Stress and neurocognitive efficiency in managerial contexts

A study on technology-mediated mindfulness practice

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Abstract

Purpose – The purpose of this paper is to test the potential of an innovative technology-mediated mental training protocol for the empowerment of stress management and neurocognitive efficiency in highly stressful professional contexts, with people who occupy top management positions. The innovative protocol specifically combines mindfulness practice and a wearable neurofeedback system managed via smartphone.

Design/methodology/approach – The longitudinal research included pre- and post-training assessment steps in order to test training effects with respect to subjective level and physiological markers of stress, anxiety and mood profiles, cognitive abilities and markers of neurocognitive efficiency.

Findings – Results showed decreased stress, anxiety, anger and mental fatigue; increased participants' information-processing efficiency; increased electrophysiological markers concerning the balance and reactivity of the mind-brain system; and improved physiological markers of vagal tone.

Research limitations/implications – Though further investigation and replication with larger samples would strengthen present findings, the authors suggest that observed outcomes, together with the limited duration of the overall protocol and of daily practices, make the training a potentially valuable tool especially for people whose professional position imposes time limitations and elevated job duties, thus increasing the risk of drop-out from traditional stress management programs.

Originality/value – The combination of mindfulness-based mental training with the advantages offered by a novel brain-sensing wearable technology allows for overcoming the weak points of traditional approaches (e.g. notable time expense) and optimizing training opportunities and outcomes. Furthermore, this is, to the authors' best knowledge, the first systematic report of the application of such methodology in an organization and with top management professionals.

Keywords Wearable technology, Mindfulness, Neurocognitive efficiency, Neurofeedback, Neuromanagement, Stress management

Paper type Research paper

1. Introduction

Professionals occupying managerial positions are primarily involved in challenging tasks characterized by high cognitive load and requiring remarkable cognitive resources. Thus, they are exposed to extremely high pressure to succeed, and are characterized by elevated responsibilities and substantial workload. Notwithstanding known protective factors – such as high level of job satisfaction, elevated earnings, job autonomy, non-routine work and schedule control (Mirowsky and Ross, 2005; Mühlhaus and Bouwmeester, 2016) – all those aspects of manager's jobs significantly contribute to the high level of stress they experience (Mohr and Wolfram, 2010; Schieman and Glavin, 2016).

Systematic research on the impact of stress on managers is actually limited, despite the attention globally paid to the topic of occupational stress. Still, available literature quite consistently underlines the negative impact of occupational stress on managers' mood, perceived health and performance efficacy (Institute of Management, 1993; Schieman and Reid, 2009; Mohr and Wolfram, 2010; Dewa *et al.*, 2011; Schieman and Glavin, 2016).

Consequently, the influence of managers' health and level of stress on their performance at work, on well-being of the employees and on the organization's effectiveness is nowadays a hot topic in organizations and management research, together with research on effective ways to manage the high stress load managers are exposed to and its consequences (Little *et al.*, 2007; Balconi, Natale *et al.*, 2017; Crivelli and Balconi, 2017a).

Indeed, a high level of chronic stress may become at last dysfunctional, since it can alter mental abilities, wear out cognitive resources and worsen performance (Lupien and McEwen, 1997; Chrousos, 2009). Therefore, considering the negative consequences of chronic stress levels on physical, mental health and on quality of life (Schneiderman *et al.*, 2005; Chrousos, 2009), in the last years research on stress management within work contexts strongly indicates that occupational stress can increase cardiovascular risk and directly alter the neural regulation of cardiovascular activity (Rosengren *et al.*, 2004; Backé *et al.*, 2012); alter the functionality of endocrine and immune systems, thus increasing individual susceptibility to various diseases (Chandola *et al.*, 2010); affect autonomic responsivity and regulation, with heightened heart rate (HR) and blood pressure and reduced vagal tone (i.e. reduction of the ability of the parasympathetic system to down-regulate autonomic arousal associated, e.g., to chronic distress) not only at work but even during leisure time (Vrijkotte *et al.*, 2000; Lucini *et al.*, 2007); and more generally, affect quality of life and psychological well-being because of interpersonal conflicts and work-to-home interference (Institute of Management, 1993; Schieman and Reid, 2009; Dewa *et al.*, 2011; Schieman and Glavin, 2016).

In addition, sustained exposure to stress also has implication on neural activity and on the efficiency of cognitive systems involved in attention regulation, which are mediated by a broad frontal–parietal network (Ptak, 2012). Then, sustained hyperactivation related to stress responses influences neural and cognitive functioning by affecting the ability to properly exert executive, attentive, decision-making and memory processes (see Roozendaal *et al.*, 2009; Girotti *et al.*, 2018). Indeed, the brain is particularly sensitive to the damaging effects of high stress levels, as shown by some studies that have observed how prolonged exposure to high stress levels causes the worsening of executive functions (Arnsten, 2009; Girotti *et al.*, 2018), which are the set of basic and crucial cognitive skills that allow us to monitor ourselves and the context, adaptively respond to environmental requests, distribute cognitive resources and regulate our behavior. Furthermore, prolonged exposure to stressful experiences also affects the activity of hippocampus, amygdala and prefrontal cortex, thus resulting in the dysfunctional alteration of self-monitoring and affective regulation skills (McEwen and Gianaros, 2011; Arnsten, 2015).

Among the educational and intervention protocols designed to empower stress management skills in the workplace and to try to prevent health risks and reduced performance by lowering the negative influence of exposure to stressors, the most diffused are relaxation techniques, cognitive-behavioral psychological training and meditation practices (Lamontagne *et al.*, 2007; Richardson and Rothstein, 2008). Mindfulness-based interventions have been, in particular, deemed as valuable ways to cope with stress-related problems, since they have been shown to efficiently reduce stress and related consequences in different clinical and non-clinical contexts (Creswell, 2017). Even when used in organizations and work environments to manage occupational stress mindfulness meditation showed an interesting potential, as reported in various reviews on the topic (Ravalier *et al.*, 2016; Janssen *et al.*, 2018), though actual outcomes and methodological limitations of such approaches are still debated (Jamieson and Tuckey, 2017) and also negative results have been reported (see e.g. Bartlett *et al.*, 2018).

Recently, novel approaches that integrate mental training practices with wearable brain-sensing devices showed their improved potential for neurocognitive empowerment – understood as the improvement of cognitive skills and of neural processes supporting

them – and for promoting efficient stress management skills with respect to traditional intervention protocols (Bhayee *et al.*, 2016; Balconi, Fronda *et al.*, 2017; Crivelli *et al.*, 2019; Balconi and Crivelli, 2019). In particular, they have also been shown to induce measurable improvements of participants' cardiovascular functionality (namely, the vagal tone) at rest and under high cognitive workload (Balconi *et al.*, 2018, 2019), as well as improved electrophysiological markers of relaxation, focus and attention regulation (Crivelli *et al.*, 2019). The present study aimed at testing the potential of an innovative technology-mediated mental training protocol for the empowerment of stress management skills and of neurocognitive efficiency (i.e. the efficiency of performance at cognitive tasks) even in highly stressful professional contexts, with people who occupy positions characterized by very high levels of responsibilities and top management duties. The innovative protocol specifically combines mindfulness meditation practice and a wearable neurofeedback system managed via a dedicated smartphone app.

Building on previous findings, we expected that, after specific training on the wearable device, participants would have presented: reduced perceived levels of stress, anxiety and mental fatigue; a concurrent improvement of autonomic down-regulation of physiological stress responses, as measured by cardiovascular markers of increased vagal tone, especially during exposure to a stressful situation; improved performance at challenging cognitive tasks, as marked by the reduction of time needed to process task-relevant information; and a consistent improvement of electrophysiological markers of neurocognitive efficiency, as marked by the modulation of EEG activity especially in correspondence to prefrontal and parietal areas, which constitute a network that mediates attention regulation and is negatively affected by repeated exposure to stressors.

2. Methods
2.1 Sample
The sample was constituted by 16 professionals (8 women; $M_{age} = 44.38$, $SD_{age} = 6.22$; $M_{edu} = 19.13$, $SD_{edu} = 2.47$) with top management duties at a public service company, which operates in the greater Milan area and in part of the province. Exclusion criteria were: history of psychiatric or neurological diseases; ongoing concurrent therapies based on psychoactive drugs that can alter central nervous system functioning; clinically relevant stress, anxiety or depression levels; occurrence of significant stressful life events during the last six months; and preceding systematic meditation experience. None of the participants reported a history of neurology or psychiatric disturbances. Absence of clinical or subclinical signs of cognitive impairment was checked via standardized neuropsychological assessment based on cognitive tests standardized on the Italian reference population (Spinnler and Tognoni, 1987; Caffarra *et al.*, 2002). Absence of clinically relevant signs of stress, anxiety and depression was checked via standardized psychometric tests (Perceived Stress Scale (PSS), Cohen *et al.*, 1983; State-Trait Anxiety Inventory (STAI), Pedrabissi and Santinello, 1989; Beck Depression Inventory, Ghisi *et al.*, 2006). All of the participants had normal or corrected-to-normal hearing and vision.

Written informed consent to participate in the study was collected from all participants. The experimental design and procedures follow the principles of the Declaration of Helsinki and were approved by the Ethics Committee of the Department of Psychology of the Catholic University of the Sacred Heart.

2.2 Experimental procedure
Building on previous pilot and fully structured trials (Balconi, Fronda *et al.*, 2017; Balconi *et al.*, 2018, 2019; Crivelli *et al.*, 2019; Balconi and Crivelli, 2019), the present study was designed as a longitudinal study including two main assessment steps – before and at the end of the training – in order to keep track and test potential effects of the

technology-supported mental training with respect to subjective level and physiological markers of stress, anxiety and mood profiles, cognitive abilities and markers of neurocognitive efficiency. Each assessment session lasted approximately 90 min.

2.2.1 Training protocol. The training protocol is based on mental training practices based on the mindfulness meditation tradition. In the protocol, however, such practices are supported by dedicated wearable neurofeedback devices (Lowdown Focus brain-sensing eyeglasses, SmithOptics Inc., Clearfield, UT, USA), i.e. highly usable technological devices able to non-invasively collect users' EEG activity and, thanks to a smartphone app, to convert such activity into real-time feedbacks mirroring the modulation of users' mindset and related neural activity. In particular, the device and the app that we have tested can inform the wearer on the focused vs distracted/agitated status of their minds and brains, thus helping them to develop deeper awareness of their bodily arousal and greater stress coping resources.

The protocol lasted for two weeks and included daily sessions of practice (total number of sessions: 14). The duration of daily practices were gradually incremented starting from 10 min a day till 20 min a day (1st to 5th session – 10 min; 6th to 10th session – 15 min; 11th to 14th session – 20 min), so to introduce progressively increasing levels of commitment and challenge. Participants were further requested to be constant in their practices and to systematically plan them at the same moment of the day, in order to control for potential influence of the physiological modulation of cognitive and bodily processes due to circadian rhythms.

During practice, participants were asked to find a quiet place, sit comfortably and intentionally focus their attention on breathing and related bodily sensations. Such breathing awareness practice derives from *Vipaśyanā* meditation and is currently considered a form of focused attention meditation, which is thought to primarily strengthen concentration, focusing and self-regulation skills (Lutz *et al.*, 2008; Lippelt *et al.*, 2014; Hommel and Colzato, 2017). Such practice was chosen because it is among the simplest mindfulness-related practices, and it can be then easily taught to and performed by people that, for the first time, approach mental training. In the meanwhile they also wore the brain-sensing eyeglasses that, by using dry electrodes embedded over the nose bridge and in the temples, non-invasively collected practicers' EEG activity and transferred it via Bluetooth to the smartphone app. The app then used such source of information to deliver real-time acoustic feedbacks on changes of the physiological signature of practicer's mindset, namely, it used modulations of the EEG profile (e.g. when moving from a focused mindset to an agitated and distracted mindset) to manipulate the sound environment in which the practicer is immersed (e.g. by progressively increasing the intensity of wind and rainstorm sounds).

2.2.2 Assessment protocol. 2.2.2.1 Subjective level of stress, anxiety and mood profile. Potential effects of the training on subjectively perceived level of stress was tested via the PSS (Cohen *et al.*, 1983). The PSS is constituted by ten items, scored on 0–4 Likert scales, and is deemed as a quick and reliable tool in basic and applied research on stress and coping skills (Monroe, 2008). Training effects on the level of situational anxiety were, instead, tested via the state subscale of the STAI (Pedrabissi and Santinello, 1989). The state subscale of such tool is constituted by 20 items, scored on a 1–4 Likert scale, which also mirror negative effects associated with signs of anxiety. Finally, the modulation of mood profile was assessed via the Profile of Mood States (POMS) inventory (McNair *et al.*, 1971). The POMS is constituted by 53 adjectives describing different mood states and the examinee has to rate how much those items describe their feelings on a 0–4 Likert scale. Responses are then used to calculate six subscales: tension, depression, anger, confusion, fatigue and vigor. The POMS, together with the STAI, is deemed as a valuable tool to explore modulation of mood in experimental trials testing the potential of stress management interventions (Rossi and Pourtois, 2012).

2.2.2.2 Cognitive abilities. Given the unique cognitive profile of participants, the efficiency of their information-processing and cognitive control skills was tested via challenging computerized tasks tapping on attention, monitoring and executive functions. Going down to specifics, participants were asked to complete the MIDA battery (De Tanti *et al.*, 1998), a digitalized battery based on a series of reaction time subtasks. The subtasks differ in terms of cognitive effort and were designed to explore various aspects of attention control, from basic orienting responses to discrimination and response inhibition skills. During all subtasks, participants reaction times are scored, together with omitted responses (a sign of lack of attention), early responses (a sign of lack of control) and – during the most difficult subtask – false alarms (i.e. responses that are given when they should have been withheld, a sign of lack of inhibition). The MIDA computerized battery has been standardized in Italy (normative sample $n = 354$).

A further computerized task was instead designed to better investigate response selection and executive control mechanisms under time pressure. Namely, participants were asked to complete a Stroop-like task (Stim2 software, Compumedics Neuroscan, Charlotte, NC). During this task, four color-related words (the Italian words for yellow, blue, green and red) were rapidly presented on a PC screen (duration: 300 ms; total number of stimuli: 160). Each of them could have been written in yellow, blue, green or red, and participants had to discriminate between congruent and incongruent color–word associations by quickly pressing two different response buttons. Participants' performance was scored by computing mean response times, response accuracy and number of omitted responses.

2.2.2.3 Markers of neurocognitive efficiency. Electrophysiological markers of neurocognitive efficiency were assessed both during rest (both eyes-open and eyes-closed resting, three 90-s run each) via neurometrics based on frequency-domain continuous EEG activity and during an activating task (the above-described computerized Stroop-like task) via event-related potentials (ERP).

As for the former, we recorded participants' electroencephalographic activity via a portable EEG system (V-Amp system, Brain Products GmbH, Gilching, Germany). Data were collected by using a 15-channel montage (Ag/AgCl electrodes referenced to linked earlobes, Figure 1). Sensors were placed according to the 10-10 International System (Chatrian *et al.*, 1988). vEOG was also recorded in order to keep track of ocular artifacts for subsequent correction and rejection, so to avoid data contamination.

To compute a first set of neurometrics based on frequency-domain EEG measures, neural activity during resting recordings (both eyes open and eyes closed) were then processed offline by applying a bandpass filter (range: 0.1–50 Hz) to reduce environmental and biological noise and an ocular correction algorithm (ICA based; Jung *et al.*, 2000) to minimize the impact of eye-movements and blinks on collected data. After segmentation and further visual inspection of data, they were converted into frequency components by Fast Fourier Transformation to extract power density values of standard EEG frequency bands (δ: 0.5–3.5 Hz, θ: 4–7.5 Hz, α: 8–12.5 Hz, β: 13–30 Hz and γ: 30.5–50 Hz). Values from selected scalp regions (frontal area (Fz), central area (Cz) and parietal area (Pz)) were then used to compute two main neurometric measures: the alpha–beta ratio (ABr) and the alpha blocking index (ABlock). The ABr – a quantification of the balance between neural correlates of a relaxed/focused vs overactive/agitated mindset – provides a measure related to the global status of the system. The ABlock – a quantification of the prompt modification of neural oscillations linked to information processing – provides a measure of the global responsiveness and reactivity to environmental stimulations of the neural system. ABr measures were computed as the ratio of the power density of the alpha band to the power density of the beta band recorded during eyes-closed and eyes-open resting. ABlock measures were computed as the average of the decrease of alpha power density following the eyes-closed to eyes-open transitions.
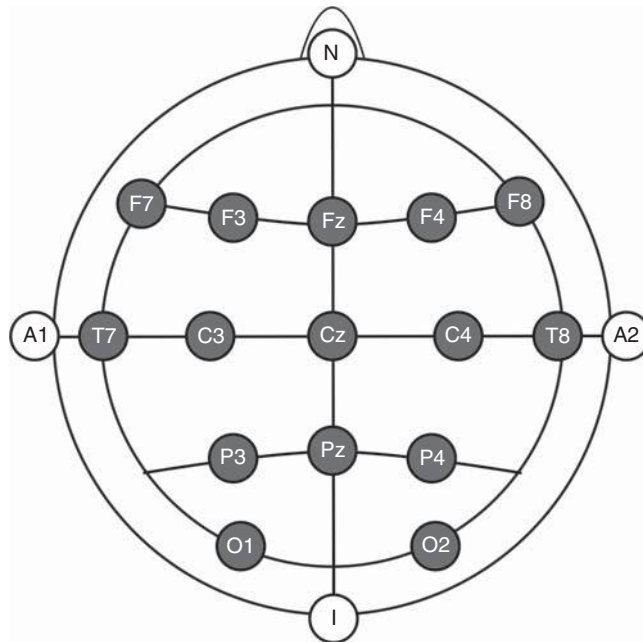
Figure 1.
EEG montage
according to the 10-10
International System

Notes: N, nasion; I, inion; A1–A2, left and right pre-auricular points

To investigate potential markers of improved information processing and allocation of neural resources during a high cognitive load, task-related modulations of EEG responses (ERP; Crivelli and Balconi, 2017b) during the challenging computerized task were also processed offline by applying a bandpass filter (range: 0.1–30 Hz) and artifact correction. Data were then segmented with reference to the stimuli onset (epoch length: 1,000 ms; baseline: 200 ms), classified according to the experimental condition (congruent and incongruent trials) and visually inspected for residual artifacts. Artifact-free segments were then averaged to compute condition-specific individual average waveforms. Following morphological analysis of such waveforms, we extracted peak amplitude and latency data of the N2 ERP deflection, which is thought to mark automatic attention orientation and implicit response control mechanisms. ERP amplitude is typically thought to mirror the intensity of the cognitive process it is associated with, while its latency is thought to mirror the timing of such process.

2.2.2.4 Physiological markers of stress. During both resting-state recordings and exposure to a cognitive stressor, namely, an effortful and challenging cognitive task, we also collected physiological markers of participants' stress responses. In particular, we non-invasively collected autonomic measures of cardiovascular activity via photoplethysmography (Biofeedback2000^{xpert} system, Schuhfried GmbH, Mödling, Austria).

Autonomic data were recorded by a peripheral sensor, placed on the distal phalanx of the second finger of the non-dominant hand. After qualitative and quantitative inspection of data to detect and remove recording or biological artifacts, we computed both standard measures of cardiac activity (HR, inter-beat interval (IBI)) and a measure of HR variability (the standard deviation of IBI), so to have a broad picture of stress-related cardiac responses and a measure of vagal tone, which is linked to the functionality of parasympathetic recovery mechanisms that foster the return to bodily homeostasis by down-regulating arousal (Mendes, 2009).

2.3 Statistical analyses
Pre- and post-training data were statistically compared via paired-sample *t*-tests (PASW Statistics 18, SPSS Inc., Quarry Bay, HK). Time (pre vs post) was used as a within factor. Normality of data distributions was preliminarily checked by computing asymmetry and kurtosis values. Finally, we computed Cohen's *d* values as a measure of within-group effect size. Effect sizes have been deemed as small when $\geqslant 0.2$, medium when $\geqslant 0.5$ and large when $\geqslant 0.8$, in agreement with Cohen's (1988) norms.

3. Results
Table I reports a synopsis of outcome measures that showed a significant modulation following the training, as well as effect size values for statistically significant differences.

3.1 Subjective level of stress, anxiety and mood profile
Statistical comparisons of pre- and post-training psychometric measures highlighted a significant decrease of perceived stress scores ($t(15) = -2.341$, $p = 0.033$, Figure 2(a)), situational anxiety (STAI-state subscale, $t(15) = -3.640$, $p = 0.002$, Figure 2(b)) and both anger and fatigue scores of the POMS inventory (anger: $t(15) = -5.882$, $p < 0.001$, Figure 2(c); fatigue: $t(15) = -3.878$, $p = 0.001$, Figure 2(d)). No other psychometric measure presented statistically significant modulations.

3.2 Cognitive abilities
The analysis of pre- and post-training data concerning participants' cognitive performance highlighted a significant decrease of response times during the computerized Stroop-like task ($t(15) = -2.780$, $p = 0.016$, Figure 3(a)) and during the complex RT task of the MIDA battery ($t(15) = -2.156$, $p = 0.048$, Figure 3(b)). No other performance measure presented statistically significant modulations.

3.3 Markers of neurocognitive efficiency
As for EEG markers of neurocognitive efficiency, statistical analyses highlighted a significant increase of the ABr index over frontal areas during eyes-closed resting ($t(15) = 2.262$, $p = 0.039$, Figure 4(a)) and a significant increase of the ABlock quantification

	Pre-training Mean (SD)	Post-training Mean (SD)	Effect size (Cohen's *d* values)
PSS (raw score)	12.06 (4.19)	9.94 (4.71)	0.584
STAI – state (raw score)	33.31 (5.71)	30.44 (6.90)	0.907
POMS – anger (raw score)	5.75 (4.21)	2.63 (3.16)	1.474
POMS – fatigue (raw score)	3.75 (2.46)	1.94 (2.26)	0.969
Stroop task – RTs (ms)	655.34 (72.93)	633.90 (74.70)	0.448
MIDA – complex RTs (ms)	489.06 (80.82)	458.69 (57.16)	0.539
ABr – frontal areas (unit)	2.83 (1.80)	3.75 (2.19)	0.568
ABlock – frontal areas (unit)	−0.01 (0.10)	0.08 (0.12)	0.705
ABlock – parietal areas (unit)	−0.05 (0.15)	0.15 (0.28)	0.804
HRV – resting (unit)	61.18 (18.62)	70.61 (17.80)	0.849
HRV – stressor (unit)	60.38 (19.12)	78.68 (23.92)	1.384

Notes: PSS, Perceived Stress Scale; STAI, State-Trait Anxiety Inventory; POMS, Profile of Mood States; RTs, reaction times; ABr, alpha–beta ratio; ABlock, alpha blocking index; HRV, Heart Rate Variability; ms, milliseconds

Table I.
Synopsis of statistically significant modulations of outcome measures: pre- and post-training data and effect size values
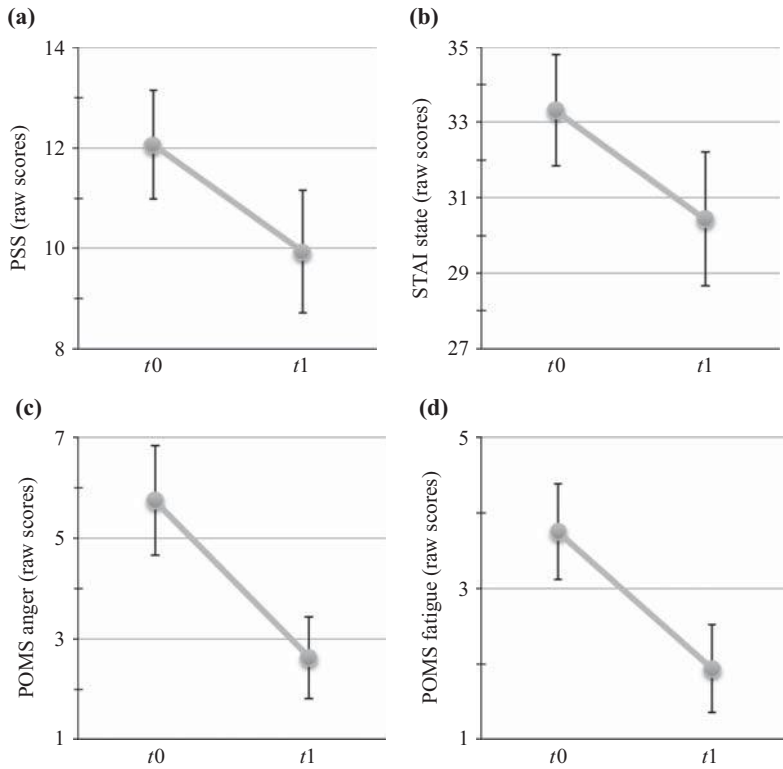
(a)

(b)

(c)

(d)

Figure 2.
Psychometric
measures, pre-
and post-training
group data

Notes: Bars represent ±1 SE. (a) Subjective level of stress as measured by the
Perceived Stress Scale (PSS); (b) situational anxiety as measured by the State-Trait
Anxiety Inventory (STAI) state subscale; (c) level of anger as measured by the Profile
of Mood States (POMS) anger subscale; (d) level of mental fatigue as measured by
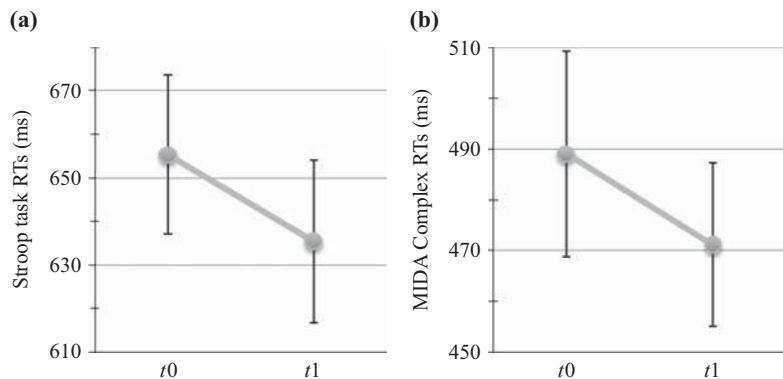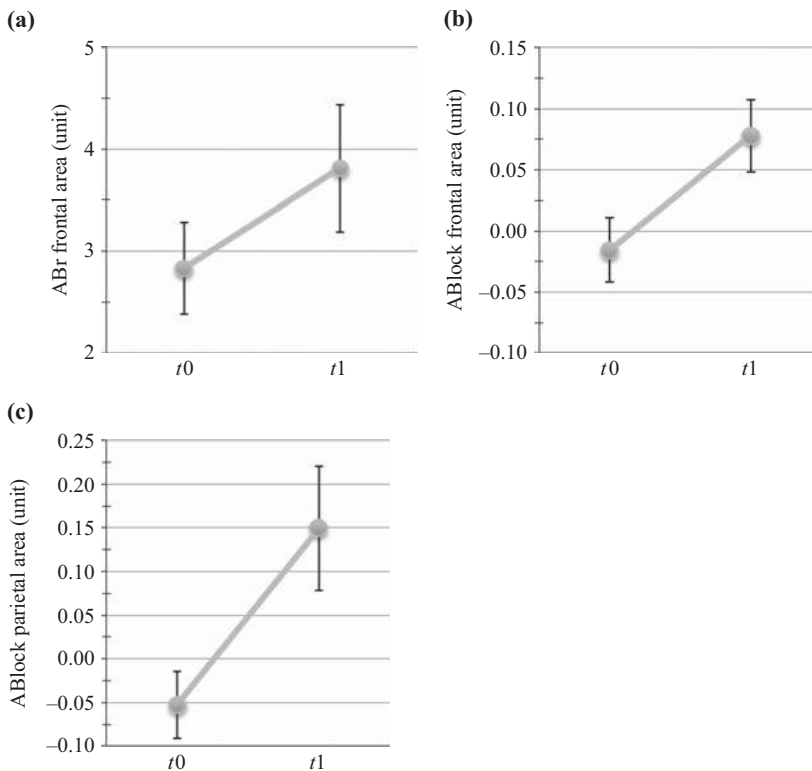the POMS fatigue subscale

(a)

(b)

Figure 3.
Cognitive performance
measures, pre-
and post-training
group data

Notes: Bars represent ±1 SE. (a) Reaction times (RTs) at the Stroop-like
computerized task; (b) RTs at the Complex Reaction Times subtask of the MIDA
computerized battery

(a)

(b)

(c)

Notes: Bars represent ±1 SE. (a) Alpha–beta ratio index (ABr) at rest, frontal area;
(b) alpha blocking index (ABlock), frontal area; (c) ABlock index, parietal area

Figure 4.
Electrophysiological
markers of
neurocognitive
efficiency, pre-
and post-training
group data

over frontal and parietal areas (frontal: $t(15) = 2.904$, $p = 0.011$, Figure 4(b); parietal:
$t(15) = 3.205$, $p = 0.006$, Figure 4(c)). No other EEG/ERP marker presented statistically
significant modulations.

3.4 Physiological markers of stress
Finally, statistical analyses of autonomic measures highlighted a significant increase of the
HRV measure during both eyes-open resting ($t(15) = 3.395$, $p = 0.004$, Figure 5(a)) and
during the exposure to a cognitive stressor ($t(15) = 5.529$, $p < 0.001$, Figure 5(b)). No other
autonomic measure presented statistically significant modulations.

4. Discussion
With the present study, we aimed at further extending previous efficacy data concerning a
novel technology-mediated mindfulness training and at testing its potential as a way to
tackle psychophysiological consequences of occupational stress at top management
organization level. Pre- and post-training data were statistically compared to evaluate the
outcomes of the training protocol in terms of subjectively perceived stress and anxiety,
modulations of mood, and cognitive performance, as well as via neurometric and autonomic
objective measures of neurocognitive efficiency (i.e. efficiency of performance at cognitive
tasks) and stress responses. At the end of the training, we observed these main results: a
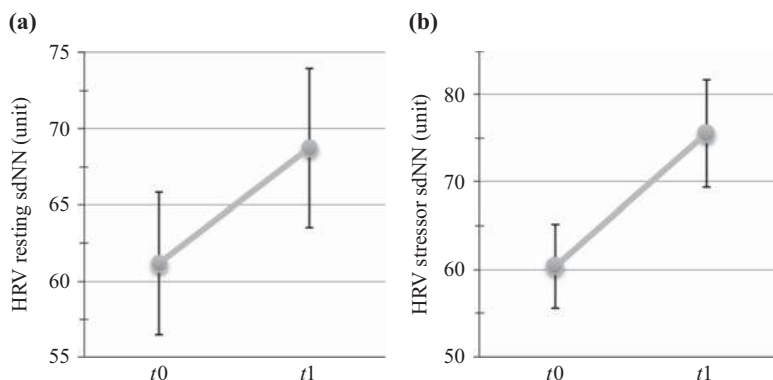
(a)

(b)

Figure 5.
Physiological markers
of stress, pre-
and post-training
group data

Notes: Bars represent ±1 SE. (a) Heart Rate Variability (HRV) measure at rest;
(b) Heart Rate Variability (HRV) measure during exposure to high cognitive load via
a cognitive stressor

significant decrease of stress, anxiety, anger and mental fatigue; a significant increase of participants' information-processing efficiency during cognitive tasks; an increase of electrophysiological markers of relaxation, ability to focus and reactivity of the mind-brain system; and improved physiological markers of equanimity and effective recovery from stress response.

Overall, the pattern of training outcomes depicts a broad positive scenario and seems to outline a potential increase of participants' well-being. Namely, perceived stress, situational anxiety and reported levels of anger and mental fatigue were lowered. Since it is now commonly accepted that dysfunctional stress levels and altered psychological health of the management staff have negative influences not only on their working and family life, but also on the well-being of their employees, on team productivity and on the effectiveness of organizations (Little *et al.*, 2007), we suggest that the tested protocol might represent a valuable training opportunity with implications both on the individual and organization welfare. In addition, available findings highlight notable practical implications for practitioners who would like to plan interventions to enable stress management skills and improve cognitive efficiency at workplace. Indeed it seemed that combining traditional approaches with highly usable and non-invasive technological devices shortens the efforts and time needed to obtain measurable improvements of cognitive and affective regulation skills even in professionals exposed to repeated stressors, with remarkable potential. Such reduction of the "dose" of practice and of practicers' commitment then translates in a reduction of monetary and time costs to implement the training protocol and of drop-outs, thus allowing to devise and offer easily accessible and replicated training opportunities by taking advantage of economies of scale and transferability.

Second, the significant reduction of perceived mental fatigue was coupled with a slight but significant improvement of information-processing efficacy, as measured by reaction times, during two challenging cognitive tasks. Such pieces of evidence, together, are in line with available literature on the effects of mindfulness practices on cognitive skills besides affective regulation ones (Lutz *et al.*, 2008; Hommel and Colzato, 2017), and depose in favor of the potential for this kind of mental training, even as a form of cognitive empowerment. Such interpretation is further strengthened by neurometric findings. Indeed, at the end of the protocol, managers presented improved objective measures mirroring the shift from a primarily agitated to a relaxed-focused mindset even at rest – a change that suggests a more

efficient containment of the carry-over effect of hyperactivation outside work environment. And again they also showed improvement of automatic responsivity of their neural system, which suggests that the protocol might have helped keeping practicers' minds fresh and responsive and reduce the negative impact of stress on cognitive functioning (Arnsten, 2009; Roozendaal *et al.*, 2009). The localization of observed effects on electrophysiological activity also supports that interpretation. Indeed, frontal and parietal areas are known to be the core hubs of a broad neural network mediating cognitive control and attention regulation and supporting the selection of relevant environmental information (Ptak, 2012) – a skill that becomes particularly critical to efficiently self-regulate and adapt our behavior to complex environments, like fluid and highly requesting business contexts (Balconi, Natale *et al.*, 2017; Crivelli and Balconi, 2017a). Therefore, we suggest that the focused attention meditation practices implemented during the training protocol lead, in addition to above-discussed effects on subjective stress and mood factors, to secondary beneficial effects on the efficiency of participants' reasoning and cognitive processes due to the training of focus and attention orientation skills.

Finally, the multi-methods assessment procedure we used also allowed us to detect a potentially interesting effect of the integrated protocol on cardiovascular measures of managers' autonomic profiles. In particular, we observed a significant increase of vagal tone, as measured by greater time-domain HRV metrics (Mendes, 2009), both during a resting condition and during exposure to a cognitive stressor. The vagal tone primarily depends on the efficiency and responsivity of the parasympathetic branch of the autonomous nervous system, which is critical for physiological recovery and down-regulation of bodily arousal after task-related or context-related hyperactivation. Therefore, HRV is considered an informative autonomic measure mirroring the impact on an individual of stressors and trying situations, as well as a valuable measure mirroring the efficiency of physiological copying skills with practical implications both for assessment and intervention on stress management in various context (Subhani *et al.*, 2018). The increase of HRV values suggests that intense mindfulness practice with the support of the wearable device was able to foster efficient psychophysiological reactivity and homeostatic mechanisms with measurable consequences even on physiological markers of stress response. Furthermore, it is worth noting that the modulation of vagal tone was found even during resting recordings, which suggests that the competences that were trained by constant practice might have partly transferred also to everyday-life functioning, besides acute stress situations. We think that this last point might be particularly important for practice in light of the broad literature on the relation between occupational stress and cardiovascular health (Collins *et al.*, 2005; Eller *et al.*, 2011; Backé *et al.*, 2012). The negative impact of work-related stress on cardiovascular activity is indeed thought to follow excessive sympathetic reactivity (i.e. dysfunctional physiological hyperactivation) during workday and altered parasympathetic recovery during leisure time (i.e. maintenance of dysfunctionally heightened physiological activation even after working hours). Introducing effective and intensive training devised to enable and optimize stress management skills of professionals at risk with the support of wearable technologies may therefore help containing health-related complications, thus lowering potential costs for the company and improving physical and psychological well-being of the workforce with limited investment with respect to standard welfare interventions.

To conclude, the present experimentation with top management professionals highlighted that the tested technology-mediated mindfulness training leads to a consistent set of outcomes, which encompassed both subjective and objective measures of psychological well-being and neurocognitive efficiency. Observed effects are also globally consistent with previous evidence from pilot and fully structured studies that tested the protocol with young adults presenting with mild-to-moderate stress levels (Balconi, Fronda *et al.*, 2017; Balconi *et al.*, 2018, 2019; Crivelli *et al.*, 2019; Balconi and Crivelli, 2019). Furthermore, it extends previous findings by

showing that, at least in a sample of professionals exposed to high stressful working conditions, it is possible to observe training effects even after two weeks of intensive practice. We suggest that this point, together with the limited time required by daily sessions of practice with respect to the notable commitment requested by traditional mindfulness protocols (typical mindfulness-based stress reduction programs include approximately one hour of daily practice), makes the integrated training a potentially valuable tool especially for people whose professional position imposes strict schedules, time limitations and elevated job duties, thus increasing the risk of drop-out from traditional stress management programs.

Despite such potential, we acknowledge that present observations would benefit from more extended testing and also from critical comparison with a control group composed by age-matched managers not involved in specific training, or even following a traditional mental training protocol with no wearable technology to support their practice and provide them with real-time feedback on their performance. This would allow us to make the practical implications of this approach stronger, and further corroborate the present empirical observations, even in light of recent findings on app-based mindfulness trainings in work environments that reported no specific support for such brief trainings (see Bartlett *et al.*, 2018). And again, it would be also interesting to investigate the effect of the technology-mediated training with samples of managers coming from different companies, or even different categories of professionals exposed to occupational and performance stress, so to evaluate the robustness of practice outcomes. Furthermore, we acknowledge that in the present project we were not able to collect outcome data concerning company climate, working experience and productivity from participants' collaborators. Future investigation would benefit from the inclusion of such additional measures concerning productivity and climate of managers' staff and companies, in order to paint a clearer picture of the extent of the impact that a training dedicated to top organization positions might have at group and company levels and to better estimate related potential economical, other than psychological, advantages.

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