Using Frontal Brain Asymmetry to Control Sensory Treatment of Anxiety and Depression

Tim J. C. Jacob[1], Jeremy Warden-Smith[1], Neil Kernot[2] and Malyka Galay Burgos[1]
[1]*School of Biosciences, Cardiff University, Museum Avenue, Cardiff, U.K.*
[2]*Chelker Technology, 16 Swadford Street, Skipton, North Yorkshire, U.K.*

Keywords: Depression, Anxiety, EEG, Alphawaves, Frontal Asymmetry, Bright Light Therapy, Smell Stimulation.

Abstract: Anxiety and depression are increasingly common disorders. Globally, more than 350 million people of all ages suffer from these illnesses. Depression and anxiety are treated with medication, psychotherapy, or electroconvulsive therapy (ECT), either individually or in combination. Drugs and ECT are not cures and often involve unpalatable adverse side-effects necessitating safer more sustainable alternatives. The antidepressant properties of bright light are well established and aroma stimulation has been shown to improve mood and reduce markers for anxiety and depression. A combinatory therapy of light and smell stimulation has been shown to have a positive impact on mood, physiological markers for stress, anxiety and depression. In particular, negative alphawave brain asymmetry, an objective marker for depression, is reduced by a 15min stimulus treatment. The proposal outlined in this paper is that real-time frontal alpha asymmetry, recorded by EEG, be used to control the frequency, duration and amplitude of the light and aroma signals to optimise the effectiveness of the treatment. The object of this treatment is to rebalance the frontal asymmetry restoring a frontal activity representative of a non-depressed, non-anxious state.

1 INTRODUCTION

It has been estimated that Common Mental Disorders affect 1 in 6 British adults every week with over half of these having a mixed anxiety and depressive disorder (Deverill and King, 2009). In the USA, in any given one-year period, 13 million to 14 million people (which equates to approximately 6.6% if the US population) experience depression (Kessler et al, 2003); globally, more than 350 million people of all ages suffer from the illness (WHO, 2012) and the annual incidence in UK is 36 per 1000 (NICE, 2004). Depression has a heavy human cost including feelings of sadness, worthlessness, isolation and an inability to enjoy life. Depressed people are more likely to take drugs, be off work or unemployed and kill themselves. Depression damages individuals, relationships and families. And it is on the rise globally.

Electroconvulsive Therapy (ECT) is thought by some to be one of the fastest ways to relieve the symptoms of depression and the use of ECT is on the rise in the UK (Guardian, 2017). It is generally given when other treatments, e.g. drug therapy, have failed. Neither ECT nor drug therapy are cures for depression and both can have significant adverse side-effects. In view of this it is important that new safer ways are developed to combat this growing problem.

Light and smell stimuli have both been used independently in human studies to achieve positive psychophysiological benefit. For example, light and smell have been demonstrated to affect mood and alleviate depression (for reviews see Oldham and Ciraulo, 2014; Herz, 2009). Bright Light Therapy (BLT) is an established treatment for seasonal affective disorder (SAD) and other mood disorders (Golden et al, 2005; Pail et al, 2011), having been successfully used for over 20 years. It has also been shown to be effective in other kinds of non-seasonal depression (Naus et al., 2013; Niederhofer and von Klitzing, 2012) and, in Major Depressive Disorder (MDD) a randomised, placebo controlled trial demonstrated that BLT was comparable to antidepressant medication in effectiveness (Lieverse et al, 2011). Smell has also been shown to have effects on mood, stress, anxiety and depression (Johnson, 2011; Herz, 2009; Ehrlichman & Bastone, 1992; Vernet-Maury et al, 1999; Alaoui-Ishmaili et al, 1997).

Jacob, T., Warden-Smith, J., Kernot, N. and Burgos, M.
Using Frontal Brain Asymmetry to Control Sensory Treatment of Anxiety and Depression.
DOI: 10.5220/0006471000840088
In *Proceedings of the 4th International Conference on Physiological Computing Systems (PhyCS 2017)*, pages 84-88
ISBN: 978-989-758-268-4

2 BACKGROUND

The concept for this Position paper originates from two recent papers in which further details about the subjects, methods and protocols can be found; Dong and Jacob (2016), Warden-Smith et al. (2017).

2.1 Light and Smell Stimulation

We have designed devices (Figures 1 and 2) to deliver an integrated stimulation protocol of fluctuating light and smell with a 60s cycle (Figure 3). A 15min stimulus session using lemon essential oil and fluctuating light (0-2500 lux) has positive effects on mood, lowers blood pressure and heart rate, increases galvanic skin resistance and rebalances frontal brainwave asymmetry and we have demonstrated that this treatment is both anxiolytic and anti-depressive. The results are presented in detail in Dong and Jacob (2016) and Warden-Smith et al. (2017). For the purposes of this present paper it is the possibility of recording the EEG signal during the light and smell stimulus protocol that is the prime consideration.

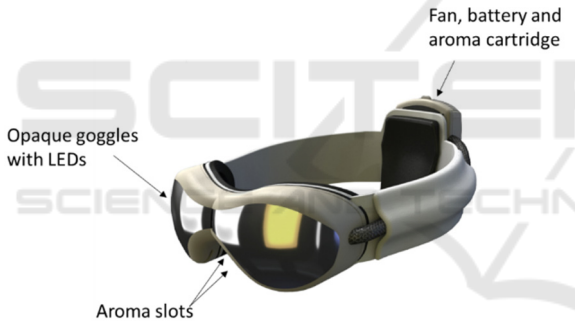

Figure 1: The light and smell stimulus delivery goggles.

The light source in the eyepieces of the goggles is UV-free light stimulus emitting up to 2500 lux when in close proximity (2-4 cm) to the eyes. Aroma vapour of essential oil (lemon) evaporating from a circular (5mm radius) absorbent cotton pad in a cartridge in the rear fan pack is delivered to the nostrils by air blown over the pad driven by an axial fan (5v,100mA, 0.7 cu.ft/min (0.33l/s), Farnell, Leeds, UK). Further details in Dong and Jacob (2016).

Figure 2: Light and smell delivery device.

A free-standing device delivering the same light and aroma stimuli as described in (a). The subject sits or lies and the visor is moved to within 5cm of the face. Odorised air is delivered from a control box containing fans and an aroma cartridge via a tube to exit at the base of the visor.

2.2 Frontal Alphawave Asymmetry

EEG alphawave power in the brain has been used as an index of brain activity. Alphawaves have been shown to be inversely correlated with brain activity (Jones, 2007). The brain in its resting state tends to produce alphawaves. Many studies have demonstrated that a decrease in alphawave activity in the left frontal hemisphere is associated with an appetitive response, approach behaviour and positive experience. Low right frontal alphawave activity is associated with negative mood and withdrawl behaviour. In normal subjects, the balance between right and left frontal alphawave activity (right-left) is positive. In depression and anxiety the frontal alphawave asymmetry (FA) becomes reversed (negative) and has been used as an objective measure of these disorders (Henriques and Davidson, 1991; Heller et al, 1997; Davidson, 1998a and 1998b; Thibodeau et al, 2006; reviewed in Harmon-Jones et al, 2010). FA can predict future development of anxiety and depression (Blackhart, Minnix and Kline, 2006) and this asymmetry has been shown to be a moderately stable individual difference in adults, irrespective of sex and history of depression (Allen et al., 2004; Vuga et al., 2005).

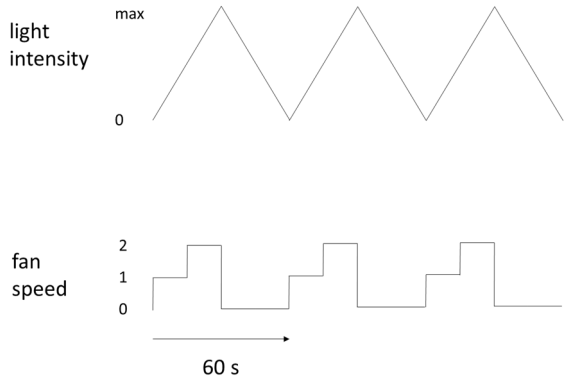

Figure 3: The light and smell stimulus protocol.

The light and smell stimulus protocol. Diffuse full-spectrum white light (maximum 2500 lux) is presented as a triangular wave starting from zero light, rising to a maximum (2500 lux) linearly over 30s and then declining linearly to zero over 30s. Simultaneously an airstream containing essential oil vapour is delivered to the nostrils at two flow rates (0.17 and 0.33 l/s) to coincide with the up ramp of the light stimulus. Three cycles are illustrated. The reason for delivering the stimuli in this manner is to overcome olfactory adaptation/habituation.

We have demonstrated that 15min stimulation with fluctuating light and smell stimuli (Fig.3) can reduce negative FA in those subjects who experience this asymmetry (see Fig.4; taken from Warden-Smith et al., 2017). The blue bars in figure 4 indicate the negative FA experienced by half (32 out of 64) of our experimental population. During the light and smell stimulation the negativity of the FA was reduced and this was maintained after the 15min stimulus period (at least for 5 mins).

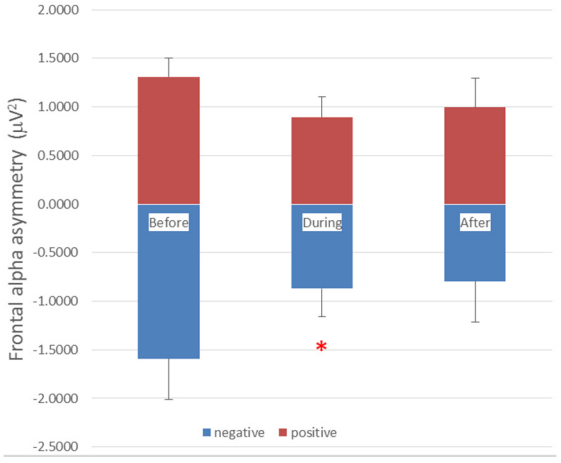

Figure 4: EEG alphawave frontal asymmetry (FA).

The effect of 15min exposure to light and lemon odour on alpha wave asymmetry. The subjects were divided into positive (red bars, n=32) and negative FA (blue bars, n=32) on the basis of their alpha wave asymmetry (F8-F7). Alpha wave power is expressed as the average ± standard error (bars) per 10s époque for 2min before, during and 5min after stimulation. *p<0.05. Taken from Warden-Smith et al. (2017).

2.3 Real Time Frontal Asymmetry (FA)

Frontal alphawaves can be measured in the brain using EEG electrodes and the FA can be determined in real-time with software (e.g. SPIKE2, Cambridge Electronic Design, UK) that, by power spectrum analysis, calculates the power in the alpha frequency band (8-12Hz) for left and right hemispheres (Fig.5). These two signal outputs can then be subtracted to give the FA (green line, Fig.5) which represents the real-time frontal brain activity with a 5s delay for the integration period.

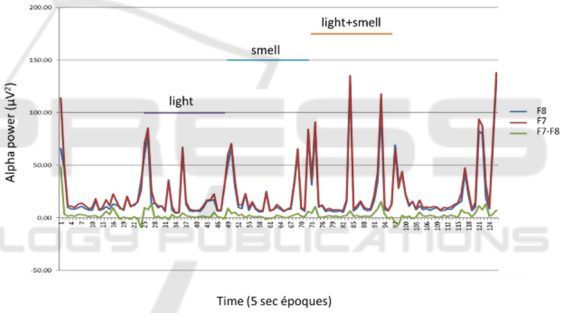

Figure 5: Alphawave power in real time.

EEG recording of alphawaves (8-12Hz) from F7 (left frontal; red) and F8 (right frontal; blue) electrode positions and the subtraction of the two (green). The alpha power was determined by spectrum analysis (SPIKE2 software, CED, Cambridge, UK) per 5s époque. The y-axis is the alpha power (μV^2 per epoque) and the x-axis represents time in 5s époques. Light (2500 lux), smell (vanillin) and light+smell were applied for 3min.

In figure 5 the difference signal between the alpha activity in the two frontal hemispheres (FA) is given by the green line. The FA varies with time and in normal, healthy subjects is positive on balance although it can include some negative episodes. The reverse is true for subjects prone to anxiety and depression, the balance is negative. How often this FA signal shifts from positive to negative and vice versa and what causes it to do so are unknown.

3 PROPOSITION

The frontal asymmetry (FA) signal reflects brain activity in the frontal lobes and is believed to convey information about psychological state. FA can be displayed in real-time and could itself be converted into a feedback signal by transducing it into a tone or colour thereby relaying the information about the sign and magnitude of the FA directly back to the subject. Positive FA is the normal, healthy state and the desired goal of the light and smell stimulus is to shift a negative FA pattern back to a positive pattern. We have demonstrated that a negative FA can be reduced by 15min light and smell treatment (Fig.4). What might be achieved by providing a direct and immediate feedback of the effectiveness of the stimulation by using the FA signal to control the stimulus protocol? This might be implemented using a negative FA reading to increasing the intensity or the frequency of the stimuli, for example by delivering a pulse of bright light accompanied by a pulse of odour when a negative FA period is detected.

3.1 Challenges

1. What are the short-term effects of different stimulus protocols on the FA sign?
2. Do longer term effects result from short term changes?
3. How can FA signal be used to control stimulus protocol to optimise the outcome?

4 CONCLUSIONS

A fluctuating light and smell stimulus protocol has been shown to have positive effects on mood and stress-related physiological markers and, in addition, rebalances frontal brainwave asymmetry towards a healthy, normal pattern. Using a frontal brainwave asymmetry feedback paradigm could radically enhance the effectiveness of such therapy and offer a real, effective, safe alternative to drugs and electroconvulsive therapy as a treatment for depression and anxiety.

REFERENCES

Alaoui-Ismaïli, O., Robin, O., Rada, H., Dittmar, A., Vernet-Maury, E. (1997) Basic emotions evoked by odorants: comparison between autonomic responses and self-evaluation. Physiol. Behav. 62, 713-720.

Allen, J. J., Urry, H. L., Hitt, S. K., & Coan, J. A. (2004) The stability of resting frontal electroencephalographic asymmetry in depression. Psychophysiology 41, 269-80.

Blackhart, G. C., Minnix, J. A., & Kline, J. P. (2006) Can EEG asymmetry patterns predict future development of anxiety and depression? A preliminary study. Biol. Psychol. 72, 46–50.

Davidson, R. J. (1998a) Anterior electrophysiological asymmetries, emotion, and depression: conceptual and methodological conundrums. Psychophysiol. 35, 607–614.

Davidson, R. J. (1998b) Cerebral Brain asymmetry. Chap 13 in Brain Asymmetry, eds. R J Davidson and K Hugdahl. The MIT Press, Cambridge, MA, USA 1998.

Deverill C., King, M., Common mental disorders. In: Adult Psychiatric Morbidity in England: Results of a household survey, eds. S. McManus, T. Brugha, P. Bebbington, and R. Jenkins, The NHS Information Centre, pp.38-58, 2009

Dong, S. and Jacob, T.J.C. (2016) Combined non-adaptive light and smell stimuli lowered blood pressure, reduced heart rate and reduced negative affect. Physiol. Behav. 156, 94–105, doi:10.1016/j.physbeh.2016.01.013

Ehrlichman, H., & Bastone, L. (1992) Olfaction and emotion. In: M. J. Serby, K. L. Chobor (eds.). Science of olfaction. New York: Springer-Verlag. p. 410–438.

Guardian, (2017) https://www.theguardian.com/society/2017/apr/17/electroconvulsive-therapy-on-rise-england-ect-nhs

Golden, R. N., Gaynes, B. N., Ekstrom, R. D., Hamer, R. M., Jacobsen, F. M., Suppes, T., Wisner, K. L., & Nemeroff, C. B. (2005) The efficacy of light therapy in the treatment of mood disorders: a review and meta-analysis of the evidence. Am. J. Psychiatry 162, 656-662.

Harmon-Jones, E. (2007) Asymmetrical Frontal Cortical Activity, Affective Valence, and Motivational Direction. Chap. 7 in Social Neuroscience: Integrating Biological and Psychological Explanations of Social Behavior. Eds. E Harmon-Jones, P. Winkelman. The Guilford Press, New York, 2007, pp.138.

Harmon-Jones, E., Gable, P. A., Peterson, C. K. (2010) The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update. Biological Psychology, 84, 451-462.

Heller, W., Nitschke, J. B., Etienne, M. A., & Miller, G. A. (1997) Patterns of regional brain activity differentiate types of anxiety. J. Abnorm. Psychol. 106, 376-385.

Henriques, J. B., & Davidson, R. J. (1991) Left frontal hypoactivation in depression. J. Abnorm. Psychol. 100, 535-545.

Herz, R.S. (2009) Aromatherapy Facts and Fictions: A Scientific Analysis of Olfactory Effects on Mood, Physiology and Behavior. Int. J. Neuroscience 119, 263-290, doi: 10.1080/00207450802333953

Johnson, A. J. (2011) Cognitive facilitation following intentional odor exposure.Sensors (Basel) 11, 5469-88, doi: 10.3390/s110505469

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Koretz, D., Merikangas, K. R., Rush, A. J., Walters, E. E., & Wang, P. S. 2003. National Comorbidity Survey Replication. The epidemiology of major depressive disorder: results from the National Comorbidity Survey Replication (NCS-R). JAMA 289(23), 3095-3105.

Lieverse, R., Van Someren, E. J., Nielen, M. M., Uitdehaag, B. M., Smit,J.H., & Hoogendijk, W. J. (2011) Bright light treatment in elderly patients with nonseasonal major depressive disorder: a randomized placebo-controlled trial. Arch. Gen. Psychiatry 68, 61-70, doi: 10.1001/archgenpsychiatry.2010.183

Naus, T., Burger, A., Malkoc, A., Molendijk, M., & Haffmans, J. (2013) Is there a difference in clinical efficacy of bright light therapy for different types of depression? A pilot study. J. Affect. Disord. 151, 1135-7, doi: 10.1016/j.jad.2013.07.017

Niederhofer, H., & von Klitzing, K. (2012) Bright light treatment as mono-therapy of non-seasonal depression for 28 adolescents. Int. J. Psychiatry Clin. Pract. 16, 233-7, doi: 10.3109/13651501.2011.625123

NICE, 2004. Costing Clinical Guidelines:Depression (England and Wales), http://www.nccmh.org.uk/downloads/DCHP/CG23CostReport.pdf

Oldham, M.A., & Ciraulo, D.A. (2014) Bright light therapy for depression: a review of its effects on chronobiology and the autonomic nervous system. Chronobiol. Int. 31, 305-19, doi: 10.3109/07420528.2013.833935

Pail, G., Huf, W., Pjrek, E., Winkler, D., Willeit, M., Praschak-Rieder, N., & Kasper, S. (2011) Bright-light therapy in the treatment of mood disorders. Neuropsychobiol. 64,152-162.

Thibodeau, R., Jorgensen, R.S., & Kim, S. (2006) Depression, anxiety, and resting frontal EEG asymmetry: a meta-analytic review. J. Abnorm. Psychol.115, 715-29.

Vernet-Maury. E., Alaoui-Ismaïli, O., Dittmar, A., Delhomme, G., & Chanel, J. (1999) Basic emotions induced by odorants: a new approach based on autonomic pattern results. J. Auton. Nerv. Syst. 75, 176-183.

Vuga, M., Fox, N.A., Cohn, J.F., George, C.J., Levenstein, R.M., & Kovacs, M. (2005) Long-term stability of frontal electroencephalographic asymmetry in adults with a history of depression and controls. Int. J. Psychophysiol. 59,107-115.

Warden-Smith, J., Paul, L., Olukogbon, K., Bointon, E.S., Cole, R.H., John, R.R., Dong, S. and Jacob, T.J.C. (2017) Light and smell stimulus protocol reduced negative frontal EEG asymmetry and improved mood. Open Life Sci., 12: 51–61, doi: 10.1515/biol-2017-0006

WHO. 2012. Fact sheet N°369, http://www.who.int/mediacentre/factsheets/fs369/en/index.html