Objectively Monitoring Wellbeing through Pervasive Technology

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Abstract
Wellbeing is an underlying theme in many local and national policies and procedures outlined by governments and health care services. In recent years a person's wellbeing has been largely monitored through the use of subjective rating scales or other retrospective interview methods. This position paper considers how technology can help to monitor wellbeing more objectively and within the individual's naturalistic environment. For this purpose, we introduce and discuss the design of the Wearable Acoustic Monitor (WAM). The WAM provides support in monitoring aspects of social and emotional wellbeing through the provision of information about a person's level of social interaction and vocal features of emotionality. We further reflect on the ethical and privacy issues that are crucial for the design of digital devices capturing audio data to explore wellbeing.

Keywords
Social wellbeing, emotional wellbeing, acoustic features, interaction design, ethics, privacy

Introduction
Being socially engaged is human nature, whether it is with a singular important person in one's life or a large group of friends. It follows that the relationships we

form constitute a crucial factor in our state of wellbeing [6]. Thus, to be socially well, an individual must feel that they are integrated and accepted in society and that they provide a valuable contribution within their social roles [3]. A feeling of social connectedness and a person's ability to interact within both close personal relationships and the wider society can be greatly affected by their state of emotional wellbeing, and vice versa. Social engagements not only allow a sense of responsibility for one another, they also allow us to participate in each other's lives. Open, shared dialogues enable valuable social support at times of distress, but beyond this, they also facilitate sharing of the great joys and achievements that life brings.

At the core of the majority of social activity is conversation and social engagement. A reduction in these can therefore directly affect the social wellbeing of the individual. In addition, having decreased emotional wellbeing often leads to a reduction in the quantity and quality of social interactions that a person partakes in. A lower state of emotional wellbeing can cause multifaceted difficulties in the everyday life of an individual (e.g. maintaining relationships, self confidence, managing stress). Additionally, the lack of an appropriate social support network has been found to be a causal factor in the development of depressive symptoms [9].

The importance of monitoring wellbeing can be appreciated when we consider the instability of life. Humans change over time through the influence of life events and shifting priorities. With change comes natural alterations in the needs and desires necessary to make us feel 'well' in both the physical and psychological sense. Whilst change in physicality can often be seen and managed, the psychological state of wellbeing can be more difficult to measure.

Monitoring Wellbeing - Related Work

Current methods of measuring an individual's emotional wellbeing, and how it may change over time, commonly involve the use of subjective rating scales. Most scales impose a temporal restriction on the assessment period. The General Psychological Well-Being Index, for instance, asks the individual to reflect on their wellbeing in the past month [2]. While repeated assessments enable clinicians to measure changes in a person's responses, these are retrospective in nature and can be influenced by the individual's emotional state at the time of presentation. Such scales only capture an aggregation of a person's overall wellbeing during a specified time period and they can be insensitive to small changes which occur in the process of altering wellbeing. Employing a methodology for measuring wellbeing, that could monitor the emotional changeability of an individual within certain naturalistic contexts, could prove a valuable tool in the exploration of the emotions experienced within certain social communication dynamics. This could provide opportunity for the individual to reflect on the types of situations or social interactions which might impact their wellbeing, either for the better or worse, and would give them the opportunity to alter their behaviors.

Recently, there has been increasing interest in HCI research pertaining to methods of measuring human interactions using technology. Choudhury and Pentland [1] developed a wearable sensor package to explore the structure and dynamics of human communication networks in the workplace. Rabbi et al. [5] employed

sensors in an assisted living facility to explore the physical and mental wellbeing of older adults. They used involvement in conversation as a measure of social engagement. In these research projects, the technology was employed in controlled environments only (i.e. specified workplace or home environment), where the researchers could place multiple sensors, not only on the individual, but on all potential interaction partners throughout a given time period. While this facilitates the identification of the speaker and those he or she interacts with, it does not account for the wearer engaging with people outside of these settings.

Figure 1: example design of a WAM

Design of a Wearable Acoustic Monitor

The Wearable Acoustic Monitor (WAM) is a stand-alone device which aims to monitor levels of socialization and social engagement. The device is designed to provide information about the wearer's social and emotional wellbeing in a truly naturalistic environment, without the need to control factors such their conversation partners or where they are having social interactions. The device is envisioned to be wrist worn in order to combat difficulties around non-compliance and social acceptability (see Figure 1 for an example of a potential WAM device design).

The WAM device records audio data containing the social interactions that the wearer engages in. A compact representation of the audio data, collected during a day, is subject to analysis using pattern recognition algorithms. To protect the privacy of individuals, the representation is carefully tuned to prevent reconstruction of the recorded speech while still allowing discriminative analysis [4]. The device aims to provide information on the amount of interactions the wearer has during a day, as well as their level of engagement within these interactions (i.e. turns taken, length of turns). Furthermore, voice acoustics can be monitored and measured through the identification of specific vocal features such as amplitude, pitch, rate of speech and pause length to give insight into the emotionality of the wearer at a given time [7]. This feature can allow for individual reflection on the contexts or situations which prove particularly stressful or pleasurable, and may inform future behaviours.

Collected data provides information on the quantity of social interaction that the wearer is taking part in. However, this still leaves challenges as to how the data should be interpreted and by whom. If the data is envisioned to inform users' behavior, how should an interface be designed to allow for reflection on their social interactions? How could sense-making processes best be facilitated through annotation functions or different forms of data visualization? One suggestion would be having a method of allowing the wearer to provide comments or reflections immediately following a particularly meaningful or negative interaction, say via a mobile phone interface or an event button. This could make the handling of large amounts of data much more manageable during analysis. Moreover, findings have shown the use of electronic diary resources to greatly increase compliance levels when compared to paper based resources [8], meaning that subjective reports provided by the user via mobile technology could prove beneficial in a clinical context.

Ethical and Privacy Considerations

There is a major ethical issue which must be addressed, i.e. that potentially sensitive information is being collected. Careful concern must also be given to

ensure that the ethical rights of conversational partners are addressed. In order to combat these issues the device does not store raw audio data. Instead, automatic algorithms provide data on only the specified aspects of socialisation. Another design option, to facilitate a feeling of control in the device users, is that wearers will be able to switch the device off at any time. Although the content of what is said and the person who has said it will not be available to anyone who is analysing the data, this feature should help to empower the wearer to feel that they would not have to discuss or reflect on something that might make them feel uncomfortable. This raises questions on the how the data which is eventually collected should be managed. Should it be possible for the individual to share their social interaction data with their therapist? What would be the privacy implications in this regard?

Conclusions

Overall, research attempting to measure social interactions through technology shows promising results. Teamed with what we know about the specific vocal features of speakers, we can realistically develop a device that not only provides objective measures of social interaction and facilitates reflections on the quality of these interactions, but could also serve as a tool for monitoring the emotional state of an individual across various naturalistic contexts. A device such as this could have extensive clinical implications. There are benefits towards objectively measuring acoustic voice features of depressed speakers, in terms of monitoring the temporal improvement of patients receiving treatment, as well as adding weight to diagnostic rating scales. Having the ability to objectively monitor a patient's emotional state within different situations in their everyday lives, would allow for a clinician to gain a better understanding of how a patient experiences certain events and would enable more tailored and appropriate treatment approaches.

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