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EMOTIONALLY RESPONSIVE WEARABLE TECHNOLOGY AND STRESS DETECTION FOR AFFECTIVE DISORDERS

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SUMMARY

As humans, we are born with no knowledge of odour. Our sense of smell is linked directly to the limbic system, the emotional part of our brain responsible for memory and behaviour, and therefore, our individual sense of smell is based purely on life's deep experiences and impressions. The roots of "Aromatherapy" can be traced back more than 3,500 years, to a time when essential oils were first recorded in human history for their therapeutic and medicinal properties. However, in the 21st century, it remains one of the most controversial complementary therapies applied in medicine because of its pseudoscience connotations and limited available data on health benefits, despite the importance of smell on human health.

Here I introduce the concept of "eScent", an emotionally responsive wearable technology that picks up on your emotions and vital signs and sends a personalisable 'scent bubble' to your nose. It combines sensing and dispensing aromatics for immersive experiences and multiple health benefits. It presents an empowering, sensory intervention and resilience builder that emits mood-enhancing aromas in a controllable way, depending on biofeedback. The advantage of essential oils merged with biometric sensors and intelligent tracking devices (e.g. an Apple Watch), could lead to a new palette of scents that are bio-synchronized to an individual's emotional, mental, and/or physical state and in a real-time manner alleviate high levels of stress, thus preventing the risk of a serious mental ill health relapse.

Closure of the loop with wearable scent delivery systems requires an innovative, creative and collaborative approach, crossing many disciplines in psychological related sciences, biotechnology and industrial design. Testing such hypotheses in translational human studies is a matter of future research which could not only lead to valuable "prodromal" interventions for psychiatry, but new stress management tools for people suffering from affective disorders.

Key words: *wellbeing – aroma - mood-enhancement - affective disorders - prodromal intervention*

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INTRODUCTION

This mini-review introduces a transdisciplinary research project called eScent that is informed by “lived experiences” and managing affective disorders. Founded on published research on therapeutic essential oils research, the research uses olfactory stimulation as a preventative health measure rather that treating serious psychiatric conditions. The goal is to develop “emotional” wearable technology tools that can be used to enhance an overall sense of wellbeing, alleviate anxiety and reduce the risk of an acute bipolar disorder episode through the power of aromatics. It crosses neuroscience, biotechnology, complementary therapies, fragrance, design, philosophy and machine learning, and combines wearable technology with a new generation of nano-particle sensing elements.

The objective is to bring a range of disciplines together from the social sciences (positive psychology, aromachology), humanities (fashion; apparel, jewellery), biotechnology, computer sciences and chemo-sensory research, and builds on two earlier projects; a controlled-release fragrance dispense device from MEMS components (Jenkins et al, 2006) and a Winston Churchill Fellowship on ‘*Sensory Fashion’,* that explored the early detection and management of Affective Disorders (Tillotson 2014).

Treating serious mental health with aromatics is an improbable choice for mainstream healthcare, although in the 18th century, camphor was readily given to patients to treat mania (Pearce JMS, 2008). This research describes a platform technology that complements orthodox treatments with micro-doses of mood-enhancing aromas that are emitted under software control at the right time, in the right place, depending on context. The purpose is to create a mobile sensory space around the user that enhances mood throughout the day and night, and is protected by a portfolio of wearable technology and intelligent textile patents (Jenkins & Tillotson 2006, 2011, 2017).

eScent dispenses *“context-dependent”* fragrances (i.e. lavender to relax, citrus to reduce anxiety, peppermint to stimulate, etc.,) from a wearable device with connected sensors that mitigates and relieves in response to detected conditions, such as insomnia, stress or anxiety disorders. It is an example of the emerging “*Internet of Me*” for its ability to detect and analyse conditions that our five senses cannot and in turn deliver lifestyle and wellness enhancing results to us.

METHODS

Essentials oils utilised for clinical aromatherapy, coupled with connected sensors and machine learning have the potential to create data-driven solutions for wellbeing and preventative healthcare*,* informed by chemo-sensory, psychology and neurology studies that show the benefits of essential oils and the influence of certain fragrances on affective as well as cognitive states in humans (Weber & Heuberger 2008).

Using reasonably good methods to test the impact of aroma on mood, a study on both men and women undergoing a stressful procedure, experienced a decreased state of anxiety and a more positive mood when exposed to orange oil (Lehrner et al. 2005). Further studies have shown lavender to include sedative properties with the potential to reduce stress, improve a sense of well-being in every-day living and help in relaxation (Fismer & Pilkington 2012), whilst other studies have found lavender beneficial in fighting insomnia (Hwang & Shin 2015) and provide stress alleviating and sleep enhancing scents to improve sleep quality (Sarris & Byrne 2011). Certain aromas have also been used to reduce behavioural and psychological symptoms of dementia in the elderly population (Fung et al. 2012).

Commercially available scent products using essentials oils have been proven to positively affect mood, memory, cognitive facilitation, self-perception and confidence as well as having anxiolytic effects (Johnson 2011), whilst pleasurable ambient scents can enhance productivity and promote positive social behaviour (Hertz 2009). Peppermint and cinnamon oil have also been shown to increase alertness and decrease frustration, anxiety and fatigue while driving a car (Raudenbush et al. 2009).

RESULTS

A User Experience case study utilising mobile scent devices attached to an iPhone, found that dispensing lavender as a personalised and localised 'scent bubble' around the facial area as and when required, changed the mood of the user from anxious anticipation to a sense of calm (Barth & Bruaer 2014). The results of the Churchill Fellowship in 2014 found that by using aroma-based stress management strategies, anxiety and stress levels could potentially be reduced through the controlled-release of bio-synchronised fragrances. Feedback from psychiatrists and psychologists interviewed at a selection of USA medical institutes (including University of California San Diego and University of California San Francisco) indicated that eScent could also be used as a *'prodromal scent intervention'* to help individuals manage triggers by recognising, learning, avoiding and therefore preventing the risk of an acute bipolar disorder episode.

In response to a real-time dynamic change in mood, behaviour, voice analysis, sleep patterns, and biology (via heart rate variability, sweat, pulse, stress-related body odour and conductive skin response), vital signs can be sensed, analysed and filtered using Artificial Intelligence and machine learning, so that a combination of *mood-enhancing* fragrances respond to emotional and sensory cues (Figure 1). Through experimentation with essential oils and working out which are the most effective aromas for the user, counteractive wellbeing scents (e.g. lavender, neroli, bergamot, peppermint, rosemary, orange oil, etc.,) are dispensed as a localised *'scent bubble'* around the face, allowing an area of constant, detectable scent, when a pre-set stress threshold is exceeded, or calming scents when a change in sleep is detected. The user sets the threshold according to their own stress and sensitivities and personal trigger warnings.

The biofeedback loop diagram illustrates counteractive wellbeing scents responding to emotional and sensory cues using a selection of biometric sensors and monitoring devices (voice recognition detection, personal body odour analysis, vital signs, etc.,), and Artificial Intelligence. This method creates a personalized 'scent profile' that is pertinent to the user alone and will rely on experimentation to find the most appropriate beneficial aromas.

In recent years, there has been a move towards scent-infused products that appeal to consumer needs by engaging with the senses to affect perception, judgment and behavior and to improve their standard of living (Krishna 2012). The results of the Churchill Fellowship found that eScent could also attract high levels of acceptability with the public (and particularly millennials), and as a 'de-stigmatising' mental health recovery tool, it would be easy to integrate into everyday scent-infused wearable items.

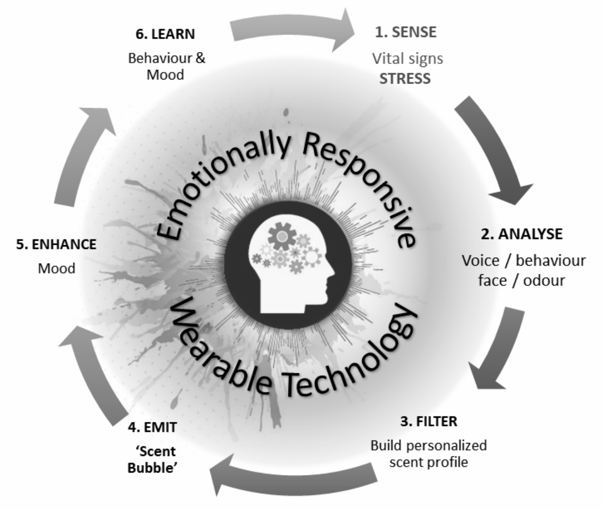

Figure 1. Emotional and sensory cues

CONCLUSIONS

Given the increasing numbers of people affected by poor mental health and the reported lack of willingness to seek support, this research in emotionally responsive wearable technology could lead to valuable strategies for enhancing wellbeing and assisting with the day-to-day management of affective disorders. Through an appealing intervention for personalised management of mental health care, the work is the convergence of the digital healthcare and scent revolutions and leverages disparate biological data sources to discover more accurate health-related correlations linked to the olfactory sense. The results are expected to provide insights into wearable sensory data collections related to digital aroma-based technologies, introducing new sensory solutions to prevent the escalation of chronic mental health.

Now in the early development stage and exploring different strategies for stress sensors in the Department of Chemical Engineering and Biotechnology at the University of Cambridge, this work also demonstrates that nano-particle based sensing elements can be incorporated within biocompatible hydrogels using stable covalent linkage (García-Astrain et al. 2015), indicating huge potential of such hybrid systems to be used in emotionally responsive wearable technology design.

Further work is also underway to develop emotionally responsive fragrance emitters which can be discreetly woven into intelligent textiles, clothing elements (a button, lapel or collar), or embedded into jewellery as an effective wellbeing intervention for people with affective disorders. By interfacing the fragrance emitter with tracking devices, aromatherapy 'health' claims can be tested in real-time. Fragrances that are dispensed in short bursts and relevant to the situation, health condition or context of location, will augment how we as humans interact with the physical world around us.

With multiple other wellbeing applications in the pipeline, controlled scent-release can also be used to treat children with Autism, encourage appetite and recall autobiographical memories in individuals with dementia. The work of eScent could lead to new immersive scent applications and sensory exercises to enhance current research on Virtual Reality for Cognitive Behaviour Therapy, especially for public speaking anxiety (Safir et al. 2011). Alternatively, it could help change human behaviour and support Habit Reversal Therapy by interfacing with monitoring devices for trichotillomania (Himle et al. 2008).

The overlooked and underappreciated sense of smell - or problems with it - can also use computer-controlled scent-release in positive ways to enable diagnostics. For example, if pulsed intermittently, a further application of eScent might pinpoint odour-identification issues to test smelling capabilities and help diagnose the early stages of Huntington's, Parkinson's or Alzheimer's disease. It has long been known that impaired smell or olfactory dysfunction is an early preclinical feature to predict the onset of such Neurodegenerative diseases (Hawkes & Doty 2009).

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