

Affective Computing and Medical Informatics: State Of The Art in Emotion-Aware Medical Applications

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Abstract. The area of affective computing has received significant attention by the research community over the last few years. In this paper we review the underlying principles in the field, in an effort to draw threads for possible future development within medical informatics. The approach is lead by considering the three main affective channels, namely, visual, audio/speech, and physiological in relation to e-health, emotional intelligence and e-learning. A discussion on the importance of past and present applications together with a prediction on future literature output is also provided.

Keywords. Affective Computing, HCI, Emotion, Health

Introduction

Emotions play a significant role in the expression of human intelligence [1]. The arguments in support of the significance of emotions introduced a new area of “emotional intelligence”, defined as “the capacity to understand emotional information and to reason with emotions” [1]. Emotional intelligence is covered by the broader area of affective computing (AC), which represents “computing that relates to, arises from, or deliberately influences emotions” [2]. It introduces new domains and applications that can provide beneficial advancement of current technologies in healthcare and medical informatics, among others.

In the everyday interaction with computers, people exhibit emotions that in certain manners might influence their health. These emotions are communicated through three channels: audio (speech), face and body gestures (visual) and internal physiological changes (blood pressure, heart beat rate, respiration, skin sweating etc.). Identification of the human emotional displays by the computer requires for it to monitor the user, and based on certain parameters, classify/recognize the current emotional state. Each of the three channels of emotional interaction by the user and the computer has its own characteristics and applications in the healthcare domain.

This paper provides a summary of the research and the state of the art in affective computing and its impact to human health. The following section describes the relation

between emotions and health, as the chief reason for the recent focus into the area of affective computing by the medical informatics society. Furthermore, there is an explanation of how each of the three channels of affective computing is applied in the current medical technologies and the resulting benefits. The fourth section examines the significance of affective computing for the emerging and advanced technologies. Finally, there is a general discussion of the present status of affective computing in the healthcare domain and future directions for its advancement.

1. Emotions and Health

It has been a known fact that emotions have an un-bound relation with human health. The impact emotions have on it has been reported for centuries, even in religious writings: “The joyfulness of man prolongeth his days”, (Bible, Ecclesiasticus.30:22) or by ancient Greek philosophers and scientists, such as Socrates and Hippocrates, who considered emotion as a determinant of human health and diseases [3]. The advancement of technology has led to major changes in a human’s life, a more dynamic lifestyle, with more unpleasant stressful situations, frustration, irritation, depression and other emotions with strong negative impact to the human health. It has been noted in [4] that helplessness and negative emotions such as stress or depression weaken the human immune system. Stress causes faster and harder heart pumping, which can lead to the amount of blood reaching heart through the coronary arteries not to be enough to support the faster work of the heart, or a condition known as myocardial ischemia [6]. Defence mechanisms are essential for an individual’s ability to cope with negative emotions such as depression and anxiety [7]. Stressful emotions can have an enormous impact on an individual’s mental health and therefore the strong adaptiveness of defence mechanisms can protect from the negative health effect.

Positive emotions highly contribute to physical and mental health. Laughter generates positive emotions, which in turn help in the improvement of the functioning of the immune system [8]. Humour and laughter act as a primary defence in stressful situations and research has shown that individuals that are able to preserve their positive mood with humour have stronger immune systems [9]. Positive emotions can also act as a medicine for cardiovascular diseases. Middleton & Byrd [10] state that elderly patients suffering from cardiovascular diseases, that were happier than others, had a lower number of readmissions to hospitals. Mental and physical health are influenced by self-esteem and self-efficacy [11], while optimism can speed up recovery from heart surgery and breast cancer [12], enhance greater social integration by increasing the positive “self-view” and happiness, prolong life and assist in coping with stressful situations [13].

The awareness of the significance of emotions and their impact on human health has boosted the motivation for improvement of the research in this field. Together with the advancement of affective technologies in the last two decades, a new paradigm for health has emerged; a paradigm that we feel may enforce the field of medical informatics to seriously take into consideration AC technologies and the evident benefit of their applications.

2. Affective Speech

Emotions in speech can be expressed semantically and through speech prosody. While semantics (what has been said) is a more obvious way of identifying one's emotional state, prosody can provide more detailed information. The term prosody combines nonsemantic cues in spoken language, such as: fundamental frequency (pitch), rhythm, loudness, intonation, formant structure of speech sounds etc.

Research into emotionally expressive speech is very significant for people with Asperger syndrome. Despite normal early language development, individuals with AS are often characterized by abnormal prosody and impaired semantics and pragmatics as well as poor social skills and emotional behaviour [14].

Affective prosody has been employed as a feature for studying the Williams Syndrome (WS), as well. The effects of WS are low non-verbal IQ, impairments in planning and problem solving, uneven cognitive profile linguistic disabilities etc. [15]. Reilly et al. have examined the affective vocal prosody on children with WS through a story telling experiment. It was noticed that the same level of expressiveness was used by the adolescent speakers with WS, regardless of the number of repeats of the story telling or the number of the audience.

An extensive number of studies, concerned with the Parkinson Disease (PD) have reported that patients with PD fail to recognize the emotional content in prosody [16]. Therefore, experiments have been performed where affective speech has been used to further investigate this impairment [17].

3. Affective Psychophysiology

Most of the disturbance caused by a certain emotion influences the internal physiology of the human body (increase of the heart-beat rate, palm sweating, increased respiration rate etc.). Monitoring of these types of emotional expressions requires employment of specific sensors such as Electroencephalogram (EEG), Electromyogram (EMG), Electrocardiogram (ECG), sensors measuring Electrodermal Activity (EDA) etc. The usage of physiological signals in identifying a user's emotional state has become popular in recent years due to the advanced development and availability of unobtrusive sensors that can provide constant and reliable monitoring of a user's internal emotional reaction [3]. Physiological sensors have been successfully integrated into clothing and jewelry; skin conductivity sensor in shoes, blood volume pressure sensor in earrings, respiration sensor in a sports bra and numerous others [18]. These sensors have enabled monitoring of users under various every-day conditions. Haley and Picard have conducted experiments for monitoring drivers' physiologic reactions during real-world driving situations under stress in normal every day surroundings [19]. Bamidis et al. have proposed a Multi-channel framework for experimenting with physiological sensing of human emotions [20].

Monitoring of patients' emotional state using physiological signals has been a primary feature of the existent and emerging applications in tele-home healthcare and ambient assistive living (discussed further in the remainder of this paper).

4. Affective Facial Expressions and Gestures

Facial expressions are mostly used by humans in identifying certain categories of emotions due to the distinct facial differences for the “universal” human emotions such as happiness, anger, sadness, surprise, fear and disgust [21]. The computer needs to be able to recognize human facial emotions as well as express them in the most natural way possible. The latter can be accomplished through artificial robots or through virtual human characters (avatars) that can mimic the human facial expressions. Some of the most characteristic applications are concerned with the ability of the computer to respond to user frustration by expressing empathetic emotions through facial expression of an avatar [22]. Apart from the above-mentioned affective speech, emotionally-expressive avatars have also been used in therapies and learning experiments for autistic people [23].

5. Affective Computing in the Medical Informatics Domain

Once equipped with such sensors, the computer is capable of identifying/recognizing emotions or emotion categories. The latter sets the base for the general vision of the benefits of AC in medicine – What can computers do and how can they be of help, once they have detected the correct emotional state of the user? Researchers have only recently started to think of possible answers to such questions and there is already a significant progress in several medical areas.

Tele-home health care (THHC) is one of the areas that have received great attention by the AC community. Internet-based communication technologies have enabled patient monitoring without the need of physical presence by the caregiver. Current systems facilitate collection of vital sign data remotely, such as ECG, blood pressure, oxygen saturation, heart and breath sounds, verification of compliance with medicine regimes, assessment of mental or emotional status and more [25]. Communication between the caretaker and care recipient through emotional channels in such environments has shown to be of vital importance to the patient [26]. Existing systems employ multi-modal interface including avatars (able to express emotions), to remind the patient for a medication, show empathy to the user when certain negative emotion is detected etc [27].

AC, recently, has been included in the research in the area of Ambient Intelligence (AmI), also referred to as Pervasive or Ubiquitous Computing. Picard considered AmI as one of the most important emerging technologies that will be interrelated with affective computing in the future [3]. The significance of AmI, together with AC, has been reported in the final report by the IST Advisory Group (ISTAG) regarding “Scenarios for Ambient Intelligence in 2010” [28]. Moreover, Riva examines the AmI implications on the future of health technologies, stating that AmI has enormous affect on technology, ergonomics, project management, human factors and organizational changes in the structure of the relevant health service [29]. Recent research attempts in AC have been concerned with the learning and education fields. The basic idea behind this initiative is the influence of emotions and mood on the learning performance and decision-making process. Picard and the Affective Group are working on Affective Learning Companion¹ project that uses software-based interactive application that will

¹ <http://affect.media.mit.edu/projectpages/lc/>

recognize the affective and cognitive state of the learner and respond in an appropriate manner (e.g., can adjust the pace, difficulty, complexity). The existent affective technologies such as virtual agents that can visually express emotions, affective speech synthesis and recognition etc, enable the successful application of AC in e-learning.

6. Discussion

Research has shown that the medical community has started realizing the crucial role emotions play in the preservation of human's mental and physical health. As reported in this paper, there is an enormous increase in studying the relation between emotions and health (medicine) in recent years. According to [4], the interest in emotions and health has been highly increased since 1991, and especially in the last 10 years. We have made an effort in adding statistics for the 2001-2007 period and estimation for the overall 2006-2010 period. In 1991, there were 2000 searches on the "emotion and health" topic, while in 2006 we have nearly 6000. The estimation is constructed linearly by taking into consideration the growth of the previous statistical data, and the number of around 3000 publications from 01/01/2006 until 10/2007. However, it has to be noted that this estimation is rather simple and cannot be considered as completely accurate; it merely illustrates the growing awareness and interest on emotions by the medical community. Additionally, even though the quantity of published papers cannot by itself be an accurate indicator of the importance of this emerging area, the boost in the published research works might indirectly indicate that researchers have decided to pay more attention into this field and, therefore, it definitely shows potential for future applications.

Since its emergence in the late 90's, AC has provided the medical community with technologies that help with better understanding of emotions, identifying their impact on health, and offering new techniques for diagnosis, therapy, and treatment of emotionally-influenced diseases. This paper has provided insight into the most representative affective technologies and their current practice into medical informatics. Moreover, we have mentioned the tele-home healthcare, ambient intelligence and e-learning as areas where the potential of AC has already been realized and initial applications have emerged. Ambient assistive leaving, which incorporates both tele-home and ambient intelligent technologies has been included in the ICT FP7 Work Programme under Challenge 7 – ICT for Independent Living and Inclusion². However, utilization of AC in medical practice is only in its infant phase. Many domains are yet to be explored. For, instance medical education, through the area of e-learning can benefit from AC. Affective speech synthesis and multi-modal emotion expression through virtual characters have started to become popular in virtual community applications for elderly people or even children with certain impairments. The number and variety of AC applications in the medical domain is dependent on the development pace of AC technologies. Therefore, with advances in each of the three sub-areas of AC (speech, face and gestures expression, physiology), we can expect an enormous increase in the interest for emotionally-intelligent applications in the medical informatics domain.

² <http://cordis.europa.eu/fp7/ict/>

7. References

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