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TRANSCRANIAL INFRARED LASER STIMULATION PRODUCES BENEFICIAL COGNITIVE AND EMOTIONAL EFFECTS IN HUMANS

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Abstract—This is the first controlled study demonstrating the beneficial effects of transcranial laser stimulation on cognitive and emotional functions in humans. Photobiomodulation with red to near-infrared light is a novel intervention shown to regulate neuronal function in cell cultures, animal models, and clinical conditions. Light that intersects with the absorption spectrum of cytochrome oxidase was applied to the forehead of healthy volunteers using the laser diode CG-5000, which maximizes tissue penetration and has been used in humans for other indications. We tested whether low-level laser stimulation produces beneficial effects on frontal cortex measures of attention, memory and mood. Reaction time in a sustained-attention psychomotor vigilance task (PVT) was significantly improved in the treated ($n = 20$) vs. placebo control ($n = 20$) groups, especially in high novelty-seeking subjects. Performance in a delayed match-to-sample (DMS) memory task showed also a significant improvement in treated vs. control groups as measured by memory retrieval latency and number of correct trials. The Positive and Negative Affect Schedule (PANAS-X), which tracks self-reported positive and negative affective (emotional) states over time, was administered immediately before treatment and 2 weeks after treatment. The PANAS showed that while participants generally reported more positive affective states than negative, overall affect improved significantly in the treated group due to more sustained positive emotional states as compared to the placebo control group. These data imply that transcranial laser stimulation could be used as a non-invasive and efficacious approach to increase brain functions such as those related to cognitive and emotional dimensions. Transcranial infrared laser stimulation has also been proven to be safe and successful at improving neurological outcome in humans in controlled clinical trials of stroke. This innovative approach could lead to the development of non-invasive, performance-enhancing interventions in healthy humans and in those in need of neuropsychological rehabilitation.

Key words: transcranial laser stimulation, low-level light therapy, attention, memory, mood, novelty-seeking.

INTRODUCTION

The goal of this experiment was to use transcranial low-level light therapy (LLLT) to enhance frontal cortex cognitive and emotional functions. LLLT is defined as the use of directional low-power and high-fluence monochromatic or quasimonochromatic light from lasers or light-emitting diodes (LEDs) in the red to near-infrared wavelengths to modulate a biological function or induce a therapeutic effect (Rojas and Gonzalez-Lima, 2011). LLLT is non-invasive, therapeutically beneficial, and promotes a wide range of biological effects including the enhancement of energy production, gene expression and the prevention of cell death. Previous research has indicated that depressed patients showed a beneficial effect on their affective state from a single LLLT treatment to the forehead using 810 nm LEDs (Schiffer et al., 2009). The present experiment tested whether LLLT benefits extend to cognitive processes involving attention, vigilance and short-term memory, and if there may be a relationship between response to LLLT and personality measures. Instead of using LEDs, we administered LLLT with a 1064-nm laser that maximizes tissue penetration (Sommer et al., 2001).

Stimulation with red to near-infrared light constitutes a novel intervention shown to regulate neuronal function in cell cultures, animal models, and clinical conditions (Eells et al., 2004). Photobiomodulation of mitochondrial cytochrome oxidase activity appears to be the primary molecular mechanism of action of LLLT. Cytochrome oxidase is the primary photoacceptor of red to near-infrared light energy, and it is also the enzyme catalyzing oxygen consumption in cellular respiration (Karu, 2000; Wong-Riley et al., 2005) and the production of nitric oxide under hypoxic conditions (Poyton et al., 2009). We have previously shown that transcranial LLLT can increase cytochrome oxidase activity in the rat brain (Rojas et al., 2008), which can provide neuroprotection against toxicity in animal models (Rojas and Gonzalez-Lima, 2010, 2011). LLLT *in vivo* can also increase cytochrome oxidase and improve the aerobic capacity of other tissues such as skeletal muscle (Hayworth et al., 2010). We recently demonstrated that transcranial LLLT can improve frontal cortex oxygen consumption and metabolic capacity and

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Abbreviations: ANOVA, analysis of variance; DMS, delayed match-to-sample; LEDs, light-emitting diodes; LLLT, low-level light therapy; OD, optical density; PANAS, Positive and Negative Affect Schedule; PEBL, psychology experiment building language; PVT, psychomotor vigilance task; SSS, sensation-seeking scale; TPQ, Tri-Dimensional Personality Questionnaire.

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