for MAUI in Telemedicine

In order to test MAUI's potential impact in the tele-home health care world, a number of experiments are in process. Our approach has been to build Wizard of Oz experiments (Dahlback, Jonsson, & Anrenbert 1993) in which a human plays the role of the Wizard while interacting and recognizing the patients' affect interacts and compare these interactions when the Wizard is replaced by our actual MAUI system.

We also have identified some key socio-technical questions that we consider crucial to the design of technology for all, including elderly.

Patient Interface

Through a Wizard of Oz type of experiment (Dahlback, 1998), we investigate how MOUE will affect the patient. Will it annoy, or intimidate the patient, will it make the patient feel more comfortable, and cared for, will it help the patient's recovery?

What type of avatar face is most appropriate to use for such an application (male, female, black, white, young, etc.), what kind of voice, tone of voice, facial expressions, etc? What demographic class of patients is more positively responsive (male, female, young, elderly, etc.)?

Multicultural Animated Avatars

Our Avatar – an anthropomorphic image representing a user in a multi-user virtual reality space – was created with the Haptek avatar system. We used the People Putty package to create a variety of avatars for a multitude of different users. The main idea behind this is to increase diversity, such that people of various ethnic background, gender, age, etc. can select and interact with anthropomorphic interface agents of their choice. Users can chose an avatar or create one avatar to their own (or someone else's) image.

User Recognition and User-Profile

The properties that can be changed with our avatar are its face, skin type, voice, hair, make-up, accessories, and the background scenery. We created a collection of avatars of different races, gender, age, etc. which can be situated within a specific background to the user's choice. These choices can then become the default value using the saving option such that the same avatar will be chosen every time that a specific user logs in. Indeed, our system has been integrated with our facial recognition system in terms of identity such that it builds user-profiles, including data such as user's name, gender, and favorite avatars.

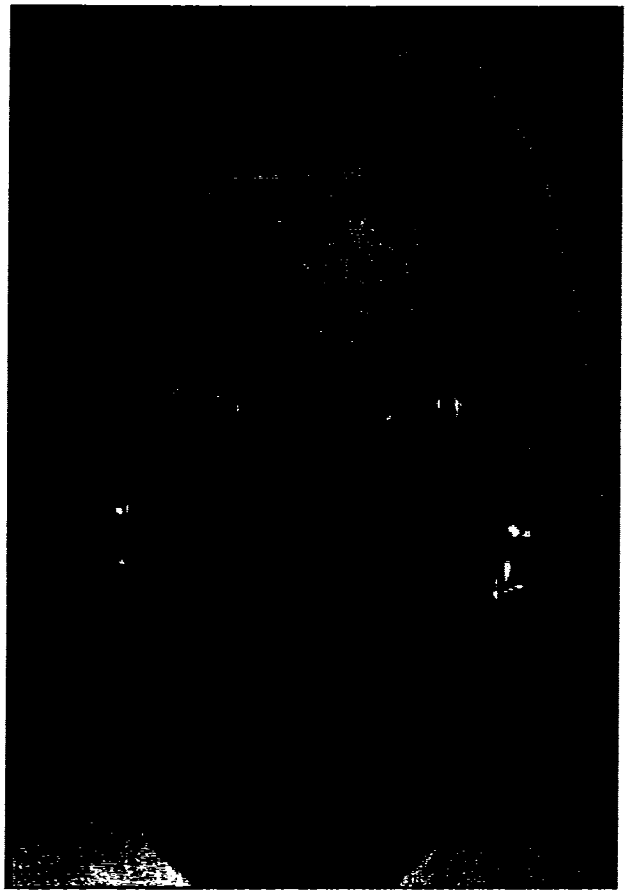

Figure 3: Avatar Expressing Anger

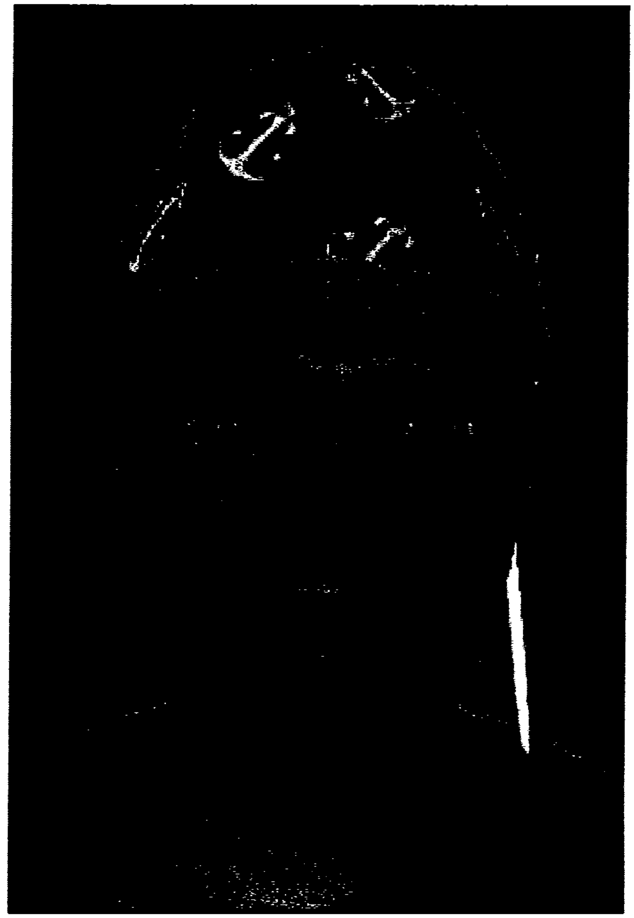

Figure 4: Avatar Expressing Sadness

In addition to collection of multicultural avatars that we have created, the user can also create their own.

Although avatars have been used in the interface previously, this is first time that user-profiles are created to enable the user to choose the character they will interact with, or for the system to automatically recognize the user and associate a specific interface agent with a specific user transpartently. The creation of multi-ethnic, etc. avatars collected under one interface is also new.

[Note: the authors can provide additional references to illustrate this point].

Mirroring the User's Facial Expressions

Most importantly our avatar can also mirror the user's facial expressions once these have been identified with the facial expression recognition algorithm (see Figures 3, 4). The user displayed in the lower left corner of the interface (from pictures taken at the desktop during the interaction), is mirrored by the avatar in the upper right corner of the interface. The upper left corner describes in details each of the specific emotional states which is useful for telemedicine applications described in (Lisetti, Douglas, & LeRouge 2001) but outside the scope of this article.

This feature is used to give feedback to the user about her/his emotional state. After the system recognizes user's emotional state, the avatar can also express this emotion with the appropriate facial expression as well as outputting the label on the screen (along with each fine-grained components shown in the upper left corner). For example, if the user is happy the avatar puts an happy expression on its face.

This feature is particularly important as people are not always aware of the expressions they portray. Hence it can be used to teach the user about their expressive patterns, and it can also help them become aware of them. Finally, depending upon various personalities, some users in learning environments can learn best if challenged with stern or reproaching faces for example, whereas others will benefit from seeing compassionate ones. This type of personality research is also under further development in our laboratory.

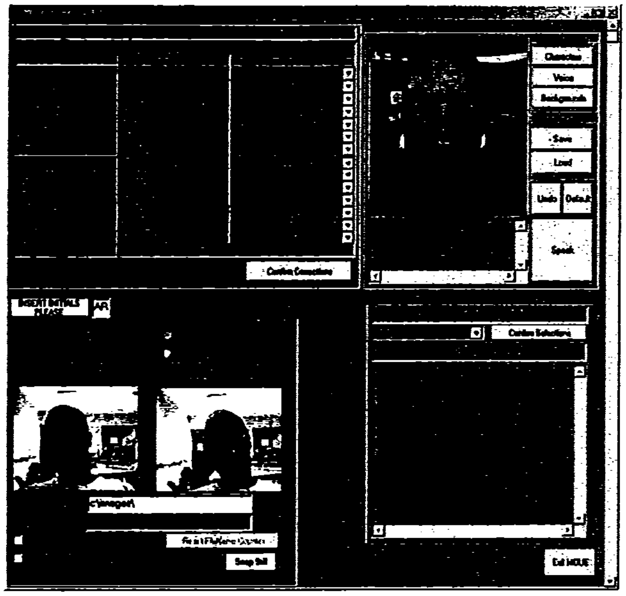

Figure 5: Avatar Mirroring Happy User

Autonomic Nervous System (ANS) Signal Recognition

ANS Related Research

As indicated in Figure 1, emotions and affect are quintessentially multimodal phenomena. The ANS is a very active system and signals emotional arousal. Several studies investigated this area of research, which we are also contributing to.

One of these studies aimed at examining differing views on the relationship between self-report of emotion and physiological expression of emotion. Experiments were performed in order to differentiate between negative emotional contexts during imagery using facial electromyogram (EMG), and to describe the facial muscle patterning and autonomic physiology of situations that involve expelling or avoiding disgusting sensory stimulation (Vrana 1993). Standard electrodes placed on each inner forearm were used for electrocardiogram while miniature electrodes were used for facial EMG, and skin conductance was recorded with a skin conductance coupler.

In another study, people were asked to observe a person with whom they lived, to report when they noticed that person experiencing an emotion, and to report what cues they used to detect the emotion.

Yet another study was designed to examine whether physiological emotion specificity occurred in the context of fear and anger. Heart rate, Skin conductance level, finger temperature, blood pressure, electro-oculogram, facial electromyograms were recorded the while the subjects were visualizing the imagery scripts (anger, neutral, fear, physical action) given to them. The results indicated that emotion-specific response patterns for fear and anger are accurately differentiable from each other and from neutral imagery conditions.

Finally a study was done to examine the hypothesis that spontaneous electrodermal activity (EDA, often assessed as skin conductance) produced a complex problem-solving task reflects task engagement. In this study skin conductance was recorded using surface Ag/AgCl electrodes while the subjects were trying to solve the given problems. The findings of this study support the hypothesized relation between appraised coping potential and spontaneous skin conductance activity.

The Emotion-Mouse study was designed to measure heart rate, temperature, GSR (galvanic skin response), and somatic movement (Ark Dryer Lu 1999). The apparatus used were a chest strap sensor for heart rate, a thermocouple attached to a digital multimeter for temperature and GSR. The computer mouse movements were recorded to measure the somatic movement.

Finally, in another study, smart physiological sensors embedded in an automobile afford a novel opportunity to capture naturally occurring episodes of driver stress. In this study, electocardiogram, electromyogram, respiration and skin conductance sensors were used.

ANS *Wireless* Sensing for Real-Life Applications

Accurately recognizing people's emotions by using multimodal sensing devices will be very useful in many areas. One of these areas which we have been focussing on is *drivers' safety*. Sensing devices can be used to measure *stress, frustration, panic and sleepiness* levels of the driver. If one or more of these are over the driver's threshold, the driver can be advised to be more careful or to have some rest or relaxation for a while.

One other application is *soldier training* in high stress. Sensing devices can measure physiological signals of the soldiers while they are trained. These data can be used to design a better training plan for soldiers without making them frustrated, confused, panicked, etc.

Finally, the sensing devices can also be used to measure the body signals of patients that are having *tele-home health-care*. These collected data can be sent to a doctor's or a nurse's personal computer for further decisions (Lisetti, Douglas, and LeRouge, 2001).

Our sensing device is a wearable body monitor called SenseWear Armband, which was created by BodyMedia and shown in Figure 6. All of the studies described above were performed using sensing devices that were connected to the body at one end, and connected to the computer at the other end. The most appealing feature of the SenseWear armband is that it is wireless, hence enabling the user to be immersed in real-life situation and to wear the non-invasive armband.

The armband, worn on the upper arm, is small and it is light. Combining all these properties we have a great device to make measurements in real life like while driving, watching a movie, eating, exercising, traveling and even sleeping. With the SenseWear Armband we can measure galvanic skin response (GSR), skin temperature, ambient temperature, heat flow, and movement. Moreover we use an an additional chest strap to measure heartbeat.

Figure 6: Wireless Non-Invasive ANS Sensing Device

Preliminary Results

In Figure 7, we show a graph of the various sensing of the two modalities we are interested in: heartbeat, and Galvanic Skin Response (GSR) while subjects watched a horror movie.

In the graph, the X axis shows the time valued between 00:00 and 23:59. The Y-axis is scaled between the minimum and maximum values in the sample set being displayed.

In the heart beat graph at the end the value drops dramatically because it shows the time when the participant took off the chest strap that measures the heart beat. Since the chest strap should be taken off before the armband, the value measured is close to 0.

Clearly, more research needs to be performed for accurate readings to be reached, and we are continuing our data collection. Our initial experiment shows, however, that we can now perform *real-life* experiments to measure affect and emotion which is bound to render affective computing research very useful. Indeed, one of the reasons emotions have been undermined and misunderstood in the past, lies in that they were too difficult to reproduce in artificial laboratory settings. We now provide ways to build user-models of emotions for real life applications.

Health-Provider Interface

What is a suitable design interface for emotional reading software to provide readings to home health care service providers? Suitable representation should provide an adequate scope of information and elicit user confidence in MOUE capabilities. Hence, additional questions arise:

What mode of MOUE feedback do health care service providers find most useful in a telemedicine home health care situation?

What is the most useful form of MOUE feedback among individual and combined options of: (1) Text; (2) Patient picture; (3) Figure (e.g. chart, graph, or table) representation.

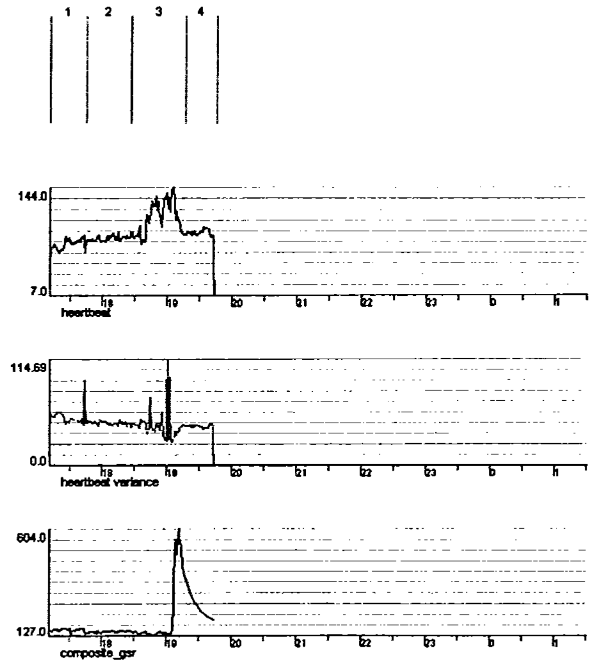

Figure 7: ANS Sensing During Movie Watching: (1) time interval before the movie; (2) time interval during first part of movie; (3) interval during scary part of movie; (4) after movie

Does the presence of a patient picture increase confidence in MOUE feedback?

Additionally, though few would argue a patient's emotional state is a factor of consideration in all forms of medical care, future research may discern that patient MOUE readings are more useful for home monitoring of certain types of health conditions.

Future Research

An interface to *recognize* and *express* affective states is attractive in that it could improve the communication from the computer to the user by:

- rendering the computer more human-like in its interaction to help the user develop trust/liking for the computer;
- adapting its interface to induce various emotions;
- recording and remembering the user's states during an interaction;
- changing the pace of tutoring session based upon the monitored user's cognitive and emotional states (i.e. bored, overwhelmed, frustrated, etc.);
- guiding the user to avoid cognitive/emotional paths where [s/]he] gets blocked;
- implicitly adapting its interface using multi-modal devices (expression, posture, vocal inflection) to provide adaptive feedback;

- give computer agents awareness of what emotional state the user might be feeling so that inferences can be drawn about the motivations implied in them;
- motivate agents to initiate actions (i.e. search and retreive items) using explicitly-set agent's competence level. The level is evaluated in terms of the accuracy of its predictions made from observations of the user;
- explicitly change some aspects of agent's interface depending on user's state;
- test emotion theories by providing an artificial environment for exploring the nature and development of emotional intelligence;
- learn from naive psychology: explain, understand, predict behaviors of others, and build user models;
- self-adjust the agent's commitment to an ongoing activity based upon valence of its current state (negative: slow down waste of energy and reevaluate context, positive: continue in the same direction);

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