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Psychological and physiological responses to stressful situations in immersive virtual reality: Differences between users who practice mindfulness meditation and controls

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ABSTRACT

Several studies in the literature have shown positive psychophysical effects during or immediately after mindfulness meditation. However, the extent to which such positive effects are maintained in real-life, stressful contexts, remains unclear. This paper investigates the effects of an 8-week mindfulness-oriented meditation (MOM) program on the psychological and physiological responses evoked by immersive virtual environments (IVEs) that simulate emergency situations that may occur in life. Before and after the 8-week period, healthy MOM participants and a group of controls not involved in any meditation course were administered self-report measures of mindfulness and anxiety, and acted in the IVEs while a set of physiological parameters were recorded. Responses of MOM participants to the immersive virtual experiences were different from those of controls. MOM participants showed increased mindfulness and decreased anxiety levels. They also showed decreased heart rate and corrugator muscle activity while facing IVEs. We explain these results in terms of the awareness and acceptance components of mindfulness. More generally, the present experimental methods could also open up new lines of research that combine psychological and physiological indices with ecologically valid stimuli provided by IVEs in an effort to increase understanding of the impact of mindfulness meditation on realistic life situations.

1. Introduction

Rooted in Eastern contemplative traditions, mindfulness meditation (MM) is usually conceptualized as nonjudgmental attention to present moment somatosensory and mental experience (Brown & Ryan, 2003; Crescentini & Capurso, 2015; Kabat-Zinn, 1990, 2003; Lutz, Slagter, Dunne, & Davidson, 2008). Initially formalized for patients with chronic pain (e.g., Kabat-Zinn, 1982; see Baer, 2003, 2010; Didonna, 2009 for discussions of different forms of MM therapies), MM interventions have been shown to be effective for the treatment of different types of physical and psychological problems observed in individuals of various age ranges and in different clinical and non-clinical contexts (for reviews see Brown, Ryan, & Creswell, 2007; Chiesa & Serretti, 2010; Didonna, 2009; Goyal et al., 2014).

For example, a number of studies based on self-report measures documented positive effects of MM therapies on anxiety, stress reactivity, depressive symptoms, ruminative thoughts, mood, and ability to regulate disturbing emotions in patients with anxiety and depressive disorders as well as in healthy individuals (Chiesa & Serretti, 2010; Desrosiers, Vine, Klemanski, & Nolen-Hoeksema, 2013; Evans et al., 2008; Garland, Gaylord, & Fredrickson, 2011; Hofmann, Sawyer, Witt, & Oh, 2010; Hoge et al., 2013; Jain et al., 2007; Kabat-Zinn et al., 1992). In these classes of patients as well as in non-clinical samples, such MM-related positive outcomes on mental health also seem to impact physiological parameters

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associated with stress and anxiety. For example, it has recently been shown in non-clinical populations that a brief training in mindfulness meditation (3–10 days of Vipassana meditation) leads to reduced heart rate (Zeidan, Johnson, Gordon, & Goolkasian, 2010) and increased heart rate variability (which is related to well-being and positive affect; Krygier et al., 2013) immediately after or during meditation tasks. Such findings have been considered to reflect feelings of relaxation (which decreases physiological arousal) or states of effortful, positive immersion in an activity promoted by MM.

Similarly, other longitudinal, within-subject studies or cross-sectional designs in which experienced meditators were compared to naïve meditators or meditation conditions to control conditions (e.g., relaxation or wait-list control conditions), have reported physiological changes during MM. Such changes include reduction of heart and respiratory rates and reduction in skin conductance level, in both clinical (e.g., individuals with fibromyalgia, a chronic pain syndrome; Lush et al., 2009) and non-clinical populations (Cahn & Polich, 2006; Delmonte, 1984, 1985; Ditto, Eclache, & Goldman, 2006; Rubia, 2009). Moreover, a recent study on a sample of depressed patients (Rohde, Adolph, Dietrich, & Michalak, 2014) was able to link negative emotional reactions, experienced when attention drifted during a MM exercise in which subjects had to focus nonjudgmentally on breathing, to electromyographic response of the corrugator supercilii muscle. The activation of this muscle has been shown to be generally associated with negative affect, and the study by Rodhe et al. (2014) observed increased corrugator activity in depressed vs. healthy individuals after drifting from breathing, a finding that can suggest a deficit of depressed patients in the non-judgmental experience component of mindfulness.

Globally, these psychophysiological findings have been interpreted in terms of a wakeful hypometabolic state promoted by MM. This state would be characterized by increased parasympathetic nervous activity (indicative of physiological relaxation and stress relief) and decreased sympathetic activity (e.g., Rubia, 2009). However, one should note that previous studies focused on the health effects of MM therapies have generally monitored physiological parameters immediately after or during MM exercises. This does not shed light about if and how such positive effects of MM translate and generalize to wider, real-world scenarios. Virtual reality (VR) may represent a more holistic and ecological research instrument, providing users with unique, realistic and immersive experiences that are under full experimenter's control and could open up new possibilities to investigate behavioral and physiological responses of meditators to stressful real-world situations.

In the last years, it has been shown that VR exposure can be so effective in terms of experimental realism as to elicit and modulate psychophysiological symptoms of anxiety and fear reactions (e.g., in terms of electrodermal activity), in both patients with anxiety disorders and healthy individuals (Diemer, Mühlberger, Pauli, & Zwanzger, 2014). More specifically, immersive virtual reality systems, as the one we use in this study, exploit realistic 3D graphics, stereoscopic viewing, and head tracking to create interactive, first-person experiences that can be more ecologically valid than traditional, non-interactive experimental stimuli (written text as well as audio-visual materials; e.g., see Parsons, 2011) and produce users' physiological responses that are consistent with real-world experiences (Chittaro, 2014; Chittaro & Buttussi, 2015; Insko, 2003; Meehan, Razzaque, Insko, Whitton, & Brooks, 2005; Parsons et al., 2009; Patil, Cogoni, Zangrando, Chittaro, & Silani, 2014; Slater, Khanna, Mortensen, & Yu, 2009; Slater, Usoh, & Steed, 1994; Zanon, Novembre, Zangrando, Chittaro, & Silani, 2014). For example, immersive simulations of emergency situations - such as fires, accidents and other life-threatening events – can provide participants with visual and auditory stimuli that are able to induce negative emotions such as anxiety (Chittaro, 2014) and fear (Chittaro & Buttussi, 2015) as a real emergency would do. Moreover, behavioral responses to virtual emergencies are also consistent with real-world ones, even when particular behaviors such as prosocial behavior (Zanon et al., 2014) or ethnic discrimination (Gamberini, Chittaro, Spagnolli, & Carlesso, 2015) are considered.

To date, the potential of VR in MM studies has been scarcely explored. A few studies have recently tried to use VR and immersive systems to foster the adoption of meditative states (Vidyarthi & Riecke, 2014) or self-compassion (an important construct related to MM, see Crescentini & Capurso, 2015) (Falconer et al., 2014). In line with these recent attempts to combine VR and meditation, earlier research explored the use of VR in combination with mindfulness and relaxation in the treatment of patients with physical and psychological problems such as chronic pain (e.g., fibromyalgia) and posttraumatic stress disorder (Botella et al., 2013; Gromala et al., 2011; Spira et al., 2006; see also Tong, Gromala, Choo, Amin, & Shaw, 2015). However, to the best of our knowledge, no study has employed VR as an instrument to study how meditators respond to stressful situations that simulate, through interactive immersive experiences in controlled conditions, emergencies that occur in real life.

The aim of the current longitudinal research was to investigate the direct impact of a mindfulness-oriented meditation (MOM) intervention on the psychological and physiological responses evoked by four immersive virtual environments (IVEs) that were designed to elicit different levels of stress (low and high, see section on Immersive Virtual Environments) and that simulated real-life scenarios and activities. We studied two groups of healthy adults, one group participating in an 8-week MOM training and the second serving as matched control group whose members were not involved in any meditation intervention. In addition to self-report measures of dispositional mindfulness and trait and state anxiety, we recorded a set of physiological parameters (cardiac, electrodermal, electromyographic, and respiratory activity) while subjects were immersed and acted in the IVEs. This was done in both groups in two different sessions (i.e., before and after the 8-week period during which one of the groups was involved in MOM training). We expected to find evidence of reduced perceived stress and anxiety as well as physiological signs of emotional deactivation and reduced arousal in the MOM subjects when they faced demanding IVEs after vs. before the meditation training.

2. Materials and methods

2.1. Participants

A total of 41 Italian participants were recruited for the study. Twenty-one participants took part in the MOM training (mean age = 43.33, SD = 10.23; mean years of education: 15.38, SD = 3.52). They were recruited through advertisements and by word of mouth from employees (administrative personnel, nurses and physicians) of the hospital “Santa Maria della Misericordia” in Udine, Italy. To control for possible influence of occupation, age, education level and gender on the measured psychological and physiological variables, control participants were also recruited among the employees of the same hospital: each MOM participant was asked to recruit in the study a colleague who was potentially interested in participating in a future MOM course. The control group consisted of 20 participants who were not involved in any meditation training (mean age = 36.75, SD = 9.85; mean years of education: 15.80, SD = 3.15). Overall, five participants (3 MOM and 2 control participants) were excluded from all the analyses