An Intelligent Framework for Emotion Aware E-Healthcare Support Systems

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Abstract-There is a prominent connection between human health and human emotion. This connection has encouraged researchers to produce numerous applications in order to facilitate patients and therapists. In this paper, through a review study we highlight how the development of intelligent emotion aware e-health systems can facilitate patient's satisfaction, emotion wellbeing, and physical health, and improve the quality of service offered by health care related businesses. Moreover, we discuss the challenges and difficulties concerning emotion recognition and modelling systems responsible for representing the patient's affective state in real life health care environments. In our research, we aim to address these challenges by proposing a novel framework for developing emotion aware health care support systems. The suggested methodology enables a holistic and reflective representation of the patient's affective state, and incorporates a number of design choices that are suitable for emotion modelling and recognition in the context of a real life health care environment. This methodology leads to the development of a unique emotion aware health care support system, which utilizes Fuzzy Logic to recognize the patient's affective state based on basic cognitive/affective cues, such as the patient's predictions and evaluations of a treatment. The system based on the calculated emotion recognition results, delivers tailored feedback to influence the patient towards a desired and beneficial affective state. As demonstrated in this paper, the proposed emotion-modelling methodology could be very useful when applied in specific real life contexts to develop novel health care systems that are able to accurately monitor and predict their user's emotions.

Keywords- E-health; affective medicine; Fuzzy Logic; Emotion Modelling; human emotion and physical health; patient's satisfaction and emotional wellbeing

I. INTRODUCTION

In modern societies, there is a call for improved health care services to promote public health. E-health aims at satisfying this call by offering quality assured and accessible healthcare for enhancing the physical and mental health of individuals by employing hardware and software tools. This need for intelligent technologies is illustrated in "Health care from the patient perspective" report (Nuance, 2015). The results calculated on data gathered by more than 3000 individuals from the United States, the United Kingdom, and Germany indicate the need for incorporating technology in health care services (figure 1). E-health's potential can be empowered by the development of emotion aware computer systems. E-health systems would benefit from exploiting the strong bond between human emotion and human physical health. From the deployment of emotion aware e-health care systems both patient and organizations will reap rewards. Private and public health care organizations will be in the position to offer better quality of service to their customers/ patients, and patients would experience health care services that promote their physical health and emotional wellbeing.

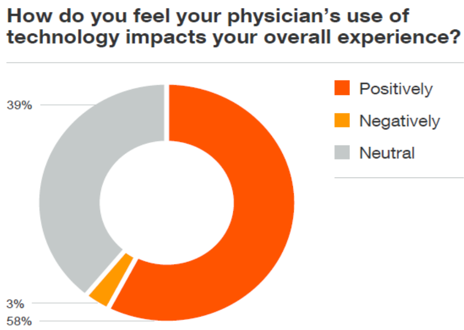

Fig. 1. Patient's sentiment towards the use of technology in health care services (Nuance, 2015)

Despite the benefits arising from the deployment of this kind of emotion aware computer applications, there is a notable deficit of e-health applications currently available to support emotion sensitive health care in the context of real life medical environments. There are several reasons that contribute to this shortage. Firstly, there are significant safety and ethical issues concerning the collection of personal sensitive data in order to train intelligent systems. Secondly, there is an inherent difficulty pertaining to the deployment and evaluation of these systems in real life environments due to the obtrusive nature of applications and the impact on the efforts of medical personnel and the recovery of the patient. Finally, human emotion is very complex in nature and it is affected by contextual information. Most recent emotion recognition applications are able to detect limited emotion categories, which are not reflective of the spectrum of emotional expressions of a patient in a medical context. The aforementioned limitations set out the basis for our research and support the necessity of developing of an emotion aware e-health care support system. Our proposed methodological framework harnesses recent advances in affective computing and fuzzy logic based machine-learning techniques to address these challenges.

The reminder of this paper is structured as follows. Initially in section 2, we discuss the notion and goals of e-health in modern societies. We highlight the close relation between physical health and human emotion. We investigate the quality of service and patient's satisfaction in modern health care environments. Finally, we present recent emotion-aware healthcare related applications. Throughout this section, we identify several open issues and challenges concerning the deployment of intelligent systems in real life health care environments. In section 3, we propose a novel methodology for modelling the patient's affective state, present a health care support system using this methodology, and discuss experimental results that demonstrate the efficiency of our approach. Finally, in section 4 we summarize and discuss our research findings.

II. BACKGROUND

A. E-health

E-health is one of the most popular research topics, and a subject of discussion and investigation by numerous academic, industrial, and government institutions. However, it must be mentioned that providing a definition for e-health was a matter of debate (Eysenbach, 2001). In the review study conducted by Oh et al., fifty-one definitions were found (Oh, 2005). Some people adopted a definition including all software and hardware, which can be used in the context of healthcare, while others used a more narrow definition relating e-health only with the computer applications using the internet. Nowadays, e-health as defined by the World Health Organization (WHO, 2015) is "the use of information and communication technologies (ICT) for health". The European Commission (EC) extends on this definition by highlighting the role of e-health to improve access to care, and enhance the quality of service provided by the health sector. As identified by EC the goals of e-health is not only to improve citizens' health but also to increase healthcare quality and access, and facilitate the development of effective, user friendly and widely accepted e-health tools (European Commission, 2015). In order for the goals of EC to be realized, patient's emotions should be taken into account when designing and implementing e-health systems. We argue that the development of these systems has a two-fold impact on the patient. Firstly, there is a close relation between the patient's health and their affective state; and as a result, emotion aware systems promote the patient's health. Secondly, by taking into account patient's emotions, it is possible to improve the quality of service offered by health care businesses and practitioners to the patient/client, thus improving their satisfaction and emotion wellbeing.

B. Emotion and health

A powerful link exists between our emotions and our physical health. This link is demonstrated by the experimental results of various review studies and research efforts, and it has been identified since ancient times. Greek philosopher Socrates, and Hippocrates who is considered the fathers of western medicine, both regarded emotions as informative clues revealing human health and diseases. This link is also present in the Bible, where it is mentioned: “The joyfulness of man prolonged his days” (Luneski, 2010). Overall, we can mention that positive emotions have a positive influence on our bodies, such as enhancing our immune system, aiding us to deal with a wide spectrum of medical conditions, and facilitating the recovery rate from various conditions. On the other hand, negative emotions are shown to have negative influence, such as suppressing our immune system. In this section, we will present a number of research examples that demonstrate this relation.

In the study by Richmand et al., the researchers examined the link between positive emotions and human health. The team gathered medical data over 2 years from a large number of patients, and collected emotion related information with the help of questionnaires. From the team's results, it was demonstrated that hope was related with a decreased probability of having or developing a disease (Richman, 2005). Scheier et al. examined the effect of optimism to recovery from coronary artery bypass surgery. The researchers collected data from middle-aged men a day before their surgery, a few days afterwards, and 6 months later. The data collected was related to the patient's recovery, mood, quality of life and the way the patient was dealing with their conditions. Optimism correlated positively with faster recovery, decreased time for returning to normal everyday life, increased quality of life, and a constructive mentality by the patient in coping with their conditions (Scheier, 1989). In the paper by Veenhoven et al., the positive effects of happiness at preventing illness were demonstrated. It was shown that happiness was strongly related with longevity in healthy populations (Veenhoven, 2008).

In Smith et al.'s work, the negative affective states of hostility, anger, and aggressiveness have been identified as risk factors for coronary heart disease. In their review, considerable evidence was provided to demonstrate this relation (Smith, 2004). Helplessness, stress and depression are negative affective states that have been shown to correlate with a suppression of the human immune system (Cohen, 1997). Cohen's results demonstrated that people suffering from depression and poor social connections, were more likely to become ill from a common cold (Cohen, 1997). In Burg et al's work it is discussed that mental stress increases the risks for coronary heart disease, and myocardial ischemia (Burg, 1992).).

C. Patient satisfaction and quality of service in modern healthcare environments

Nowadays, patients are very different compared to the patients of previous decades (Ball, 2001). Modern patients can be considered as customers, who demand the delivery of high quality services by health care institutions and practitioners. Therefore, it is becoming increasingly difficult for private and public health care businesses to provide services, which meet the quality of service demanded by their customers/patients. Nevertheless, how can someone define and evaluate quality of service in the context of healthcare environments? In the work by Donabedian, three approaches for assessing healthcare quality of service were presented and discussed. The first approach considers quality of service to be related to the outcome of a treatment/medical care. Has the patient recovered? Were their injuries restored? Did they survive a potentially fatal medical condition? The second approach proposes the assessment of the healthcare process itself, instead of its outcome. This can be explained if we consider that, a patient is not only interested in advanced technologies, which produce great results, but they are also interested in the application of good medical care. The third approach suggested that it is not the process, which needs to be investigated; instead, the focus should be on the environment, in which healthcare is taking place. This environment may include the medical equipment used, the administrative process which supports the provided care, qualifications of medical staff etc. The concept of this approach states that if the appropriate environment is provided, effective medical care shall follow (Donabedian, 2002). If healthcare businesses were able to offer medical services with a higher level of quality of service, then patient's experience would improve massively. Research points out that when the patients are satisfied, then they are more likely to follow recommended treatments, use less care facilities, and ultimately have improved clinical outcomes (Price, 2014). Emotional wellbeing of patients is a crucial factor pertaining to the quality of service offered by healthcare services. We argue that promoting the emotion wellbeing of patients, through the deployment of emotion aware systems is a practice that promotes all the aspects of quality of service identified before. Firstly, the outcome of the healthcare process is potentially improved since positive emotions have positive impact on human health. Secondly, the process itself is improved since it becomes a more pleasant experience for the patient. Finally, applying state of the art and unobtrusive equipment for promoting the patient's wellbeing is beneficial to the healthcare environment, since it facilitates the creation of a personalized patient-friendly environment tailored to the patient's needs and preferences.

D. Affective medicine

The prominent connection between human health and affective state has encouraged researchers to produce numerous diverse applications in order to facilitate patients and therapists. These applications incorporate the principles proposed by a thriving multidisciplinary scientific field called affective computing. Affective computing as originally defined by MIT professor Rosalind Picard is “computing that relates to, arises from, or deliberately influences emotion”. Through the development of systems able to: automatically detect their users' emotions; communicate with the outside world by using emotion-like expressions; feel their own artificial emotions; AC aims at providing a higher level of human machine interaction, and delivering high impact applications to promote their user's wellbeing (Picard, 1997). Affective medicine is the application of affective computing in medicine. Tele-home healthcare, ubiquitous monitoring, virtual communities with emotionally expressive characters for elderly or impaired individuals are some of the areas, where affective medicine applications have emerged. In this section, we present recent applications in the area of affective medicine.

A popular application area of affective medicine is the development of robots and other computer applications, which are able to assist and support the healthcare of people with special needs, such as older individuals or people with autism spectrum disorder. In the paper by Khosla et al., the authors tested a human like affective communication robot called Matilda. The team's results demonstrated the ability of the robot to communicate effectively with the elderly and facilitate their care, thus promoting their emotional wellbeing and quality of care (Khosla, 2013). Bian et al. presented a virtual-reality driving environment, in order to promote skill training for young people with autism spectrum disorder. The researchers utilized several physiological signals, and six popular machine-learning techniques, to identify four emotion categories: engagement, enjoyment, frustration and boredom (Bian, 2015).

Nowadays, smart phones provide a very suitable platform for monitoring health, and assess the mood and behavior of patients. Smart phones provide a mean for fast, cheap and timely interventions to be applied to patients, such as people suffering from mental disorders. In Mankodiya et al.'s research a framework was presented for monitoring the user's emotional engagement to video clips played on a smart phone. According to the proposed framework, video recordings of the user were captured by the front camera of the smart phone, and they were used to extract facial features in order to identify "joyful durations". The team's results facilitated the development of intelligent systems contributing to psychiatric research (Mankodiya, 2013). In another research attempt, Li et al. presented a mobile phone system for detecting human emotions with the help of the galvanic skin response signal (GSR) for promoting human mental health. They aimed at developing a system, which used GSR as a sole input without obstructing the user. The system achieved a notable accuracy of 70%, considering the fact that it relied only on the GSR signal (Li, 2014).

An example of an emotion aware health monitoring system can be found in the work by Wu et al. Wu et al. designed and presented a wearable biofeedback system to tackle the negative impact of emotions like stress. The developed unobtrusive system incorporated heart rate variability biofeedback to a wearable biosensor platform. This platform was responsible to warn for excessive stress and to regulate the user's affective state. The system facilitated the user to change their emotions, to more positive ones, through heart rate variability biofeedback training (Wu, 2015). Chen et al. presented an e-health monitoring system to support patients in dealing with their medical conditions. By using the system, the patient was able to monitor their affective states, and regulate their emotions (Chen, 2013).

Despite the presence of various and diverse applications in affective medicine, there is a notable absence of emotion aware intelligent systems focused on facilitating the efforts of patients and medical practitioners in real life health care environments. This absence can be explained by the inherent difficulties to collect data in the context of these environments, in order to train artificial intelligence systems. Additionally, the deployment of multisensory systems inside a real healthcare environment could potentially be obstructive to the medical practitioner's actions, and interfere with the recovery from serious medical conditions. In this paper, we try to address these challenges by providing an emotion-modelling framework for supporting patients in health care environments, which can be trained offline and provide emotion classification results and feedback based only on basic cognitive affective elements, which can be captured from simple verbal, or text based communication. Finally, it is important to point out that modern affective medicine systems are able to detect a limited set of emotion categories for their users. As it will be demonstrated in the following sections, the proposed emotion modelling methodology is able to overcome this difficulty, by applying a very modern emotion representation approach to model the affective state of individuals receiving medical treatment.

III. HEALTH CARE SUPPORT AND PATIENT'S EMOTION MODELLING METHODOLOGY

In this paper, we propose an emotion modelling methodology that combines novel emotion theories, recent advances on affective computing, and Fuzzy Logic techniques in order to recognize the patient's state and perform actions to facilitate patients and medical practitioners. Our methodology is a structured approach comprising of the following steps. Firstly, through a review study we select a set of emotions that is reflective of a patient's affective state in the context of a modern healthcare environment. Secondly, we choose a new emotion theory in order to map the selected emotions to a suitable affective space. Following this step, we conduct a user-centered scenario based survey to computationally model the patient's affective state. Moreover, the survey data are used to relate specific emotion labels to the affect dimensions described by the selected emotion representation approach. In order to achieve this, we propose the utilization of a fuzzy set and fuzzy rule extraction method that is able to elicit uncertain knowledge from data, discover hidden relations, and demonstrate these relations with the use of natural language fuzzy rules (Mendel, 2001). The final stage of this methodology is the development of a healthcare support system. We propose the development of a two-level system. The first level would be the constructed fuzzy computational model of the patient's emotions, created by the survey data. The second level would be a fuzzy control system, where a set of fuzzy rules would define the optimal interaction of the medical personnel with the patient given their affective state and propose specific intervention strategies. The developed health-care support system would be tested in a real life health care environment. An overview of the methodology proposed can be seen in figure 2.

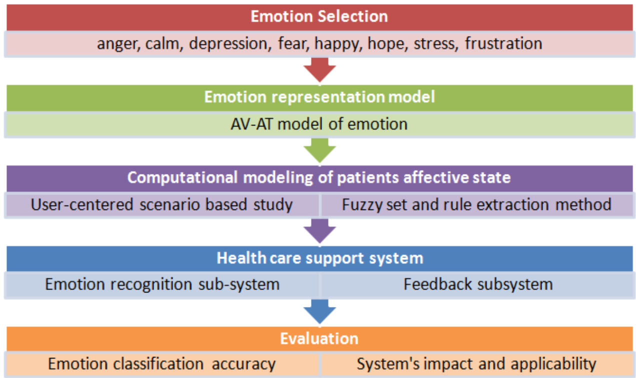

Fig. 2. Patient's emotion modelling methodology.

A. *Emotion words for patients*

The initial point in the proposed methodology, is to introduce a set of emotion words, which are suitable to describe the patient's affective state when receiving treatment. These emotions could be used as the target emotions of a computerized healthcare support system. In our proposed methodology, it is imperative to choose target emotion words that are both acceptable by emotion theories, reflective of the patient's affective state, and beneficial to the patient and the medical personnel. For these reasons, we selected the following set of emotions: anger, calm, depression, fear, happiness, hope, stress, and frustration. This selection was based on previous literature concerning medical-oriented AC systems, and on past psychological literature focusing on the relation of emotion and health. In the paper by Lisetti et al., the researchers utilized the following set of emotions (happy, sad, frustrated, angry, afraid) for their multimodal intelligent affective interface for Tele-home healthcare (Lisetti, 2003). In one of the original papers in the field of affective medicine, Rosalind Picard has highlighted the important role of stress, depression and anger in the patient's health and wellbeing (Picard, 2002). The close relation between these emotions and the patient's health was identified by Goleman in his book Emotional Intelligence, where the author presented the results of various studies towards providing evidence to support this close relation (Goleman, 1995). Moreover, as shown in the corresponding section (II.B) positive feelings such as feeling happy, calm, and optimistic (hope) are proven to have a positive impact in the patient's health and treatment. From the above we can conclude that the proposed set of emotion words (anger, calm, depression, fear, happiness, hope, stress, and frustration) is suitable for describing a patient's affective state and it can be used as the set of emotions by a healthcare support system. Some of the emotion words like hope, calm, happiness could be considered as affective states of the patient, which the system should try to enhance, while others like stress, frustration, depression should be unwanted states, which the system would like to avoid and change.

B. Emotion representation model

The aforementioned set of emotions is very reflective of the patient's affective state when they receive treatment in a health care environment; however, there are some inherent difficulties in emotion recognition systems, when using set of emotions that contain so many distinct emotion categories as the ones proposed above. AC literature has demonstrated that the emotion recognition and modelling processes are in a very close relation with the emotion theory used to describe the user's affective state. For example if a system uses facial recognition then Ekman's Big Six (anger, disgust, fear, happiness, sadness, and surprise), would be a very reasonable choice for target emotions, since these emotion categories were identified through cross-cultural facial expression experiments (Ekman, 1975). However, these emotions are not representative of the full spectrum of emotional expressions of the patient, and they are not in complete accordance with the health care context. This discrepancy was a problem identified by Zeng et al., where most of the systems in the team's review study, utilized Ekman's emotions without taking into account that the Big Six were not relevant with the context of the application area (Zeng 2009). In other cases, an AC system may choose to use a dimensional model of emotion, such as Russell's model, which utilizes an emotion representation of two basic affective dimensions arousal and valence. According to this model, emotions could be represented as points in a 2-dimensional space where the two axes are arousal (how activated or deactivated someone feels) and valence (how positive or negative someone feels) (Russell, 2003). A system using a representation as the one described above could use physiological signals to identify the user's affective state. Some signals like the galvanic skin response are related to arousal (Dawson, 2007), while others like skin temperature or heart rate are related to valence (McFarland, 1985) (Rainville, 2006). Therefore, a system operating in this context, would produce estimates of the arousal and valence levels based on sensory input, and then it would map these values to emotional labels in the arousal valence space. However, it would be extremely difficult to utilize this kind of model in our approach. The proposed set of emotions contains words, which are close in the AV space and this fact could result in very low recognition accuracy. In order to tackle the challenges described above, we propose the use of a recently introduced emotion representation, the AV-AT model of emotion (Karyotis, 2016). This model relies on the aforementioned arousal valence representation and on the Affective Trajectories Hypothesis theory (Kirkland, 2012). According to the AV-AT model, the emotions we experience are created by combining basic cognitive and affective elements. Some emotions are mostly related to the predictions we make about the future while others are more related to the evaluations an individual makes after experiencing the outcome of a situation. The AV-AT model is a two-stage approach, where in the first stage emotions can be represented as different combinations of our predictions, current arousal and valence levels, while at the second stage emotions emerge from combinations of our evaluations, arousal and valence levels following an outcome. We argue that this approach is a very suitable emotion representation framework for modelling the patient's affective state since it enables the utilization of a larger number of emotions that are more relevant to describe the patient's affective state. Moreover, this approach relies on capturing very basic affective information, which can be done unobtrusively through informal, verbal, or written communication.

C. User study

In order to model our set of emotions (anger, calm, depression, fear, happiness, hope, stress, and frustration) and discover the underlying affect relations described by the AV-AT a survey is conducted. This survey aims to relate the emotions under investigation, with the AV-AT basic elements, in the context of modern health care environments. In line with our previous research aiming to model education related emotions by using the Affective Trajectories hypothesis (Kirkland, 2012) (Karyotis, 2015), this survey comprises of different scenarios, describing common circumstances which can occur in health care environments. During this survey, the participants are asked to imagine themselves as taking part in the scenario. The scenarios are divided into two parts, the first part describes the prediction a patient makes concerning their condition/treatment e.g. an upcoming surgical operation. In the second part of the scenario, the outcome of the scenario and the evaluation of the patient are described e.g. outcome of a surgery, treatment. In both parts of every scenario in the survey, the participants provide values to score the AV-AT basic elements (prediction, valence and arousal for the first stage of the AV-AT, and outcome, valence and arousal for the second stage of the AV-AT) and every word in the set of the target emotions (anger, calm, depression, fear, happiness, hope, stress, and frustration related to each stage). A scenario example is as follows:

"You are in hospital waiting for a heart surgery. While your doctor explains the procedure, you consider how the surgery would go, and if it would be successful." (Stage 1)

"The surgery was performed successfully and you are informed by the medical personnel that there were no implications."(Stage 2)

At this point, two training sets are collected. The first set relates to the first stage of the AV-AT model, and contains values of prediction, valence, arousal, and estimates for the presence of each of the emotions. The second set represents the second stage of the AV-AT model, and contains values of the patient's evaluation, valence and arousal levels, and estimates for the presence of each of the associated emotions.

At this point, a fuzzy clustering approach is applied in order to define fuzzy sets from the survey data to represent each of the concepts under investigation. We propose the use of the popular Fuzzy-C means algorithm (Bezdek, 1981). Fuzzy C-means partitions a finite collection of elements into a collection of fuzzy clusters. Following the fuzzy clustering, a fuzzy rule extraction method based on the method presented by Wang et al. is applied on the survey data (Wang, 2003). According to this method, every training datum is converted to a fuzzy rule. All the rules with the same antecedent part are then grouped together. For every group, a single fuzzy rule is generated by calculating the weighted average of the consequents for each of the rules in the group. Finally, following the construction of the fuzzy rule base, a fuzzy classification system is built which is responsible for mapping values of the basic elements to emotion labels describing the patient's affective state. The fuzzy rules contained in the system contribute to the classification results, while at the same time they reflect the affect relations existing in this patient's emotion model. Example rules are:

If the prediction of the patient is negative, the arousal is high, and valence is negative, then stress is very high.

If the evaluation of the patient is negative, the arousal is high, and valence is negative, then anger is high.

The rules described above also demonstrate why an arousal valence approach would not produce good results. Anger and stress are both high arousal and negative valence states and thus they are not easily separable in AV space.

The proposed fuzzy approach was used to construct a computational model of emotion for representing the Affective Trajectories Hypothesis. This was achieved by utilizing data provided by a scenario-based user-centered survey (Karyotis, 2015). As illustrated in figure 3, this fuzzy approach (FM) had an improved performance compared to other popular machine learning techniques (Linear Regression (LR), Regression Trees (RT), Multilayer Perceptron (MLP), Radial Basis Function network(RBF)). The results presented in figure 3 were calculated in terms of the Normalized Mean Square Error (NRMSE)).

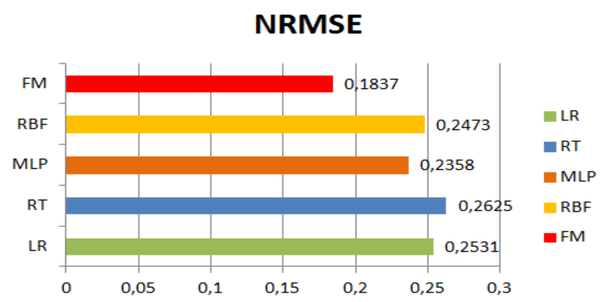

Fig. 3. Emotion classification accuracy of the proposed fuzzy approach compared to other machine learning methods in terms of NRMSE (Karyotis, 2015)

D. Healthcare support system

At this point, we proceed to develop the final version of the healthcare support system. Due to the very low computational burden of the proposed approach, the system could be installed in a standard smart phone or tablet, which can also be used by the medical practitioners as a means to record the course of treatment/recovery/vital signs of the patient during the day. The proposed system is a closed loop system, which collects basic inputs related to the patient's cognitive affective state, and then produces outputs to influence the patient towards a desired affective state. The system comprises of two fundamental fuzzy logic based sub-systems. The first sub-system is the fuzzy model of the patient's affective state developed with the help of the survey data. This fuzzy classification system is responsible to map values of basic elements such as the patient's prediction about an upcoming surgery, or the patient's evaluation of a specific treatment to values of the target emotions (anger, calm, depression, fear, happiness, hope, stress, and frustration). Values for these basic elements are extracted by explicitly asking the patient or by inferring values based on the interaction of the patient with the medical personnel. The second sub-system is a fuzzy control system responsible to produce specific feedback based on the detected affective state of the patient. Expert opinion and intervention strategies are used in order to construct the fuzzy rules describing the decision making process of the system. The output of the system includes quotes to reassure and motivate the patient if they are stressed, and suggestions to the medical personnel to adjust their behavior/attitude towards an angry or depressed patient in context of the support roles.

E. Evaluation

We suggest that the developed healthcare support system is tested and evaluated in terms of its performance to recognize the patient's affective state, and in respect to its ability to enhance the patient's health and wellbeing. In order to achieve this, it is recommended that a set of experiments are conducted in a healthcare context, where the medical personnel would use a version of the system installed in a standard tablet. The interaction would be recorded by a standard video camera, and the values of the emotions generated by the system would be stored. During post analysis of the video recording, experts could label the video recordings using the aforementioned emotion words, and then the provided labels for a given situation will be compared with the responses generated by the system. In this manner, the system's classification accuracy could be evaluated objectively without obstructing the efforts of the medical personnel, or annoying the patient. To triangulate our evaluation analysis, patients and medical personnel would be asked to complete questionnaires specifically designed to measure the benefits of the system and its applicability in a real setting after their experience with using the system. Through these questionnaires, the patient would answer questions such as: How would you rate the feedback of the system? Did the system's presence affect the behavior of the medical personnel or the provided medical services? Was your health/emotional wellbeing promoted by this system? The medical personnel would be asked to provide their opinions to describe the impact of the system on the patient; to report if the systems aided them or if it was an obstruction; and finally to offer their view about further improvements.

Our previous work has demonstrated that the proposed emotion modelling methodology can be applied under a real life environment to recognize a person's affective state. As it can be seen in figure 4, by utilizing the proposed approach, it was possible to identify accurately the affective state of a user, even when a large set of emotion categories was used (8 emotions categories, namely: flow, excitement, calm, boredom, stress, confusion, frustration and neutral) (Karyotis, 2016). The system developed by using this approach, was able to provide values for all emotion categories (red) that were accurate estimations of the values provided by the user (blue) (figure 4). Moreover, it was demonstrated that by utilizing the AV-AT emotion representation approach, it was possible to differentiate efficiently between emotion labels. In terms of recognizing the dominant emotion (the emotion with the highest value among all the provided emotion categories), the AV-AT model of emotion massively outperformed the classification results calculated by applying the popular arousal valence model (figure 5).

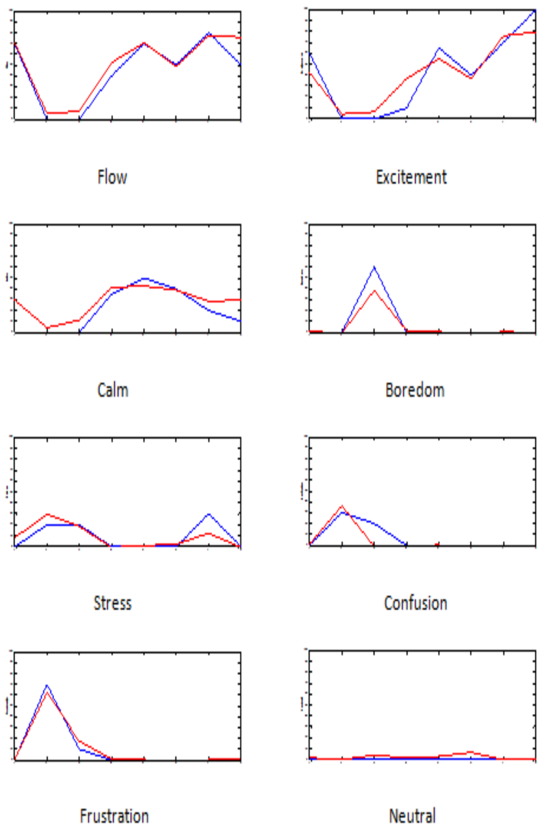

Fig. 4. User provided values (blue) vs system provided values (red).

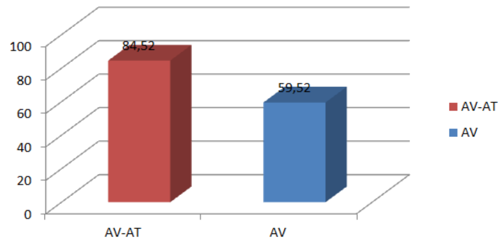

Fig. 5. AV-AT model VS arousal valence (AV) emotion recognition accuracy (%) (Karyotis, 2016).

IV. CONCLUSIONS

In this paper, through our literature review, we demonstrated that patient's satisfaction, emotion wellbeing, and physical health can be influenced in a positive manner by the deployment of intelligent emotion aware e-health systems. Additionally, the quality of service provided by healthcare related businesses can also be enhanced. Moreover, it was highlighted that there is an obvious lack of solutions concerning affective medical systems specifically targeted to help patients and physicians in the context of real life modern healthcare environments. In order to address this gap, we proposed the development of a healthcare support system. The development of this system relied upon a novel emotion modelling methodology comprising of a number of research steps aiming to address the challenges associated with a medical environment, and the complex nature of patient's emotions. This emotion modelling methodology provides a number of ideas contributing to the development of effective healthcare computing applications. Firstly, it proposes an emotion representation that enables the use of sets of emotions, which are representative of the patient's affective state. Previous emotion recognition systems categorized their user's affective state into a small number of emotion categories, which were not reflective of the entire spectrum of the patient's affective expressions. Moreover, with the help of a scenario-based online survey and by applying fuzzy logic techniques, we created a computational model of the patient's affective state without the necessity to gather training data from a real environment, which may prove a very challenging task. The extracted model is used as an emotion recognition module inside a healthcare support system. We opted for this system to operate by using basic inputs, which can be extracted or inferred by simple verbal communication between the patient and the medical personnel in order for the system to be as unobtrusive as possible. From the experimental results presented in this paper, it was demonstrated that the suggested emotion-modelling framework could be very beneficial when applied in specific real-life contexts, and that a system developed by using the proposed framework is able to monitor effectively the emotions of its users.

Developing successful and applicable emotion aware healthcare support systems has a significant impact on empathetically treating patients as individuals and improving the quality of care of healthcare providers. The patient can benefit from these systems as promoting emotional wellbeing can result in improved recovery. Healthcare businesses and practitioners could profit from these systems by providing more effective and personalized services to their patients/customers, thus enhancing their customer's satisfaction. Future work will involve the optimization of the developed system, and its deployment in real life medical settings, to evaluate its impact on patients and practitioners, to gain insights and strategies for the wider applications of smart personalized medical care systems.

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