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Neuroenhancement at the workplace: boosting organizations' mind

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1. The application of neuroenhancement within professional contexts: what and why

Nowadays companies are increasingly focused on the concepts of lifelong learning, continuous training, and worker well-being. On the other hand, professionals at all levels are encouraged to provide maximum results with the minimum effort, to manage energy and optimize performance and processes. But how can this continuous improvement of oneself and one's performance be promoted?

Neurocognitive enhancement is one of the possible options proposed by neuroscience discipline. Neurocognitive self-enhancement can be defined as "a voluntary attempt to improve one's cognitive skills and behavioral performance, employing neuroscience techniques able to influence the activity of neural structures and neural networks sub serving such skills and supporting cognitive performance" (Balconi et al., 2017).

At the basis of neurocognitive enhancement is the idea that the empowerment of cognitive abilities and neural efficiency can be applied across all the lifespan by systematic activation and re-activation of cortical-subcortical networks mediating cognitive functions. This process can foster brain plasticity, conceived as the ability of neural structures to strengthen existing connections and create new ones based on experience and training (Balconi et al., 2017).

Targeted neurocognitive enhancement interventions can be aimed at enhancing

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either one (or more) cognitive process and function of neural information processing system (e.g., attention, memory, perception, and learning), that certain cognitive strategies (Chapman & Mudar, 2014).

There are also three different ways to interpret neurocognitive enhancement, that is, in terms of increase, decrease, and optimization of the performance. According to the increase meaning, neurocognitive enhancement refers to interventions aimed at augmenting cognitive abilities' operation over normal functionality (Bostrom & Sandberg, 2009). In this case, the improvement is considered as an intervention finalized to enhance human operation beyond the necessary for the maintenance of a good human health condition. Secondly, the individual well-being amelioration can be obtained also by decreasing the functionality of capacity or its effects (Earp et al., 2014). Thirdly, neuroenhancement interventions could be aimed at optimizing specific cognitive functions to support and ameliorate the performance in daily tasks (Anand et al., 2011).

The aim of neurocognitive enhancement interventions is, therefore, to modulate cognitive functioning to improve performance and achieve an optimal level of functioning in a given specific task, but also to promote flexible behaviors to the external environment (Agar, 2013). Regarding the transferability of neuroenhancement effects, previous research demonstrated the application of cognitive training targeting cognitive functions improvement is useful also for the development of distinct and new performance during daily activities (Anguera et al., 2013; Au et al., 2015; Chapman & Mudar, 2013; Dahlin et al., 2008; Nyberg et al., 2003).

Given these premises, a question arises spontaneously: why to apply neuroenhancement in an organization?

At least two reasons are highlighting the potential of neuroenhancement application in a company. Firstly, it could promote well-being at work by increasing neurocognitive efficiency of workers (at every level, from junior to senior positions), and consequently it could augment workers' quality of life by improving their performance. Secondly, it could act as a preventive intervention for age management, given its efficacy in preventing cognitive decline.

What characterizes and constitutes the main advantage of neuroenhancement is the adoption of the neuroscience techniques and tools that bring together several added values, for instance:

1. in healthy samples with high-level cognitive performances there is a ceiling effect in terms of behavioral performance. However, with neuroscience tools is possible to measure the effects on the neurophysiological and psychophysiological level, which indicate that profound change has occurred;
2. objective assessment and measurability of the markers of improvement;
3. comparability between performer/performance of the same person;
4. long-lasting monitoring.

Adopting the tools of neuroscience to apply neuroenhancement protocols in the company, therefore, means working in a perspective that promotes the well-being of the

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person and the company. It takes into account the safety of neuroenhancement application and could have a virtuous impact on productivity, economy, and job satisfaction.

2. Neuroscientific tools for neuroenhancement in the company

Within this framework, neuroscience studies focused on various types of interventions that allow enhancing brain functions and capabilities (Cinel et al., 2019; Cohen Kadosh, 2014).

The effects of new non-invasive cognitive enhancement treatments have been explored for their induction of neuromodulation or neurostimulation effects on the brain. Specifically, on one hand, several studies have observed the efficacy of non-invasive brain stimulation techniques (NIBS) such as transcranial electrical stimulation (TES) on the enhancement of cognitive functioning (Brunoni et al., 2012). On the other hand, different studies have demonstrated the effects of awareness-based techniques, that promote cognitive enhancement through cognitive processes regulation (Balconi et al., 2017; Bhayee et al., 2016).

Between these latter techniques, neurofeedback (NF) demonstrated to be efficacious in cognitive enhancement on healthy individuals (Gruzelier, 2014). NF is a technique based on the principle of operating conditioning that allows individuals to learn to self-regulate their cortical activity. The basic principle of NF could be conceived as a loop. Indeed, NF measures the individual brain activity, then it processes the brain patterns of interest (e.g., alpha waves for relaxation) and provides the user with audio or video feedback stimuli related to the activity of processed cortical rhythms. Briefly, NF devices collect electroencephalographic (EEG) brain waves signal and effectively provide real-time feedback on the person's mind-body state activity (Gruzelier, 2014).

Compared to traditional NF, new NF wearable device added value lies in the high usability, low-cost and portability. NF wearable devices' reliability in quality signal was previously compared with EEG signal and demonstrated good quality standard and precise feedback (Balconi et al., 2017; Bhayee et al., 2016). Nowadays wearable devices provide actual opportunities to easily make even naïve practisers access to implicit markers of their internal neural and bodily states (e.g. EEG rhythms) and process such information at the conscious level. Data on the outcome and efficacy of a mental training protocol supported by these wearable brain-sensing devices showed the devices helped practisers to train and optimize the efficiency of attention regulation, control, and focusing skills. These effects are marked by a reduction of response times during complex cognitive tasks without loss of accuracy. Moreover, at the central level, an enhancement of event-related electrophysiological potentials marking early attention orientation and cognitive control was detected (Balconi & Crivelli, 2019). The adoption of wearable neurotechnology

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could be a feasible way to apply neurocognitive enhancement in the company, given the devices are practical, easy-to-use, the feedback interface is user-friendly, and the system is adequate for professionals of all levels.

To summarize, the main advantage of NF technique is that critically grounds on the active role of the participant (since it applies the principles of operant conditioning) and, in this way, it promotes plasticity and cognitive empowerment by actively training participants' self-awareness and active control over physiological correlates of cognitive skills. In contrast, NIBS are based on externally-induced stimulation or modulation of ongoing neural activity and do not necessarily require the active engagement of the stimulated individual (Enriquez-Geppert et al., 2013). It has been suggested that is exactly such peculiar feature of NF empowerment interventions that might have additional results on long-term retention of training effects since the participants are directly involved in finding and consolidating personalized strategies to intentionally modulate their neurophysiological activity.

In addition to neuromodulation and neurophysiological self-control techniques, other studies have observed the efficacy of mental awareness-based practices on neurocognitive improvements, such as mindfulness. Indeed, in recent years, the strive to improve personal potential and efficiency of cognitive functioning also lead to the revival and the renewed diffusion of mental training activities.

A growing literature on the effects of mental training and meditation practice highlighted their potential for modulating overt behaviour and covert psychophysiological activity (Quaglia et al., 2016) and for inducing short-term and long-term empowerment effects on cognitive and emotion regulation skills (Balconi et al., 2017; Keng et al., 2011). In particular, mindfulness application for self-empowerment in non-clinical settings such as the workplace, notably grew, likely because it allows the practiser to train focusing, monitoring, and attention skills by engaging and maintaining a specific aware and attentive mindset (Bartlett et al., 2019).

In Western culture, mindfulness is defined as a peculiar form of mental training based on self-observation and awareness practices focused on the present and requiring conscious intentional focusing on and acceptance of one's bodily sensations, mental states, and feelings, nonjudge mentally, and moment by moment (Kabat-Zinn, 2003).

Recently it has also been shown as a chance to increase individual psychological well-being (Balconi et al., 2017; Crivelli et al., 2019b; Keng et al., 2011). It allows one to perceive and accept consciously individual's mental states and the associated physiological feelings (Keng et al., 2011). Besides, previous research has shown the efficacy of mindfulness training also on several cognitive functions, such as in attention self-regulation and sustained attention (Balconi et al., 2019; Crivelli et al., 2019b), preventing working memory decline (Jha et al., 2017), reducing cognitive reactivity and mental rumination (Raes et al., 2009) and decreasing physiological stress reactivity markers (Balconi et al., 2018; Crivelli, Fronda, & Balconi, 2019b).

Despite many neurocognitive enhancement techniques were originally developed

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for clinical application, they are now increasingly applied for the empowerment of healthy individuals. Several studies have shown the beneficial effects of neurocognitive enhancement on health promotion, autonomy, and success (Bostrom & Sandberg, 2009; Clark & Parasuraman, 2014; Greely, 2008) increase in learning and acquiring skills in complex tasks related to demanding professions (Coffman et al., 2014; Parasuraman & McKinley, 2014), but also in work engagement (Liu et al., 2020), and leadership and job performance (Bartz, 2018; King & Haar, 2017).

Formerly, it has been reported a brief overview of the main non-invasive neurocognitive enhancement methods, ranging from neuroscientific techniques (such as NIBS and neuro/biofeedback) to cognitive mental training (such as mindfulness). Comprehensively, for obtaining greater neuroempowering effects a combination of these methods could be adopted. These techniques could also be useful to train workers' ability to cope with daily working issues. Mindfulness could be helpful to be mentally present in the moment and facing the task, while its combination with neurotechnology could boost the development of the awareness of one's capacity and support problem solving.

In line with this, we recently demonstrated the efficacy of the combination of mindfulness-based practices supported by NF techniques (Balconi et al., 2017). Adaptive changes in neurocognitive activity and brain connectivity induced by mental training might be further increased by providing practisers with additional valuable information on the modulation of their psychophysical states due to practice.

3. Neurocognitive efficiency at the workplace

Below the first systematic report of the application of such methodology in an organization and with top management professionals will be described.

Specifically, we applied a technology-mediated mental training protocol for the empowerment of neurocognitive efficiency in highly stressful professional contexts, with people who occupy top management positions. This innovative neurocognitive protocol specifically combines mindfulness practice and a wearable NF system managed via smartphone (Balconi & Crivelli, 2019). Sixteen top managers were selected based on their formal company position, with a specific role as managers who lead a group of resources of at least 10 people, with a long experience of at least 5 years in people management. They belonged to some main companies representing national or international top companies in some specific sectors (services, transport, food, consulting, advertising, insurance). The training protocol has been validated by previous research in both experimental and applied contexts (Balconi et al., 2017; Balconi & Crivelli, 2019; Crivelli, Fronda, & Balconi, 2019a; Crivelli et al., 2019a, 2019b).

After the two weeks of training, results showed a significant increase in participants' information-processing efficiency during cognitive tasks; an increase of electrophysiological

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markers of ability to focus and reactivity of the mind-brain system, and a decrease of mental fatigue. This evidence is in line with the available literature on the effects of mindfulness practices on cognitive skills (Hommel & Colzato, 2017; Lutz et al., 2008), 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 indices indicating the shift from a previously agitated to a relaxed-focused mindset. A change that suggests a more efficient containment of the carry-over effect of hyperactivation outside the work environment.

The localization of the observed effects on electrophysiological activity also supports this interpretation. Indeed, frontal and parietal areas are known to be the core hubs of a broad neural network mediating cognitive control, attention regulation, and supporting the selection of relevant environmental information (Ptak, 2012). This latter is a skill that becomes particularly relevant to efficiently self-regulate and adapt our behavior to complex environments, like fluid and highly requesting business contexts (Balconi et al., 2017; Crivelli & Balconi, 2017).

Therefore, we suggest that the focused attention meditation practices implemented during the NF training protocol lead to beneficial effects on the efficiency of participants' reasoning and cognitive processes due to the training of focus and attention orientation skills.

Overall, 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.

Available findings highlight notable practical implications for practitioners who would like to plan interventions to enable stress management skills and improve cognitive efficiency at the 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 high demands.

Such reduction of the "dose" of practice and users' commitment then translates in a reduction of monetary and time costs to implement the training protocol and of drop-outs. This allows to devise and offer easily accessible and replicated training opportunities by taking advantage of economies of scale and transferability.

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4. Prevention interventions for age management and attention regulation

Another evident advantage of applying neuroenhancement protocols at the workplace regards age management interventions.

Indeed, in the last decade, the systematic shift of employment quotas in favor of over-50 professionals has been observed in Italy. These changes have brought new challenges in terms of maintaining the performance of senior workers and their subjective well-being.

In the context of age management interventions, recent neuroscientific studies have shown the effectiveness of NF protocols on stress reduction and cognitive efficiency in a sample of senior managers. Starting from this evidence, an integrated neurocognitive training protocol was developed for the empowerment of cognitive, metacognitive, and social functions in managers over 50. A first pilot case carried out an intensive three-week protocol consisting of i) neurofeedback training via wearable device; ii) cognitive training focused on cognitive flexibility, working memory, multitasking, reasoning, creativity and problem-solving; iii) metacognitive-social training focused on perspective-taking, self-awareness, and self-regulation (Balconi et al., 2020).

The effects of the training were assessed with a pre- post-training multilevel assessment. Psychometric, neuropsychological, and behavioral outcome measures have been integrated with the detection of neurometric (EEG) and autonomic markers (Heart Rate, HR; Heart Rate Variability, HRV) at rest and during the execution of challenging tasks.

Preliminary results suggest an increase in working memory performance, cognitive flexibility, problem-solving, inhibitory control, self-awareness, and self-regulation, as well as a decrease in perceived stress levels. The analysis of the EEG and autonomic task-related markers (event-related potentials N200 and P300, power alpha and beta, HR) consistently show a profile of greater neurocognitive efficiency. The preliminary results highlight the potential of the integrated intensive protocol as a valid option for preventive age management interventions in high-level professional contexts.

Furthermore, in a preventive manner, a similar NF protocol was applied in a critical and acute stress context, that is the driving performance, in which focused and sustained attention, inhibition of distractors and control of motor response are considered to reduce distractibility and to promote functional behavior (Balconi & Angioletti, 2020).

Specifically, the study aimed to explore the effects of a neurocognitive enhancement protocol supported by wearable NF on the cognitive performance of drivers, observing the markers behavioral and electrophysiological (event-related potentials, ERP) of the ability to regulate attention. Fifty healthy drivers participated in the study. The experimental participants completed an intensive enhancement protocol based on mental training practices supported by NF, while controls have completed an alternative protocol based on

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breathing practices, without the support of the device. All participants were drivers subjected to a pre/post-training evaluation, which included the execution of a cognitive task during the immersive driving experience, standardized computerized tests, and the simultaneous recording of ERPs markers of attention and cognitive control. Results showed better performance in signal detection for the task cognitive experience immersive post-training with neurofeedback in the group receiving the NF training compared to controls, as well as higher electrophysiological markers related to orientation activity and processes cognitive control (greater amplitude of the ERP component N200).

Such evidence suggests practical implications for the development of neurocognitive protocols proactive prevention measures to increase driving performance, to improve mechanisms of focused and sustained attention of drivers.

5. Conclusion and remarks

Concerning the company context, the debate on the potential and the opportunities of different methods and techniques for neuroenhancement was mainly fuelled by the growing complexity and competitiveness in both social and professional contexts, but also by the drive to ever greater performances.

Indeed, in recent years neuroethics highlighted ethical implications of neuroenhancement interventions at different levels in terms of safety, autonomy, justice, moral, and potential negative impacts on society and professional contexts (Farah et al., 2004; Fronda et al., 2018, 2019). From an ethical perspective, two major concerns should be considered when applying neuroenhancement interventions in a company. On one hand, these interventions were judged as a threat to inter-individual equity and tend to suppress inter-individual differences (Butcher, 2003). On the other hand, previous studies have criticized healthy individuals' neurocognitive enhancement as an intervention that can change individual's personality, removing features that represent individuals' unique personality traits (Farah, 2005; Wolpe, 2002).

However, there are also several potential positive effects and the usefulness of neurocognitive enhancement can be appreciated in various applied contexts. As mentioned above, several studies highlighted the efficacy of neurocognitive enhancement techniques in the improvement of cognitive processes. Of great interest for the professional working context, some studies have observed the possibility, provided by neurocognitive improvement techniques, to remove social unfair inequalities (Bostrom & Sandberg, 2009) and to produce individuals and social positive effects, demonstrated by the increase of some functions operation such as working memory, attention, and cognition, and by the improvement of performance and successful activities (Balconi & Pozzoli, 2005; Sahakian, 2007).

Considering the strengths and weaknesses of neuroenhancement applications, but

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also its ethical issues, it is here proposed that integrated neuroenhancement protocols adopting mental training and non-invasive techniques (such as NF) could be perhaps the fittest current and more appropriate practice for the company context.

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