Affective Computing in Tele-home Health: Design Science Possibilities in Recognition of Adoption and Diffusion Issues

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Abstract

This study exemplifies the integration of IS behavioral science in the area of technology adoption and diffusion into the design science process. We first identify the computer-mediated paradox, as it exists in the tele-home health care setting and its potential impact on providing quality patient care inclusive of affective assessment. From the design science perspective, we then introduce an intelligent interface aimed at improving affective distance communications between a patient and health care provider and patient emotional state monitoring in the tele-home healthcare context. Specifically, we investigate input processing the patient's sensory modalities (or modes) via various media and building (or encoding) a model of the patient's emotions to offer the health care provider with an easy-to-use and useful assessment of the patient's emotional state in order to facilitate patient care. We then use an IS adoption model developed and tested in the general telemedicine context in an exploratory manner as a means to inform design science regarding adapting affective state output in consideration of adoption and diffusion issues. Based upon this integrative exploration, we propose to expand the application of "Wizard of Oz" type studies (Dahlback, et al. 1993) to computer-mediated communication (CMC) environments to investigate how emotional state assessments influence responses from health care professionals and how MOUE can be accepted into the health care environment.

Tele-home health

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 et al. 2000). According to the National Association for Home Care, more than 20,000 medical professionals provided approximately 7.6 million people in the U.S. home care services for acute illness, long-term health conditions, permanent disability, or terminal illness (National Association of Home Care, 2001b). Factors such as medical cost control and an aging population continue to seed the home health care industry (Warner 1997b) (Darkins et al. 2000).

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 balancing quality ideals against the feasibility of frequent of on-site visits. Longer durations between communications may potentially 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.

In response to such home care issues, 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 enhance the quality of home health care through increased monitoring (Siwicki 1996). Tele-home health provides communication options between the medical professional and patient

when hands-on care is not required. 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 1997a).

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 et al. 1996). Tele-home health possibilities include telephone reminder systems, wireless personal emergency response systems, vital sign monitoring devices, video conferencing, medication reminder systems, and web-based systems. Interactive communications may be either synchronous or asynchronous. Three common forms of interactive communication include:

- *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.
- *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 traumatic stress disorder patients) and who do not want direct contact with a medical institution until they are in deep crisis.
- *In Home Messaging Device* (see http://www.hhn.com/products/appliancedemo.html for demo): 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. Such devices typically provide 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.

Patient medical needs and to a lesser degree, cost factors dictate the type of system recommended.

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 when using tele-home health tools. Vital sign readings and medicine reminders may be

effectively communicated through current physiological detection devices used in tele-home heath care, but affective state assessment may prove a greater challenge in providing comprehensive, quality tele-home health care.

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.   Unfortunately, none of the common forms of interactive communication used 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".

Literature indicates that emotional states may be conveyed through voice, facial expression and other physiological representations (Lisetti et al. 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 in-home messaging device shrinks the vehicle of communication down to objective text-based responses, which limits expressive freedom. As we decrease the modes of communication and freedom for expression, fewer affective clues pass through the communication process.

Hence, the computer mediated computer paradox is a relevant factor in the tele-home health care setting, which may hamper affective assessment and ultimately the quality of care.

MOUE

A MOUE (**M**odel **O**f **U**ser's **E**motions), a system which builds a model of user's emotions during interaction from observing the CMC user (e.g. patient) via multi-sensory devices, addresses some communication paradox challenges experienced in the tele-home health care setting, which we identified in the previous section. Such a system currently under development aims at:

- Identifying emotion components satisfied by its sensory observations;
- Having a database of emotion concepts for each of the most commonly experienced emotions of a given user;
- Providing feedback to the user about his or her state;
- Categorizing similar emotions and infer emotional trends;
- Instantiating its own emotion-like motivational state (future research);
- Initiating some appropriate multi-modal adaptive action from that state (future research).

MOUE described in detail in (Lisetti, 2002)) has three main components: (1) A sensory-motor apparatus performing distributed low-level processing and integrating the result into a ``perceptual interpretation of facial expression'', (2) an ontology of emotion

concepts based on schema theory, built as a distributed semantic network and in which each active node represents a characteristic of the current emotion and (3) an active interface which externalizes to the user the perceived emotional state and reciprocally allows the user to correct and fine-tune the systems interpretation of his/her own internal emotional states.

The overall paradigm for MOUE (Model Of User's Emotions) (Lisetti, in press) is shown in Figure 1. Emotion seems to be best accounted for and represented by including *both* physiological and subjective components in a model of user's emotions (Lisetti, 2001). Accordingly, the system takes as *input* both mental and physiological components associated with a particular emotion experienced by the user.

Using the same terminology as Maybury and 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: **V**isual, **K**inesthetic, and **A**uditory (**V**, **K**, **A**)[1]. The system can also receive input from **L**inguistic tools (**L**) in the form of linguistic terms for emotion concepts, which describe the subjective experience associated with a particular emotion.

Utilization of facial expressions is an appropriate indicator of subjective components as research on automatic facial expression recognition has shown very promising results (Lisetti, 2000) and facial expressions can be captured in less invasive manners required to capture and measure breathing patterns or heart beats. Because of the multi-modal nature of the MOUE system and its simple natural language processing abilities, it will be possible to map out user's inner states more accurately with the system's growing sensing abilities (such as breathing patterns, or heart beat).

Our main approach is therefore to use the results of MOUE sensing the user's sensorimotor cues (facial expressions so far, but it could also be vocal information, galvanic skin response, breathing patterns, or heart beat) to describe a specific multi-modal emotional state that might correspond (with high probability) to the user's current state.

The *output* of the system is given in the form of a synthesis for the most likely emotion concept corresponding to the sensory observations. The synthesis constitutes a descriptive feedback about the user's current state, derived from the user's ongoing video stream, and a selected sequence of still images. The emotional state concepts include neutral, angry, frustrated, sad, and afraid. Recent experiments captured physiological and facial expression readings as input for MOUE assessment indicated promising results (Lisetti et al. 2003). Specifically, results indicated 70% success in detecting neutral, 80% success in detecting anger, 80% success in detecting fear, 70% success in detecting frustration, and 90% success in detecting sadness.

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[1] We limit ourselves to the three modalities (V, K, A) because we currently have found more emotion-relevant literature on those modalities than on the other two modes: Olfactory and Taste (O, T).
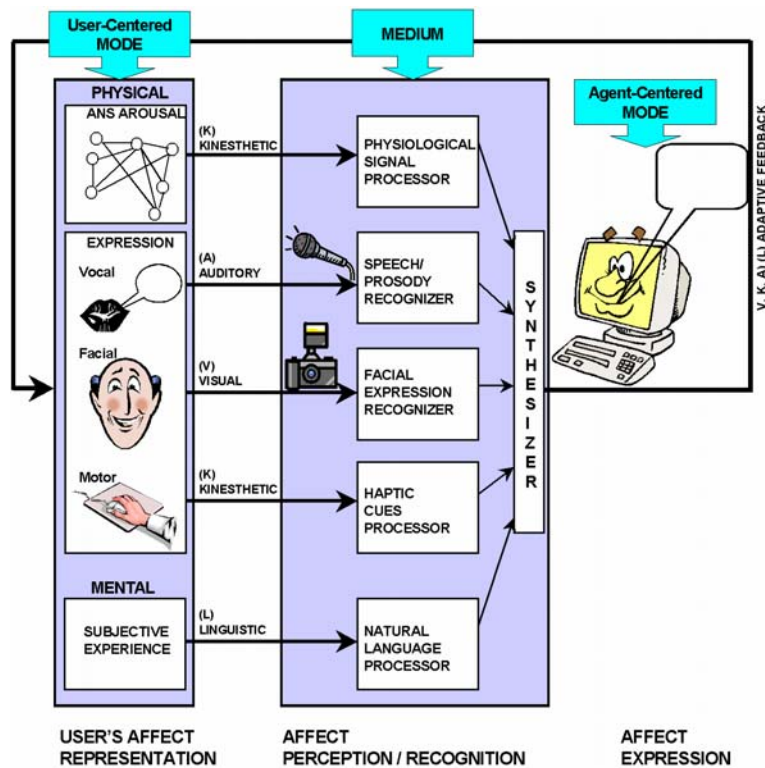
Figure 2: MOUE Paradigm: Combining AI and HCI for Affective Computing (Lisetti et al. 2003)

MOUE in Tele-Home Health

The introduction of an intelligent affective interface into a tele-home health care setting holds promise of providing improved capabilities for affective state assessment and monitoring to potentially increase the quality and possibilities of tele-home health care in a cost-effective manner. Patient's affective risk level may be objectively monitored according to individual emotions and/or aggregated for overall emotional risk assessments. Additionally, the clinician can have a reading of the patient's emotional state during synchronous communication to compensate for the loss of modalities.

However, research findings and personal accountings attest that the development and availability of promising technology does not necessarily beget the successful utilization of the technology (DeLone et al. 2002). The potential for improvements in the affective assessment are contingent upon development AND appropriate use of innovations. A primary issue in enabling the application of MOUE to tele-home health care is *acceptance,* which has long been recognized as a critical success factor in IS literature (e.g. Brancheau et al. June 1996; Davis 1989).

Though there is a strong IS technology acceptance research stream (Agarwal 2000), little research explores the exploration integration of IS acceptance constructs into the development of innovations (i.e. design science). Given the cost and effort in developing innovative technologies, such as MOUE, consideration of acceptance into proposed contexts should be evaluated during the development process. We use significant

relationships found in the Chau and Hu technology acceptance model (see Figure 3) developed in consideration of the broad context of telemedicine as a means to integrate insights from IS behavioral science research in the area of technology adoption to further development and consideration of MOUE to the tele-home health context. We develop these insights based on prior research, ten semi-structured interviews with tele-home health providers employed by three leading tele-home health organizations, and direct observation of tele-home health providers in the process of performing their job.

Both patient and medical provider acceptance are desired. The tele-home health case managers (e.g. nurse, nurse practitioner, dietitian, etc.) and, ultimately, the physician in charge of the case are responsible and accountable for establishing the direction and execution of tele-home health care and the introduction of various technologies into the tele-home health context. Without adoption by health care professionals, the successful utilization of MOUE in the tele-home health context is severely inhibited, if not impossible. Past research has demonstrated health-care professionals have unique characteristics as a user group, which may impact the nature and propriety of commonly proposed antecedents to acceptance in this context (Hu et al. 1999). Hence, we primarily focus this discussion on MOUE acceptance from the perspective of health-care professionals.
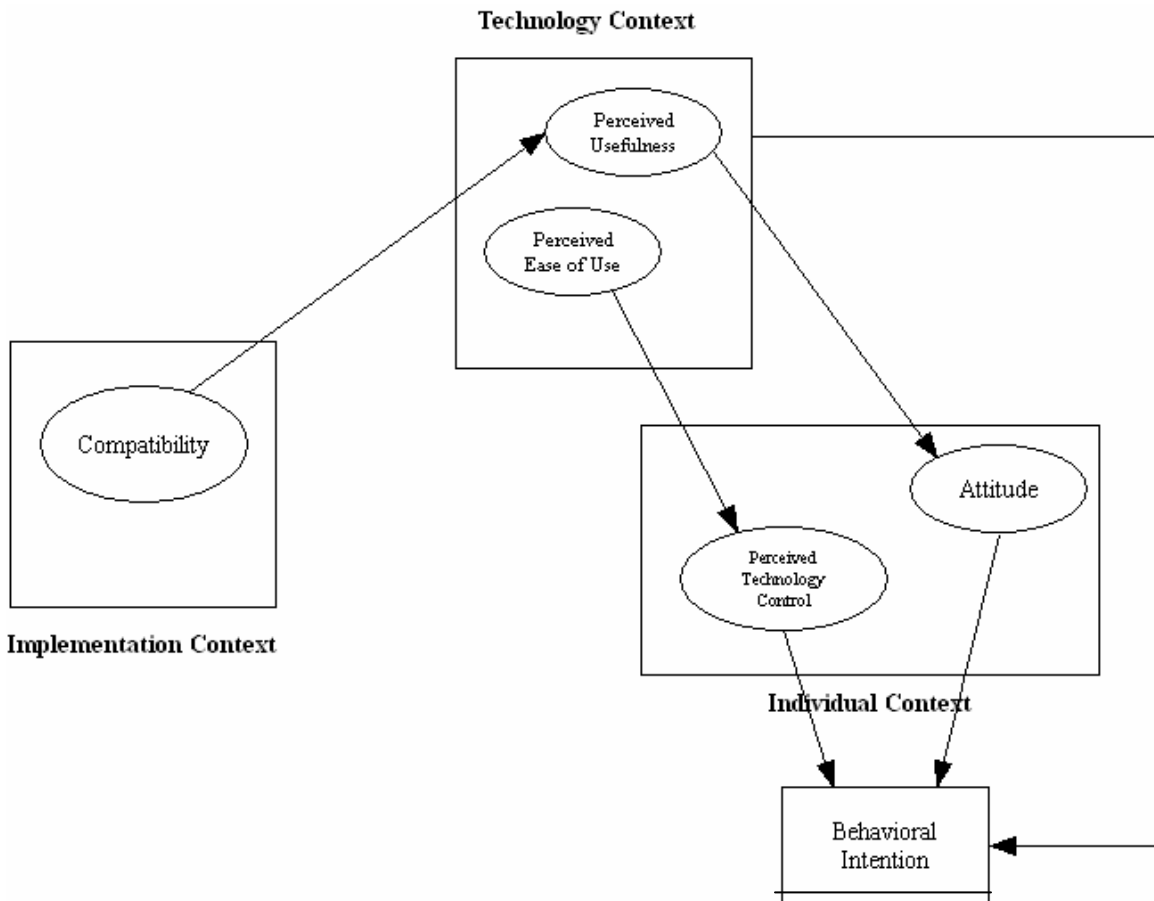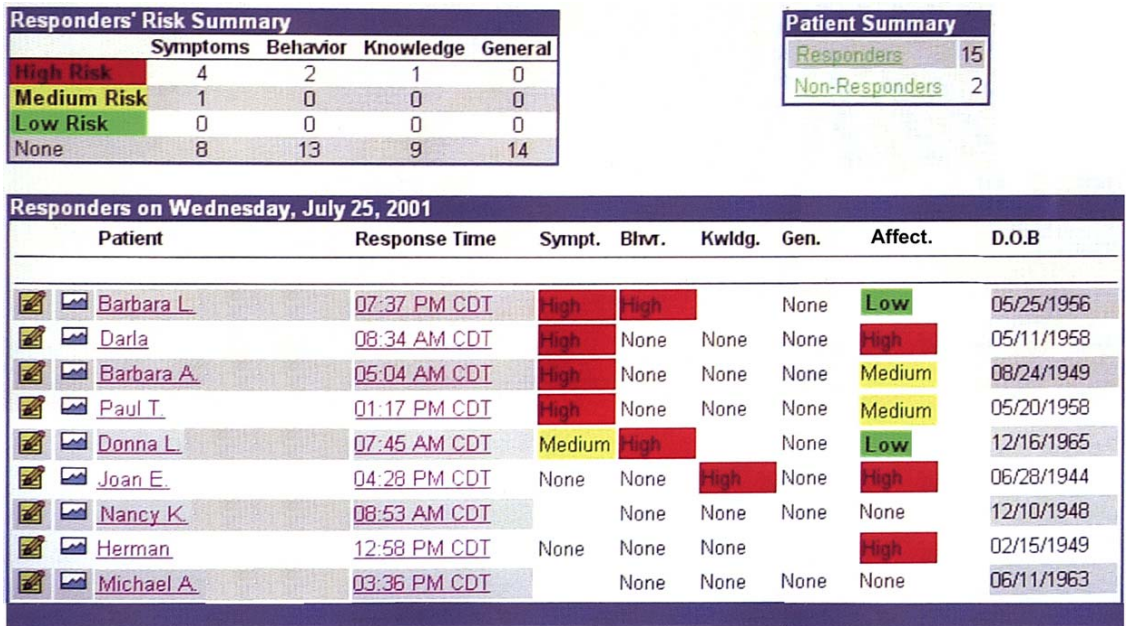

Figure 2. Chau and Hu Model of Information Technology Acceptance by Individual Professionals – Significant Relationships (Chau et al. 2002)

Implementation Context

Compatibility – Compatibility refers to the degree to which the use of telemedicine technology is perceived by a clinician to be consistent with their current work practices or preference. Prior research indicates physicians may become entrenched in a style or routine of practice in which they categorize a patient's needs and then select "…appropriate standard programs (such as, treatments or protocols) from a repertoire, and subsequently execute them (Chau et al. 2002 p. 200).

Tele-home health case managers operate in the same categorization process under the direction of a physician. Our interviews and direct observations indicated clinicians spend much of their time reviewing integrating data from multiple indicators of patient status in a manage by exception manner to manage caseloads of up to 250 patients per tele-home health clinician. Tele-home health literature supports these observations and in fact, provide accounts of even higher patient/clinician ratios (e.g. Crist et al. 1996). Past literature, interviews, and direct observation indicate that clinicians are comfortable with current output format and styles, which seems to accommodate the process of contingency categorization.

Hence, it is of no surprise that clinicians queried regarding MOUE output options expressed the preference for amalgamation within the current presentation format and specifically the use of tables, graphs, and color-coded schemas to avoid disruption of established patterns of practice. We present a prototype of aggregated patient status information that emulates the interface motifs currently in use for one popular tele-home health system to integrate MOUE output in the tele-home health context in Figure 3.

Responders' Risk Summary

	Symptoms	Behavior	Knowledge	General
High Risk	4	2	1	0
Medium Risk	1	0	0	0
Low Risk	0	0	0	0
None	8	13	9	14

Patient Summary

Responders	15
Non-Responders	2

Responders on Wednesday, July 25, 2001

Patient	Response Time	Sympt.	Bhvr.	Kwldg.	Gen.	Affect.	D.O.B
Barbara L.	07:37 PM CDT	High	High		None	Low	05/25/1956
Darla	08:34 AM CDT	High	None	None	None	High	05/11/1958
Barbara A.	05:04 AM CDT	High	None	None	None	Medium	08/24/1949
Paul T.	01:17 PM CDT	High	None	None	None	Medium	05/20/1958
Donna L.	07:45 AM CDT	Medium	High		None	Low	12/16/1965
Joan E.	04:28 PM CDT	None	None	High	None	High	06/28/1944
Nancy K.	08:53 AM CDT		None	None	None	None	12/10/1948
Herman	12:58 PM CDT	None	None	None		High	02/15/1949
Michael A.	03:36 PM CDT		None	None	None	None	06/11/1963

Figure 3. Integrated output with Affective State

Individual Context

Perceived Technological Control: Perceived control refers to the health-care professional's assessment of perceived ability to use the telemedicine technology. Perceived control in the tele-home health context refers to both technological capability and autonomy. Health care professionals (particularly physicians) are thought to exercise considerable autonomy in their work process and accordingly, considerable control over the use of technology in the patient care context (Chau et al. 2002). Though home health care case managers may be subject to greater levels of control imposed by home health care organizations and/or attending physicians, they are the home health care patient's "front-line" care decision makers and possess some autonomy in their work process.

MOUE adds data to the present context with no data costs. The use of this additional data will likely be volitional. Research indicate both nurses and patients may promote innovations that provide the possibility of improved patient care (Anderson 2000; Darkins et al. 2000; Whitten et al. 1997).   Given the trend toward the use of multiple and increasingly sophisticated devices, including wearable biochemical sensors that track a multitude of physiological measurements in tele-home health care (Crist et al. 1996) (Kinsella 2000), the introduction of new sensors or added application of currently existing sensors to affective state interpretation may not seem foreign or disruptive to the existing tele-home health care atmosphere. Based upon the aforementioned, it seems tele-home health professionals will manifest perceived ability to use MOUE and possess motivations for use assuming issues surrounding technological context and implementation context are satisfied.

Attitude: The general attitude regarding tele-home health and innovation in this area seems favorable. In a 2001 Report to Congress on Telemedicine, the Office for the Advancement of Telehealth indicated generally high patient and provider satisfaction in summarizing over forty telemedicine studies measuring satisfaction(Department of Health and Human Services, Health Resources and Services Administration, Office for the Advancement of Telehealth 2001a). Indications are clinicians, particularly home care nurses, and patients have not been daunted by the introduction of new technologies (Kinsella 2000). It is of note that participants in MOUE studies to date using BodyMedia SenseWear© (a small wireless wearable computer patients cuff to their upper arm, can measure galvanic skin response, skin temperature, ambient temperature, heat flow, and movement MOUE physiological input) responded they were comfortable (emotional and physical comfort) wearing the device.

However, individuals generally rely on their human senses to provide indicators of another's emotional state rather than external devices, even when communication is taking place via distance. Two of our interviewees seemed to have some anxiety with MOUE spawned by fears of artificial intelligence. MOUE innovators and implementers should acknowledge the introduction of MOUE might require some degree of conceptual shift for some potential users. As such, proactive change management efforts (e.g. education on the positive uses of MOUE, limitations, etc.) may be warranted.

The development of technology that may involve conceptual shift, such as MOUE, may benefit from recognizing that such things as attentive participant education may be necessary as developmental experiments are staged. Additionally, experimentation exploring change management possibilities may provide direction on addressing future use situations where conceptual shift may be necessary. These concerns also indicate

patient acceptance may influence health care provider acceptance. Specifically, if experimentation and use indicate patients are comfortable, caregivers concerns regarding intrusion on patients may be subsided. This furthers the call for experimentation related to patient acceptance during the development process.

Technology Context

Perceived Ease of Use: A second acceptance issue relates to the cognitive load of the tele-home health clinician in assimilating a variety of patient data. As such, technology output provided in these settings must support user-processing efficiencies. Efficiencies can be achieved through interfaces that promote quick absorption of data and present data in a form that harmonizes with accepted systems currently in use. Output from currently deployed devices typically utilize tables and charts to allow clinicians to quickly digest status and drill down to observe more detailed information. Alert signals (e.g. color codes and audio alerts) are also used to reduce improve processing efficiency while appropriately focusing attention (Crist et al. 1996). Figure 4 provides a prototype of a "drill-down" MOUE output providing affective state information in graphic form of the general nature currently used to present physiological information.

Perceived Usefulness - This issue centers on beliefs and the perceived value of technology providing indicators of emotional state. MOUE must be seen as "encompassing sufficient utilities for supporting or facilitating …core patient care services"(Chau et al. 2002 p. 199). Interviewees concurred that affective state is a relevant factor in most health conditions. As stated by one interviewee:

"There are very few health problems that the emotional state does not play a factor. As a result the emotional state is a real concern whether there is visualization or not. This makes the Care Coordinator (home health care case manager) a key component in using the appropriate clinical judgment when choosing the technology. Certainly in the mental health population the affective/emotional state is more fragile."

Additionally, interviewed indicated some current concern over the ability to pick up affective clues while to try to manage large caseloads using current forms of communication. Though there is an increasing level of awareness, especially in the medical profession, that physiological readings can provide indications of emotional state, there seems to be little formalized capture and integration of this data into medical practice. As such, the introduction of MOUE into tele-home health may be perceived as providing some remedy to this need, which may enhance perceived usefulness.

However, we acknowledge perceived usefulness is dependent on the quality of the technology (i.e. MOUE indicators accurate and understandable output) and may be influenced by compatibility and attitude.

Future Work

Given the costs and effort required to fully develop and implement complex systems such as MOUE, a "Wizard of Oz study" integrating interface prototyping seems an appropriate (Dahlback et al. 1998) means to investigating many of the field implementation issues in somewhat of a simulated environment. Wizard of Oz (WOZ) studies are studies where subjects are told they are interacting with a computer (HCI) system (and perhaps

receiving "real" information) through a multi-modal interface, though in fact they are not. Instead the interaction is mediated by a human operator (CMC), the wizard, with the consequence that they subject can be given more freedom of expression, or be constrained in more systematic ways, than is the case in existing multimodal affective intelligent interfaces.

Such experiments permit avoidance of "the chicken or the egg" problem: *how can one evaluate the usefulness and importance of intelligent affective feedback and readings before they exist?* Wizard of Oz studies can allow researchers to develop some grounded understanding of how relevant artificial intelligence research in affect recognition will promise to be in the adoption/implementation phase within a given context.

Wizard of studies have been developed in the field of natural language processing. (Dahlback, 1998) and we extend their paradigm to the evaluation of the potential of multi-modal affective intelligent interfaces. Based upon the potential integration issues as discussed using the Chau and Hu model (2001), we claim Wizard of Oz experiments are most appropriate to provide a simulated environment to test MOUE interfaces in light of adoption and diffusion issues (at least in tele-home health care), and to therefore establish the motivation and need for further research in affect recognition and models of user's emotions.
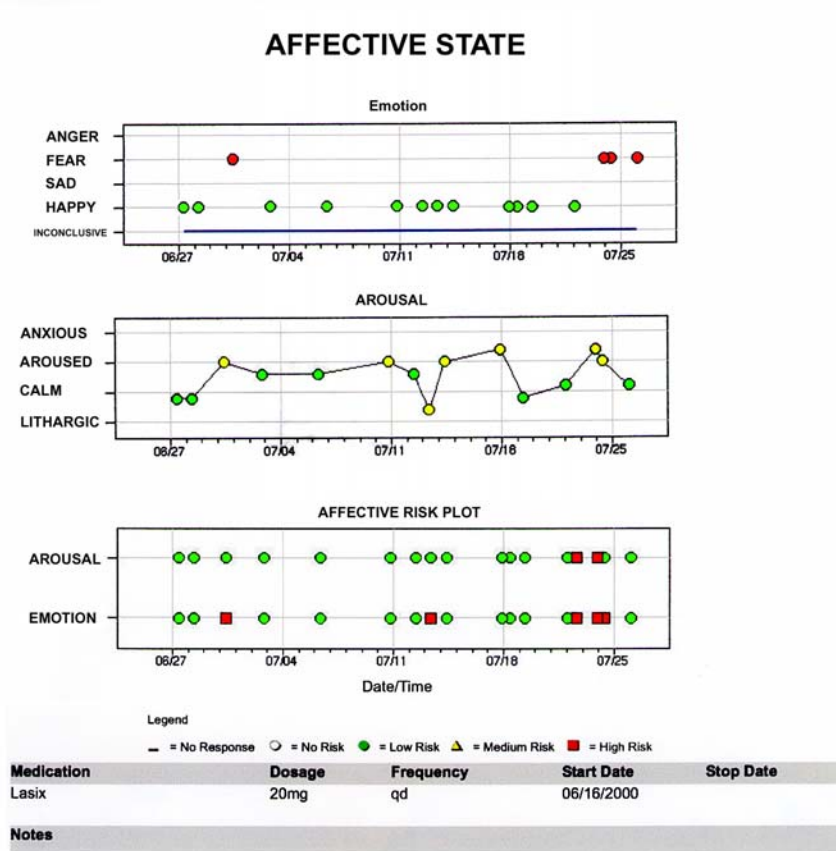
Figure 4: MOUE Drill-Down Output Representation for Tele-home Health Context

Contribution

It seems tele-home health care settings provide a rich landscape for research and application of affective computing to improve the quality of patient care. We introduce an intelligent interface aimed at improving affective distance communications between a patient and health care provider and patient emotional state monitoring in a tele-home healthcare context. Specifically, we investigate 1) input processing the patient's sensory modalities (or modes) via various media, 2) building (or encoding) a model of the patient's emotions and 3) adapting its output to offer the health care provider with an easy-to-use and useful assessment of the patient's emotional state in order to facilitate patient care. We exemplify the integration of IS behavioral science into the design science process by addressing adoption and diffusion variables found significant in an adoption and diffusion model studied in the general telemedicine context. Our proposed methodological innovation expands the application of "Wizard of Oz" type studies (Dahlback, et al. 1993) to Computer-Mediated Communication (CMC) environments to investigate how MOUE assessments influence responses from health care professionals and how MOUE can be accepted into the health care environment.

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