Physiological Signals Monitoring in Interaction with Machines to Address Healthy Aging

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Abstract

In this paper, development of age-friendly services and settings in interaction with machines that is among the WHO recommended strategies is addressed. In healthy aging, mental wellbeing plays an important role while over 20% of people in the age group of 60 years and above are affected by mental wellbeing issues worldwide. Mental wellbeing problems have an impact on physical health and vice versa and could cause severe illness. Life stressors are among the main contributors for mental wellbeing problems. People in the mentioned age group are more exposed to life stressors specifically during pandemic. Early stress detection and mood swings could potentially help better mental wellbeing that is currently mainly relying on self-reports which is very biased and subjective. Also, traditionally physiological measure of stress quantified by levels of cortisol requires laboratory settings. Therefore, the need for assistive technologies that addresses early detection and awareness of experienced stress, while providing suitable actions is addressed in this paper for the purpose of mental wellbeing issues caused by stress in everyday life without dependence on laboratory settings for the purpose of healthy aging.

I. Introduction

With the advancements in technology, it is more likely that people interact with machines in assisting their everyday life activities and connecting with other people virtually specifically during the pandemic which could potentially cause more distress. To address mental wellbeing needs, development of age-friendly services and settings in interaction with machines are among the WHO recommended strategies. Mental wellbeing is important at people's time of life including the age of sixty years and over by considering the fact that over 20% of the population in the age group across the world suffer from a mental disorder. The proportion of this age group population will be increased from 12% to 22% between 2015 and 2050 based on World Health Organisation (WHO) report in 2017 [1]. It means that it is an expected increase from 900 million to 2 billion people over the age of 60. The most common mental disorders in this age group are dementia and depression affecting around 5% and 7% of the world's older population, while anxiety disorders affect 3.8% of the age group population. Mental wellbeing issues cost globally £22 trillion per year & to the UK economy £70–100 billion per year.

Mental wellbeing has an impact on physical health and vice versa. The over sixty years age group with physical health conditions such as heart disease have higher rates of depression than those who are healthy. Additionally, untreated depression in an older person with heart disease can negatively affect its outcome based on the WHO report [1]. Psychological stress has several effects on the body from muscular ache and tension to digestive track issues and over arousal which can lead to heart attacks, arrhythmias and possible sudden death. Headache, back pain,

heartburn stomach-ache, elevated pressure and rapid hearth beat as well as depression and anxiety disorder are included in the stress effects on body [1].

Mental wellbeing issues affect people in all age groups including age sixty years and over which could potentially influence the people who are living and interacting with the affected person such as family members and carers. In addition, the burden of the health-related issues would be on the health system and the people who are working there such as nurses, general practitioners and health professionals. Frequent contacts and visits to the health system that are not very urgent are among the burden on the health system due to the mental wellbeing issues. Effective strategies are required in understanding of the roles and responsibilities of public and the mentioned stakeholders for the purpose of improving mental wellbeing.

Life stressors are among the main contributors for mental wellbeing issues [1]. For adults aged over sixty years there could be loss in capacities and a decline in functional ability including reduced mobility, chronic pain, frailty or other health problems. There is more chance of experiencing events such as bereavement, or a drop in socioeconomic status with retirement. All of these stressors can result in isolation, loneliness and psychological distress in the group age requiring long-term care. In addition, with the advancements in technology it is more likely that elderly people interact with machines in assisting their everyday activities and connecting with other people virtually specifically during the pandemic which could potentially cause more distress.

To explore this problem a questionnaire was shared with the community of people who are age 60 and over whereas the number of participants was 130. When asked whether they use machines/technology (smart phones, computers, assistive robots, or etc) in their everyday life 93% responded “yes” and 75% of respondents mentioned that their use of machines/technology has increased during the pandemic while 92% of respondents mentioned that they experience frustration or distress while interacting with such machines/technology. It is also reflected in the international standard for governing Human Machine Interaction that for the first time in 2019 it is specified the requirement for wellbeing and the experience of users to be considered when designing systems.

Among the WHO recommended strategies to address mental wellbeing needs of people in the older population there is development of age-friendly services and settings [1]. Considering stress as the main contributor to mental wellbeing problems, the research question is whether development of systems and services for early detection and awareness of experienced stress and emotions (mood swings) therefore providing suitable actions could affect mental wellbeing in the population of age 60 years and over. To be able to detect and provide suitable actions in the event of stress and mood swings there is a need to know more about stress and emotions psychological background, and the impact on the human body’s physiology. Stress can be viewed from biological, behavioural and phenomenological perspectives. In addition, stress influencing mental illness is a condition that affects a person’s thinking and emotions; therefore, there is need to consider the user’s emotions and mood swings as well.

From a biological perspective, stress is the body response to stressful stimuli. Initially, stress was defined as a non-specific neuroendocrine response of the body to a demand placed on it. Hypothalamopituitary-adrenal (HPA) and the autonomic nervous system (ANS) that mediates the general adaptation syndrome will be activated in a stressful situation. After the stimulus, a neuroendocrine chain reaction starts in the brain. Epinephrine and cortisol will be released by Adrenal glands into the blood with an effect on cardiovascular, musculoskeletal, gastrointestinal, nervous and endocrine systems. The cortisol biomarker can be measured through salivary or blood sampling. It also has an effect on skin conductance or heart-rate variability (HRV) measures enabling measurement of stress through the above biomarkers.

From a behavioural perspective, stress has an impact on human behaviour both at individual and group levels as well. Behavioural measures of stress include engaging in displacement behaviours such as scratching, face touching and lip biting which is associated with emotional state as well. Behavioural characteristics do not infer internal subjective feelings but are used as external markers for behaviour adaptation. Therefore, behavioural signals can be used to assess when a person is exposed to a stressor.

From a phenomenological perspective, self-perception of stress is the key aspect in identifying experience of stress. Stress is considered as a two-way process including both the stressor and the individual assessment of resources to lessen, tolerate or eliminate the stressor and the stress it produces. Studies show that stress experience is moderated by the ability of a human subject to feel his body signals such as the heartbeat indicating the importance of biofeedback. Furthermore, individual's perception of stress can be measured using questionnaires, Likert and visual analogue scales.

In mental health literature, the existing solutions for early stress detection and mood swings are mainly relying on self-reports in response to a standardized list of questions which is very biased and subjective. It is important to be able to measure levels of stress and emotions, objectively. Studies show that stress levels are present in biomarkers and physical expressions. Traditional physiological measure of stress is quantified by levels of cortisol in various sources such as saliva, blood or urine. Such measurements require laboratory settings and could be invasive. Other modalities to recognise levels of experienced stress and emotion include facial expressions, eye movement, posture and gesture, as well as speech is used in the literature. However, capturing such modalities either require laboratory settings or are bulky to be carried in everyday life. The already developed digital wristbands are mainly for measuring stress rather than other features such as detection of emotions and mood swings, as well as biofeedback and etc.

In this paper after addressing the problem and the limitations of existing solutions in the introduction section, a non-invasive technique is explored in Section II, that can be used in everyday life and not being dependent on laboratory settings for the purpose of early detection and awareness of experienced stress, emotion, and mood swings therefore providing suitable actions. The paper will be concluded in section III.

II. Methodology

Development of assistive technologies to address mental wellbeing issues caused by stress and provide suitable actions for healthy aging is an innovative approach in this paper. It is proposed to recognise early stages of mental wellbeing issues by detection of experienced stress and emotions therefore mood swings through monitoring and processing of physiological and behavioural signals in everyday life. Based on the processed signals biofeedback will be provided to enable awareness of the potential mental wellbeing issues caused by stress to inform the user to adopt different style of coping and thinking as well as proper sign posting. Through proper logging of the information, clinicians would be able to monitor the individual's changes in mental wellbeing status for informed decision making. Furthermore, the processed information could be incorporated in the decision-making process of machines that the users are interacting with to assist them in everyday life and potentially could cause stress. Through such an approach both the user and machine will be aware of the user experienced stress during interaction; therefore, enabling them to adapt their functionality such as speed of operation in order to enhance the experience and therefore less stressful situation.

Experienced stress and emotion therefore mood swings could be detected in everyday life by monitoring and processing of physiological and behavioural signals associated with the

experienced stress and emotion; therefore, prediction of unhealthy situation. Computational algorithms such as signal processing and machine learning techniques are proposed to extract useful information from the sensors' signals [2]. In the literature, accelerometers are used to measure behavioural signals and bio- sensors measure bio-signals such as Galvanic Skin Response (GSR), Electromyogram (EMG), Heart Rate (HR), Heart Rate Variability (HRV), respiration rate, and skin temperature. Such signals have the potential to be collected by the sensors that are required to be wearable in everyday life and not being cumbersome with the potential to be embedded in a wearable device or the devices that are used commonly in interaction with machines [3].

Biofeedback could be provided to the user in order to bring awareness about unhealthy situations to adopt different styles of coping and thinking as well as proper sign posting. A review of the literature shows the importance of biofeedback for mental wellbeing that enables an individual to feel his body signals, interpret and respond to these signals. Effectiveness of biofeedback in terms of cost and health improvements in comparison to traditional mental healthcare is proved although the existing techniques requires laboratory settings. In addition, it is proposed to provide feedback for managing stress through calming breathing technique using visual feedback such as flashing light, haptic and auditory. In the state of distress people may not be able to think clearly about what to do and to whom to refer, such assistive technology could help through proper sign posting to seek professional support.

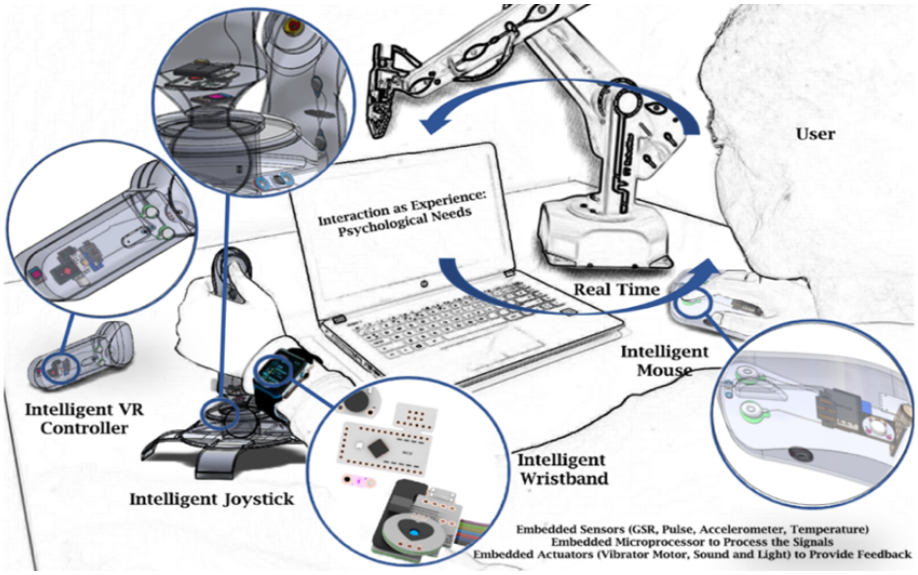

Figure 1, Incorporating electronic systems into devices to sense, process and provide feedback.

Logging stressful experiences and mood swings in daily life which could be used for informed decision making by clinicians is another proposed feature of the assistive technology. If the device would be able to log stressful experiences in the long term it will inform clinicians in informed decision making about mental wellbeing issues which could potentially complement the standard self-report questionnaires results which are subjective and commonly used for the purpose of mental health diagnosis.

Functionality adaptation of interacting machines in stressful situations is another proposed feature of the assistive technology. It is more likely that elderly people interact with machines in assisting their everyday activities potentially causing stress. Therefore, in this paper it is proposed to address and incorporate the user experience in Human Machine Interaction (HMI); therefore, both the user and machine will be aware of the user experience during interaction [4]. By incorporating user experience in the machine decision making process during

interaction and enabling them to adapt their functionality such as speed for the purpose of less stressful interaction; there would be the chance for better mental wellbeing [5]-[6].

For this purpose, it is proposed to incorporate embedded electronic systems into devices, which are easy to use, and not interfering with our everyday life for the purpose of mental wellbeing. The devices are the ones that are commonly used in everyday life such as a wristband or the ones that are used in the interaction with machines such as a joystick, or handheld controller. Through such embedded systems including biosensors, physiological signals (heart rate, skin conductance, temperature and body motion) will be collected, processed and mapped into the basis of the user psychological model using machine learning techniques. For the machines that elderly people are interacting with daily, there could be a cognitive layer to incorporate human factors such as stress level and emotion during interaction. It will enable the machine to alter the controlled instructions in order to provide adaptable behaviour such as change in speed [7]-[8]. The interaction can be enhanced if the user is aware of the state during the interaction achievable through the embedded actuators to provide haptic, visual or auditory feedback in real-time without the need for laboratory setting (see Figure 1).

There is high potentiality for usability, engagement, and adoption of this proposed approach by the stakeholders as an example in the mentioned survey 86% of respondents agree that it would be helpful if the technology or machines were able to recognise their frustration in using them and be able to support them with this regard. In addition, 95% of respondents confirmed that it would be helpful if the machines were able to adjust their functionality (such as speed or display etc) or provide support based on their experience. 87% of respondents think that such approach could lead to improved mental wellbeing while 91% confirmed that if such technology would be developed, they will use it.

The key challenges in wider adaptation of the methodology could be related to: ethical concerns related to collections of personal information and the bio-signals which could be addressed by careful data protection and addressing the relevant concerns to gain ethical approval; the complexity imposed as a result of development of such technologies to the user which could be addressed by proper user interface design to keep the system appearance simple and user friendly as possible; the cost imposed due to embedded electronics which could be kept as low as possible by considering the advancement in electronic technologies, sensors are now small, cheap, and sufficiently reliable to be deployed as wearables and embedded systems; therefore, it is now the right time to address the proposed idea [9]-[10]. As long-term vision, this work will positively impact on the mental wellbeing for the purpose of healthy aging and therefore quality of life of the people. It will bring awareness and reduce the potential stress in everyday life in addition to the potential stress during interaction with machines which can improve the users' mental wellbeing [11]-[12] whereas an example of it is shown in Figure 2. These outcomes would, in turn, alleviate the burden this condition produces on society and the NHS.

Figure 2, An example of sensing the user experience and psychological conditions in real-time to be able to act accordingly through providing feedback, log the data, and adjust the functionality.

III. Conclusion

In this paper, development of age-friendly services and settings in interaction with machines is addressed considering that over 20% of people in the age group of 60 years and above are affected by mental wellbeing issues worldwide as addressed in WHO report on mental health of older adults in 2017. Mental wellbeing problems have an impact on physical health and vice versa and could cause severe illness whereas life stressors are among the main contributors of the issues. With the advancements in technology, it is more likely that people in the age group interact with machines in assisting their daily activities potentially causing stress. Development of intelligent assistive technology studied which could be potentially wearable such as a wristband or embedded in the devices that are used in interaction with machines such as joystick, or handheld controllers. The technology will address early detection and awareness of experienced stress, emotion and mood swings; therefore, providing suitable actions in everyday life without dependency on laboratory settings with features that come in form of an device. Biofeedback would be provided to the user in order to bring awareness about unhealthy situations to adopt different styles of coping and thinking as well as proper sign posting. Stressful experiences and mood swings in daily life would be logged which would be used for informed decision making by clinicians. Functionality of interacting machines such as speed would be adapted in stressful situations; therefore, addressing the user experience for the purpose of mental wellbeing and healthy aging.

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