Sensing Mood to Counteract Dementia

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1. INTRODUCTION

With this paper we want to stimulate discussion about the use of mobile and unobtrusive sensing devices for detecting relevant mental and emotional states in patients, to provide for optimally timed assistance and care for persons with dementia, such as Alzheimer's disease (AD).

Among the risk reducers for dementia in general and AD in particular are intellectual stimulation, regular physical exercise, and regular social interaction (see e.g. Ball et al., 2002; Kramer, et al., 1999; Seeman, 1996). Recent research has demonstrated the strong relationships between levels of sensory and physical stimulation and of social communication to both cognitive performance and psychological wellbeing (Fratiglioni et al., 2000; Park & Minear, 2005). But in many modern societies elderly people are increasingly isolated and physically, mentally and socially under-stimulated, as confirmed by recent surveys (see Rabbitt, 2005). The results are accelerated cognitive decline and the suffering associated with loneliness and increasing confusion and often anxiety. To motivate patients to be active, both physically and mentally, is therefore very important to maintain or improve the patient's quality of life and to support ongoing therapies.

However, the willingness for physical exercise, socializing or intellectual tasks varies over the day and between days, depending not only on the general state of health, but also on the individual's biorhythms, the weather, the music playing on the radio and various other factors - of which the caretaker is often not in control or even aware. It is hence desirable to detect those particular moments in the day when the patient is open to stimulation, be it for a chat, a walk, or a game of checkers. From the caretaker's point of view this would allow her to optimize and schedule her own activities according to the patient's actual state and to adjust her activities accordingly. This is important in nursing home environments with caretakers being responsible for many patients, but also beneficial for patients cared for at home, where mostly non-professionals look after family members in need while also trying to maintain own private or even professional life.

In this paper, an exemplary scenario is described to illustrate ways in which mobile and non-obtrusive devices can be used to support caregivers of persons with dementia by monitoring their patient's cognitive and emotional state and communicating relevant information to their caregivers. We also suggest that if the actual state of the patient is known in this way, then the environment could itself adapt to meet his or her current needs. For example, a person may be shielded from certain kinds of communication when these would prove distressing. Other examples include system-guided breathing exercises to improve relaxation, or the initiation of periods of interactive game play for sensory, cognitive, and physical stimulation, as appropriate to the detected state and therapeutic regime.

2. SENSING COGNITIVE STATES

Sensing and recognizing emotional and other cognitive states with computers is a challenging, but also a very promising undertaking, requiring the integration of hardware (sensors), mathematical methods for data enhancement and filtering, pattern recognition and classification. The cognitive as well as the emotional state of a human is manifested in specific physiological reactions controlled by the autonomic nervous system (cf. Hudlicka, 2005, Mathews et al., 2005). These reactions have been studied for a long time, particularly emotion-related physiology, and currently have attracted intensified interest due to the availability of new technologies. While most devices used so far to study emotion and cognitive performance are stationary, advances in technology have led to the development of small yet powerful data processing machines which are suitable for mobile use and can even be integrated in furniture and clothing. Microcontrollers, programmable hardware (FPGAs) and application specific integrated circuits (ASICs) allow for ever smaller devices which can process increasing amounts of data. Today it is possible to measure peripheral physiological parameters of patients while they move about, record the data, or transmit them immediately to processing computers in the vicinity.

Several possibilities to infer a person's mental state exist, such as observing the person's posture, kinematics, movements, or facial features, or analyzing voice characteristics and physiological data.

While facial expressions are one of the most obvious manifestations of emotions (Ekman & Davidson, 1994), detecting them is still a challenge (see Cowie et al., 2001) although some progress has been made in recent years (Aleksic & Katsaggelos, 2005; Fasel & Luettin, 2003). Problems arise especially when the observed person moves about freely, since facial features can only be monitored when the person is facing a camera. Wearing a head-mounted camera facing the face is unacceptable in most situations.

Posture and body movements also contain signs of emotions. A large vocabulary of semantic primitives has been identified by communication researchers, anthropologists, and psychologists (Picard, 2001; Gibbs, 2006). Although each of these methods of emotion detection has limitations, with the kind of long-term monitoring possible in home settings new possibilities arise, based on identifying typical patterns in behavior, posture, and movements. There are two options to infer emotions in gesture: symbols (e.g. thumbs up), and semantics based on the fact that distinct emotions are associated with distinct qualities of body movement, such as tempo or force. Obviously the second, semantics based on distinct patterns, would be the choice for inferring states in AD patients since voluntary signs can't be expected and shouldn't be relied on.

Speech parameters have also been examined for correlations with emotional and mental states, with increasingly acceptable results (Burkhardt & Sendlmeier, 2000; Douglas-Cowie et al, 2003; Küstner et al., 2004; Laukka et al. 2005; Tonti, 2006). Challenges here are similar to those for facial features. As the person moves about, it is necessary to track her position to get adequate measures of the speech signal. But in contrast to facial features, speech delivers emotion information on several levels, or channels, which can be analyzed independently. So it is possible, for example, to analyze the content of utterances for words or phrases related to emotional or cognitive processes, even when the speech signal is not of sufficient quality for signal analysis (Schröder, 2000). In the case of patients with mental diseases, particularly semantic analysis of utterances could prove to be a good information source, since their verbal activity seems to correlate with different mental states (e.g. Closs et al., 2005).

For measuring physiological parameters, several commercial systems exist, such as Thought Technology's Procomp Infinity, Mind Media's Nexus device, and BodyMedia's SenseWear system. Further systems have been developed by and for the scientific community among which are stationary, mobile, and wearable systems (Picard & Healey, 1997; Ark et al 1999; Scheirer et al 2002; Haag et al, 2004; Peter et al, 2005), as well as furniture equipped with sensors (Tan et al., 2001; Anttonen & Surakka, 2005). Projects developing clothing with integrated sensors are currently in process, such as the EU- funded WEALTHY project (WEALTHY, 2004).

While all the mentioned modalities have their limitations, multimodal data analysis can be used to overcome those limitations. For instance, speech analysis can be correlated with visual analysis, providing it with linguistic and/or paralinguistic signs and increasing the confidence of the detected states. Pause detection can assist evaluation of the facial mouth area analysis and audiovisual analysis. Integration of both modalities with physiological data can further improve the success rate of the analysis.

3. EXAMPLE SCENARIO

Nowadays technology can easily be integrated in common living environments, as illustrated in figure 1. Here, as an example, a multi-purpose display is mounted on the wall, able to show pictures of loved ones, favorite movies or still images, communications from friends or other significant persons, requested information or reminders. It can also serve as a window to the outside world by providing access to doctors and other health care services, online shops, social networks, news channels, chat rooms, or other Internet services. Included in the frame are also small cameras and microphones (in each corner of the frame) allowing for a stereo capture of the scene for monitoring body movements, gestures and posture, as well as utterances. The TV set in the background is also equipped with a camera and microphone for the same purpose while the patient is watching TV. The TV set actually could feature similar properties as the wall mounted screen. It's simply a tribute to the habits of the room's inhabitant.

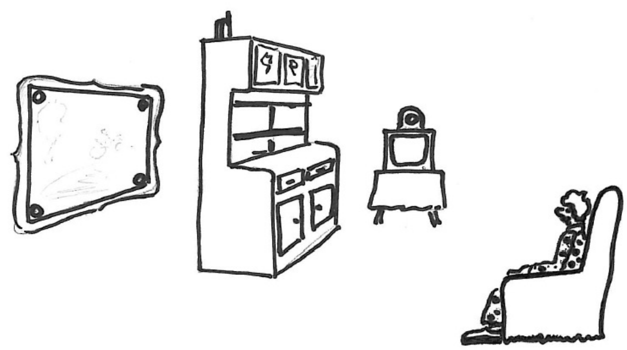

Figure 1: A common living room environment with integrated sensors for detection of mood and cognitive state.

In other rooms of the home there are speakers and cameras to track the person or to call her attention to the multipurpose display in the living room. The cameras also track the movements of the person.

One possibility is that the person wears a very functional glove. It features a display for reminders, notes, and pictures, a pocket for the wireless phone, and, through the phone, a very comfortable means to take notes. Additionally, sensors are integrated in the glove, taking physiological measurements like skin resistance, skin temperature, and pulse.

An alternative possibility, perhaps with a more natural interaction and somewhat less obtrusive, is where the person wears a t-shirt, wireless headphones with built-in microphone and a watch. The t-shirt has sensors integrated within it and which take physiological measurements such as skin resistance, skin temperature, and pulse; the watch, apart from being used as a watch, can be used to display reminders, notes and pictures, and with the wireless headphones the watch can also function as a mobile phone that can also be used to take notes for the notebook. In this extension the person can freely move both in her home as well as outside the home.

A WLAN router on the cupboard connects the wireless devices with a host computer located in the person's home, either directly in the home or via a connection between the mobile phone and the host computer in the home, which distributes the data to a database and to processing applications. The database can be used for further analysis of the data, for instance for therapeutic purposes. Processing applications could, for example, be a time planner for the caring personnel, or ambient intelligence controls, as described in the following section.

4. FROM SENSING TO MEANING

In the scenario described above, the following relevant information on the patient could be acquired:

- location of the patient in the home (cameras)
- bodily orientation (standing, lying, sitting)
- bodily activity of the patient (cameras, motion sensors in clothing or devices worn)
- semantic meaning of utterances (microphones)
- voice signal analysis of utterances (microphones)
- heart rate, electro-dermal activity, skin temperature (wearable physiology sensors)

From these data, a variety of conclusions on the patient's state can be made, such as the actual emotional state of the patient and her cognitive activity, tracked over time. Additionally, and also based on those measurements, the environment can log the inhabitant's activities. The evolving database allows the creation and steadily refinement of a personal profile of the patient in question. This allows therapeutic measures to be tailored to the habits and biorhythms of the patient, and to check for success of those measures.

Current needs of the patient could be inferred and communicated to the carer or the person herself to allow for the optimization of her daily schedule. For instance the following could be inferred.

The patient is:

- interested in doing "something", e.g. when looking for the games box in the cupboard
- in need of help, for example when groveling over the floor with the pills drawer opened
- interested in communication, e.g. by sitting eagerly in front of the turned off multipurpose display or playing with the mobile phone
- needs attention, for example when sitting in the armchair with apathetic face, eyes opened, and low physiology
- would like some attention, e.g. when sitting in the armchair, looking at the turned off display, with physiology aroused and active face, limbs and fingers
- in need of quietness, e.g. when sitting in the armchair, looking at the turned off display, with physiology being low, active face and passive limbs and fingers;
- being entertained, e.g. when actively watching a film
- needs changes to her daily routine of the patient.

Direct responses fom the system will sometimes be appropriate. For example, if the person seems to be stressed, the speakers could start to play music that the person enjoys, and/or show a relaxing video or images on the multipurpose display. If the data indicates that the person is restless then the system can suggest a game, some exercise or even that it should contact a relative or friend. If the person appears depressed the system can attempt to improve the person's mood, for example by suggesting that the person should sit down in front of the multipurpose display, and showing sights and sounds that remind her of significant others and happy memories, in the form of videos, photos and sound recordings. Social interaction can also be encouraged, though on-line games or chatting with other people in a similar condition and situation.

Further scenarios are imaginable, as are other sensors and the retrieval of more information from the acquired data.

5. CONCLUSION

In order to improve the life quality for elderly persons with dementia it is important to provide both a safe and stimulating environment, one that also reduces their loneliness and sense of vulnerability. As far as possible, the sensing technology should be hidden and be designed to create as natural an interaction as possible. It is also important that the technology is wireless in order to allow the person to move around freely. This supports a more active life, including physical exercises, socializing and daily mental tasks or entertainments, in addition to a safer life.

Since the old person's openness to these activities varies over the day and between days, it is highly desirable to detect those times in the day when the patient will benefit from stimulation, and those times when she will not. Such knowledge can be used to the benefit of not only the older person, but also care staff and supporting relatives. Detection of emotional and cognitive states, from a variety of different kinds of sensor, is now a realistic possibility and could provide significant benefit in cases of dementia, such as that arising from Alzheimer's disease (AD).

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