Internet Interventions 2 (2015) 330–339

Contents lists available at ScienceDirect

Internet Interventions

journal homepage: www.invent-journal.com/

Can the effectiveness of an online stress management program be augmented by wearable sensor technology?

Abigail Millings [a,*], Joanna Morris [b], Angela Rowe [b], Sally Easton [b], John K. Martin [c], Dennis Majoe [d,e], Christine Mohr [f]

[a] University of Sheffield, Western Bank, Sheffield, UK
[b] University of Bristol, 12a Priory Road, Bristol, UK
[c] Ultrasis UK Ltd, 23 York Road, London, UK
[d] ETH Zurich, Rämistrasse 101, 8092, Zurich, Switzerland
[e] MA Systems, 89 High Street, West End, Southampton
[f] Université de Lausanne, Bâtiment Geopolis, Quartier Mouline, Bureau Geo - 4117, CH-1015, Lausanne

ARTICLE INFO

Article history:
Received 28 November 2014
Received in revised form 27 April 2015
Accepted 27 April 2015
Available online 8 May 2015

Keywords:
Biofeedback
Stress management
Psychoeducation
CCBT
Quantified self

ABSTRACT

Background: Internet interventions for mental health concerns are known to be effective, but how can developing technology be utilised to improve engagement and augment the effectiveness of these programs? One option might be to incorporate feedback about the user's physiological state into the program, via wearable sensors.
Objectives: This mixed-methods pilot study sought to examine whether the effectiveness of an online intervention for stress in students could be augmented by the use of prototype wearable sensors.
Methods: Students who were stressed, but not depressed, were allocated to a stress management program alone ($n = 34$), with sensors ($n = 29$), or to no intervention ($n = 35$). Interventions lasted 4 weeks. Outcome measures included measures of stress, anxious, and depressive symptoms, and were measured immediately after the interventions and 4 weeks later. Participants in the two program groups were interviewed to gain feedback about the program and the sensors.
Results: Significant pre-post reductions in stress ($p = .019$) were observed for those in the program alone group. Significant reductions in depressive symptoms were observed among postgraduates ($p = .006$), but not undergraduates, in the program only group. The program plus sensors group had a broadly similar, but weaker set of results, indicating that the sensors impeded, rather than augmented, the effectiveness of the program. Qualitative data explicate this finding, highlighting participation burden as a key issue. Participants provided detailed feedback about the program, the sensors, and biofeedback exercises, which are summarised and discussed with reference to the quantitative findings.
Conclusions: The newly developed stress management program could be an effective way to improve student mental health. Wearable sensor technology, particularly biofeedback exercises, may be a useful contribution for the next generation of e-therapies, but further development of the prototypes is needed and their reliability and usability will likely affect user responses to them.

1. Introduction

The use of technology for the promotion of self-driven psychological wellbeing has grown exponentially in recent years, and the Internet can be used for the delivery of psycho-education and therapies such as cognitive behaviour therapy (CBT) to promote mental health and wellbeing (Andersson, 2009). It has been established that so-called 'e-therapies' can be effective and acceptable (Andrews et al., 2010; Barak et al., 2008) and cost effective (McCrone, 2004) in the treatment of a wide variety of psychological problems, including stress, among otherwise healthy individuals (Rose et al., 2013; Zetterqvist et al., 2003). Attention is turning to the future research agenda in e-mental health (Andrews and Williams, 2014; Barak and Grohol, 2011), where issues such as how to personalise and promote engagement with e-therapy programs have been highlighted as requiring attention (Cavanagh and Millings, 2013a). Some suggestions include enhancing therapeutic relationship factors (Cavanagh and Millings, 2013b), others include widening the pool of techniques utilised in e-therapies to include cognitive bias

* Corresponding author.
E-mail address: a.millings@sheffield.ac.uk (A. Millings), joanna.morris@bristol.ac.uk (J. Morris), a.c.rowe@bristol.ac.uk (A. Rowe), sally.easton@bristol.ac.uk (S. Easton), john.kmartin@btinternet.com (J.K. Martin), dennis.majoe@inf.ethz.ch (D. Majoe), christine.mohr@unil.ch (C. Mohr).

http://dx.doi.org/10.1016/j.invent.2015.04.005
2214-7829/

modification (Andrews and Williams, 2014), and yet others are turning to ambient intelligence (Alcañiz et al., 2009). A further direction is the inclusion of sensor technologies.

Recently, sensor technology for the detection and measurement of biological signals, such as in biofeedback, has been developing apace. The potential capacity of sensor technologies to augment the e-therapy experience, through objective, automatic monitoring and feedback, has attracted some interest (Alcañiz et al., 2009). Recent interdisciplinary funding strategies such as EC Seventh Framework Programme schemes like ITC Personal Health Systems have enabled a new synergy between e-therapies and sensor technologies. By way of context, several projects funded by such strategies involve a combination of sensors and Internet-delivered CBT treatment, with a goal of making e-therapies for depression and other mental health problems more personalised, and capitalising on the abilities of intelligent technologies to use and interpret physiological data in the delivery of e-therapy content. Two such projects were ICT4DEPRESSION (http://cordis.europa.eu/project/rcn/93794_en.html), which offered a mobile CBT treatment with wearable biosensors, and Help4Mood (http://cordis.europa.eu/project/rcn/97478_en.html), which brought together a 3D expressive virtual agent and activity monitoring for recovery from depression. In the present paper, we present an exploratory, mixed methods pilot study, from a project in the same funding round as those mentioned, investigating the feasibility of using prototype wearable sensors for periodic monitoring and biofeedback alongside an e-therapy program for stress.

1.1. Biosensors for monitoring and feedback

Self-tracking is the practice of recording and monitoring aspects of oneself (e.g. sleep quality, management of a chronic condition, mood states, etc.), for the purposes of learning, noticing patterns, and effecting change (Swan, 2012). The appeal of 'self-tracking' or the 'quantified self' movement has grown rapidly since the inception of smartphones, which makes data capture and representation available to the masses. The inherent curiosity humans have about themselves makes self-tracking an engaging activity with a potential for clinical benefit.

Biofeedback can be considered a real-time relative of self-tracking, involving the feeding back of a biological signal, in a perceivable and comprehensible form, to the individual from whom it originates. The individual can then attempt to exert control over the signal, and produce a change in it. The continuous feeding back of the signal in real time provides reinforcement for behaviours that are having the desired effect on the signal (Zaichkowsky and Fuchs, 1988). For example, an individual might view a light flashing to indicate each beat of their heart, and attempt to slow the rate.

Offering individuals the technology with which to monitor certain biological signals, known to be associated with stress, both over time, and in real-time biofeedback, might serve to promote engagement with an e-therapy program for stress management. Two such biological signals were identified for monitoring and biofeedback purposes in the current study: heart rate variability (HRV) and alpha power.

1.2. Heart rate variability (HRV)

Heart rate oscillations occur normally. Low HRV has been associated with anxiety disorders and stress (Friedman and Thayler, 1998), whereas high HRV is thought to indicate good emotion regulation abilities (Appelhans and Luecken, 2006). HRV is also commonly used in biofeedback (Lehrer, 2013). The goal of HRV biofeedback training is to produce increases in heart rate during inhalation and decreases in heart rate during exhalation, thus maximising overall heart rate variability (Lehrer et al., 2000).Training typically involves providing a visual signal of heart rate activity to the trainee, with the goal of trainees increasing their HRV (if low), often through modulating their breathing instruction. Because of the known relationship between HRV and stress (Vrijkotte et al., 2000), HRV was identified as an appropriate biosignal to allow participants to measure for themselves, periodically during the stress management program, and also to use in a realtime biofeedback exercise.

1.3. Alpha power

Alpha asymmetry is defined as unequal alpha power generation coming from the two hemispheres of the brain, and has been found to be associated with mental ill-health. Bruder et al. (1997) found that patients with depression, both with and without co-morbid anxiety, had significantly higher alpha asymmetry than healthy controls, and a meta-analysis found that despite many inconsistencies across studies, broadly, data support the notion of a link between frontal alpha asymmetry and depression and anxiety (Thibodeau et al., 2006).

When biofeedback involves feeding back of signals originating in the brain, it is termed neurofeedback. Neurofeedback has been used to reduce physiological symptoms such as migraine incidence (Stokes and Lappin, 2010), and to improve cognitive performance (Zoefel et al., 2011). Increases in alpha have been linked with meditative states (Cahn and Polich, 2006). Alpha neurofeedback training has been found to increase cognitive performance (Hanslmayr et al., 2005) short term memory (Nan et al., 2012), and may have benefits for anxiety and depression (Hammond, 2005). In our study, we therefore enabled participants to measure their own alpha asymmetry, periodically, during the stress management program, and also to practice a form of alpha neurofeedback training.

1.4. The current study

In the current study, we examine the feasibility of using prototype wearable sensors for periodic monitoring of biological variables as well as biofeedback and neurofeedback, to augment the effectiveness of a stress management program. We conducted an exploratory study comparing the effects of i) an online stress management program on its own; ii) the same program in conjunction with bio- and neurofeedback sensors; and iii) a no intervention control group; on psychological distress (stress, depression, and anxiety) during a stressful time period. Although the biosignals described above were measured in a self-tracking manner, they are not treated as outcomes here, due to a) their use only occurring in the sensors group, and b) the vast variation in use by participants in that group. We did not conduct a power calculation due to the novelty of the program plus sensors system (there was no prior art on which to base a power calculation), and because our goal was to examine the feasibility of using the prototype sensors, rather than to conduct a properly powered trial. Due to the novelty of the interventions, we employed a mixed methods design. Qualitative interviews were used to gain insight into the experience of the participants in both active intervention groups (stress management program alone, and stress management program with sensors).

2. Method

2.1. Participants

Participants were recruited via poster and email advertisements across a UK university campus. Advertisements offered the opportunity for learning stress management techniques and monetary compensation for time. Compensation was awarded at an hourly rate, which resulted in different payments across groups. Those in the control group earned £23, those in the stress management program group earned £51, and those in the stress management program plus sensors group earned £122. Participants had to complete the majority of the research tasks requested in order to receive payment. Inclusion criteria were