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Do managers "feel" the group? Managers' autonomic responses during a creative task

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Abstract

This study aimed at assessing the psychophysiological correlates of managers, compared to a group of non-managers, during a creative problem-solving dynamic through the use of a psychophysiological method exploiting autonomic measures data collection. Individuals performed a realistic complex problem-solving task (RCPT), a modified version of the NASA Moon survival problem exercise, in two distinct conditions: individually or in groups of three participants. Two main patterns of findings were observed, specifically, for the managers' group: first, electrodermal activity and cardiac variability indices increased during the group compared to individual condition; second, cardiovascular indices decreased in the above-mentioned condition. No statistically significant results were observed for the non-managers group. Results suggest that managers could be able to "feel", even at a deeper and psycho-physiological level, which social condition (in this case, the group one) is more suitable for solving a complex problem in a creative way.

Keywords: creativity; problem-solving; autonomic indices; manager; neuromanagement

1. Introduction

Management nowadays must face the challenge of promoting creativity inside the working environment. Modern organizations tend to rely more not only on knowledge and skills, but also on creative visions, personal experience, and innovation (Wróblewska, 2015). Thus, managers and their collaborators are required to develop and utilize creative thinking, expertise, and motivation to be able to face daily challenges in a globalized working environment.

Creative problem-solving and intuitive thinking are typical of entrepreneurial personalities, and they can usually promote innovation (Wróblewska, 2015). According to Besemer & O'Quin (1999), the definition of creative problem-solving concern in the development of high-quality, novel, and elegant solutions to complex and ill-defined problems, Along with idea production, it also calls for activities like problem identification, data gathering, and idea assessment (Hunter et al., 2007). As a result, the analysis of creative problem-solving dynamics and processes developed by managers working individually and in groups could be of high interest to the organizational setting.

Creative thinking is supported by the brain-and-body axes activation, encompassing both neuropsychological processes, as well as physiological responses (Frith et al., 2020; Zhou et al., 2017). Previous research adopted electrophysiological (EEG) and neuroimaging techniques to explore the neurophysiological processes during creative problem-solving (Fink et al., 2009; Sawyer, 2011). However, the use of neuroscientific techniques applied to the central nervous system (CNS) provides information only on the neurophysiological activation and investigates a portion of the complete picture related to the overall activation of the person, neglecting the peripheral activation. In fact, it is well known that emotions and body responses interact with cognition, especially during complex problem-solving and decision-making (Frith et al., 2020).

Cognitive processes are embodied in sensorimotor systems: body movements or body postures can lead to fluid thinking and creative idea generation (Hao et al, 2017). Interestingly, Silvia et al. (2014) found that people with high creative achievement (measured with the Creative Achievement Questionnaire, CAQ; Carson et al., 2005) generated higher creative ideas and display significantly higher sympathetic activity augmentation from baseline to task (Silvia et al., 2014). On the other hand, Ghacibeh et al. (2006) showed how stimulating the vagus nerve can lead to an impairment of creativity performance and cognitive flexibility levels, thus suggesting that peripheral activations can even negatively affect the cognitive performance (Ghacibeh et al., 2006).

Before, autonomic nervous system (ANS) indices, such as heart rate variability (HRV), were shown to be informative of brain cognitive load and stress overload (Tomasino, 2007; Wróblewska, 2015). For instance, a former work detected employees mental stress based on Heart Rate (HR), HRV, and other markers in office-like situations (Wijsman et al., 2013). Another study conducted in a business environment explored how measuring the HRV of business administration majors can help determine how deep breathing affects the outcomes of decision-making (De Couck et al., 2019). Specifically, HRV is considered to be reflective of the heart-brain interactions, providing information related to different emotional states (Wróblewska, 2015), health, and wellbeing (Tomasino, 2007).

Moreover, prior research has shown that physiological activity is connected to interpersonal mechanisms, such as empathy (Levenson & Ruef, 1992) and other social and emotional behavior (Adolphs, 2003; Balconi & Lucchiari, 2005). For instance, it has been demonstrated that the physiological reaction may discern between various emotions (Levenson, 1992; Balconi & Vanutelli, 2017a), provide information about the development of sophisticated cognitive processes (such as social dilemmas) (Grossmann et al., 2016), or even illustrate the relationships and social connection between individuals (Chaspari et al., 2015; Vanutelli et al., 2017). Evans and Steptoe (2001) reported that working alone, with a lack of social support, was linked to greater daily HR, that persisted into the night of workdays (Evans & Steptoe, 2001). In a subsequent study by Wright et al., the link between cardiovascular indicators and psychological well-being in occupational contexts was also shown (Wright et al., 2009).

Also, with reference to the organizational contexts, leadership was explored through autonomic indices on sample of leaders and employees. In a first study, employees' psychophysiological responses (HR and indices of electrodermal activity [EDA], including skin conductance level and response, SCL and SCR) were explored during a dyadic ecological performance review in which the managers rated the employee through a quantitative or narrative assessment (rate versus non-rate condition) (Balconi, Venturella, Fronda, De Filippis, et al., 2019).

Researchers discovered that couples in the non-rate condition displayed stronger arousal-related reactions (SCL and SCR), which may have highlighted an increase in involvement brought on by a rewarding exchange. Employees in the rate condition, on the other hand, displayed greater HR, which is typically correlated with adverse and stressful circumstances as well as avoidant behaviors.

According to another work (Balconi, Venturella, Fronda, & Vanutelli, 2019), the use of univocal vs reciprocal feedback (given only by the leader or by both individuals) as well as the assignment of a quantitative or just a qualitative assessment can influence autonomic indices. The results showed a stressful response (increased HR) during the rating and unidirectional condition as well as higher emotional engagement (SCL/SCR) during the no rating and reciprocal condition. These works illustrated the viability and high ecological validity of recording autonomic measurements in organizational environments and shed light on the psychophysiological reactions of leaders and employees by modifying specific variables of importance for the organizational context.

Indeed, because neuroscientific tools can be highly susceptible to movement artifacts and are often applied in the laboratory, they are not always the most adequate choice when trying to create ecological settings that replicate genuine social dynamics. Contrarily, psychophysiological measurements may be obtained using portable devices that are less expensive and yields easily accessible findings (Massaro & Pecchia, 2019).

Moving towards the field of creativity, recently Lee et al. (2022) used EEG and indices of cardiovascular activity to study how creative ideation in work-related problem-solving is affected by stress. According to the presence and intensity of stress, authors demonstrated considerable variations in participants' ability to solve business problems creatively. When compared to the non-stressed group, the stressed group's degree of business problem-solving creativity was comparatively low, and it was accompanied by an increase in HR and a decrease in HRV (Lee et al., 2022).

Given these premises, the current study investigated the psychophysiological differences (in terms of autonomic indices variation) between managers and non-managers in performing a creative problem-solving task in two distinct conditions: an individual and a group condition. According to what has been discussed so far, we believe that, given their expertise and the high creative achievements requirement that they must face, managers could show a different psychophysiological profile compared to non-managers during the creative problem-solving task. Moreover, considering the positive impact of reciprocal interactions (Balconi, Venturella, Fronda, & Vanutelli, 2019) and social support (Evans and Steptoe, 2001) on autonomic indices, we expect to observe psychophysiological markers of emotional engagement (such as an increase in EDA) and low-stress levels (a decrease in cardiovascular indices and an increase of HRV) during the group compared to the individual condition.

2. Method

2.1 Participants

This study was conducted on 27 individuals with an age range from 21 to 54 years old (Mean age = 36.50; Standard Deviation (SD) age = 14.50). The sample was composed of 15 managers recruited from an automotive company and a convenience group of 12 participants (selected as non-managers) enrolled from the Catholic University of the Sacred Heart, Milan, Italy. Normal visual acuity, or adjusted to normal visual acuity, was between the criteria required for enrollment. The existence of sensory and cognitive deficiencies, a history of neurological or psychiatric conditions, and current psychoactive drug-based treatments that may affect how the CNS functions were used as exclusion criteria. Within each group (managers versus non-managers), participants were divided into triplets at random and instructed to complete a creative task. For their participation in the study and permission for data publication, participants signed written informed consent.

The study procedure was carried out in accordance with the Declaration of Helsinki (2013) and was approved by the ethics committee of the Department of Psychology, Catholic University of the Sacred Heart, Milan, Italy.

2.2 Creative problem-solving task

The Realistic Complex Problem Task (RCPT) was used in both the individual and group conditions of this study. For the RCPT, a modified version of the NASA Moon Survival problem exercise (Hall & Watson, 1970) was used to gauge the originality and creativity of the decision made. The following instructions were given to each participant:

"You will now be presented with a brief situation. We ask you to read it carefully and to answer some questions, putting yourself in the situation presented and trying to use an unusual but innovative way of thinking."

The script that follows, which describes a complex problem that is realistic, was then presented:

"You have been selected to participate in a work-related dinner taking place in a countryside house of your CEO, in which the top management team of your corporation is participating. Unofficially, you have been informed that there is a chance that your team will receive more funds and more room for decision. So, you will have to provide a detailed report of the projects realized in the past two years, along with reached goals. You are perfectly on time, though before reaching the destination, the van you are traveling with begins to startle and stops abruptly, due to an engine malfunctioning, without repair. You find yourself on a secondary countryside road with no cars passing and no houses nearby, at 10 km far from the destination. It's 8 pm and the dinnertime is set for 8.30 pm. You then check your phones to see that you are out of service. Searching in the car, you find several objects."

The participants were then given a list of 16 items, which included a laptop with a charger, a block note, pens, a laser pointer, an umbrella, a lighter, a torch, hand sanitizer, a long-sleeve shirt, an empty water bottle, a pair of headphones, a pack of paper tissues, smartphone with charger, the emergency warning triangle, first aid kit, the parking disk.

After carefully reading the list, each participant was instructed to select 3 items from the available 16 options. The directions below were given for the specific condition:

Each participant was instructed to select 3 items from the available 16, after carefully reading the list. The following instructions were given for the specific individual condition:

"You can bring 3 items with you to help you reach your destination before dinner is over and to take part in the meeting. Attention! Given the limited time available to complete this last part of the journey, you will have only 5 minutes to decide whether or not to bring each individual object with you and to express the reasons for the choice, preserving a criterion of innovation and trying to contemplate an innovative use of objects. Try to provide a motivation for the choice of each object using a creative, innovative, and unusual way of thinking."

Following the individual condition, the following instructions were given for the task's performance in the group (group condition):

"Now we ask you, by discussing it with your colleagues, to converge on the choice of three objects that the group will bring with it. For each object you are asked to express the reasons for the choice, preserving a criterion of innovation and trying to contemplate an innovative use of objects. You will have 10 minutes to choose the three objects and provide an explanation for each of the chosen objects."

2.3 Experimental procedure

Individuals took part in the experiment in a silent room and were instructed to take a seat comfortably in front of a circular table where the experiment was conducted. For the experimental procedure, autonomic measures were continuously collected (Figure 1ab). To start a 120-second resting baseline was collected by asking the participants to maintain a comfortable position.

Then, the RCPT, a modified version of the NASA Moon Survival problem exercise (Hall & Watson, 1970), was explained to subjects.

For the individual condition, participants had five minutes to find a solution individually. Participants were specifically instructed to read the

RCPT description and select only 3 of the 16 objects that may be used in a creative way to address the complex problem proposed in the RCPT.

During the group condition, the participants were divided into small groups of three people, triplets, and they were given 10 minutes in which to discuss the objects they had chosen individually and begin negotiating over which 3 (in total) to keep coming up with creative solutions to the complex problem. Each group was given an equal amount of time and told to use the group consensus approach, as defined by Hall and Watson (1970) and used in a former study (Meslec & Curşeu, 2013).

Participants were video recorded as the tasks were being completed, and response times were recorded for both the individual and group condition: the duration of the experiment was around 30 minutes.

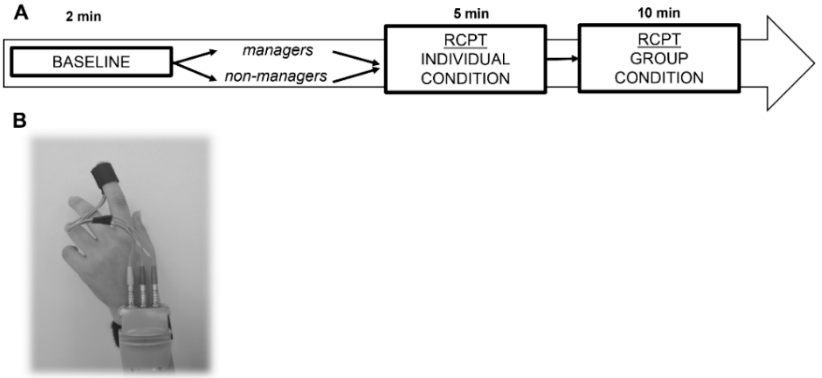

Figure 1ab. Study procedure. (a) Description of the experimental procedure. (b) Biofeedback 2000X-pert device with a MULTI radio module (Schuhfried GmbH, Mödling, Austria) montage, over the non-dominant hand

2.4 Autonomic measures recording

Using the portable Biofeedback 2000X-pert device with a MULTI radio module (Schuhfried GmbH, Mödling, Austria), the autonomic activity was non-invasively recorded. A peripheral sensor was attached to the second finger of the non-dominant hand's distal phalanx to record data. This device enables the measurement of SCL, SCR in μS, and HR in beats per minute (bpm). The SCL value was collected with an EDA gold electrode using current-current measurement at a sampling frequency of 2 kiloHertz (kHz). Polarization is avoided when an alternating voltage is used. With a sampling frequency of 20

Hz, the SCL calculation has a measurement precision of 12 nanoseconds (ns). Photoplethysmography was used to assess PVA, BVP, and HR at a sampling frequency of 500 Hertz (Hz). To prevent hand movements from interfering with the recordings, the transmitting unit's accelerometer, calibrated in meter/square second (m/s2), was used to track the movement of the non-dominant hand.

After data have been thoroughly examined qualitatively and quantitatively to find and remove biological or motor (recording) artifacts, standard measures of cardiac activity (HR, inter-beat interval [IBI]) and a measure of HR variability (HRV, as the standard deviation of IBI) were calculated in order to have a comprehensive picture of stress-related cardiac responses and vagal tone, which is associated with the operation of parasympathetic recovery mechanisms that promote the return to bodily homeostasis by down-regulating the arousal response (Mendes, 2009).

2.5 Statistical data analysis

Autonomic indices data were collected continuously during the tasks. The kurtosis and asymmetry indices were adopted to determine the normality of the data distribution. For statistical analyses, a set of paired t-tests (IBM SPSS 25) with Group (2: managers and non-managers) as between-subject factor and Condition (2: individual and group) as within-subject factors was computed for each of the following autonomic indices: SCL, SCR, BVP, PVA, HR, IBI, and HRV. Preliminary Levene's tests were computed to test the homogeneity of variances between the two groups and to adapt the computation of subsequent inferential tests accordingly.

3. Results

3.1 Autonomic results

3.1.1 SCL and SCR

For the SCL index, a significant effect was found in the managers' group for the variable Condition ($t(14)= 4.34$, $p = .01$). Higher mean values were found in the group compared to the individual condition (Figure 2a).

Regarding SCR, a significant effect was detected in the managers' group for the variable Condition ($t(14)= 3.98$, $p = .01$). Greater mean values were collected in the group compared to the individual condition (Figure 2b).

For these indices there were no other statistically significant effects.

3.1.2 Cardiac indices (BVP, PVA, HR, IBI and HRV)

Considering the BVP index, a significant effect was observed in the managers group for the variable Condition (t(14)= 5.45, p = .01). Lower mean values were found in the group confronted with the individual condition (Figure 3a).

Also, a main effect was found for the PVA index in the managers' group for the variable Condition (t(14)= 4.47, p = .01). Lower mean scores were observed in the group compared to the individual condition (Figure 3b).

A similar effect was found for the HR index in the managers' group for the variable Condition (t(14)= 5.89, p = .01). Lower mean scores were observed in the group compared to the individual condition (Figure 3c).

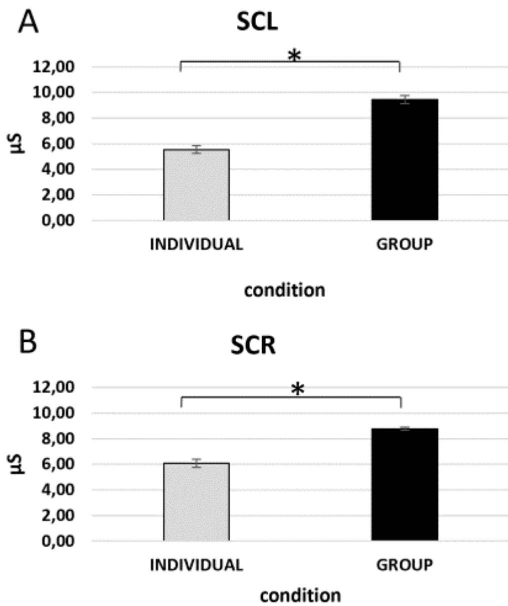

Figure 2ab. Electrodermal activity results. Bar charts show higher SCL (a) and SCR (b) mean values for the managers group in the group compared to individual condition. For all charts, bars represent ± 1 SE; the asterisk marks statistically significant differences, with p ≤ .05

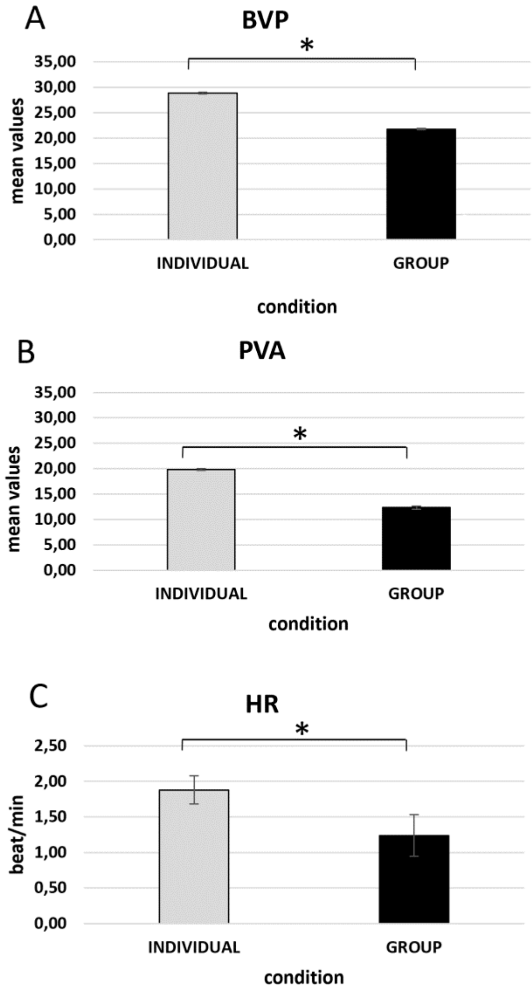

Figure 3ac. Cardiovascular indices results. In the graphs, the lower BVP (a), PVA (b) and HR (c) mean values for the managers group in the group compared to individual condition were displayed. For all charts, bars represent ± 1 SE; all asterisks mark statistically significant differences, with p ≤ .05

For the IBI index, a significant effect was observed in the managers' group for the variable Condition (t(14)= 4.59, p = .01). Higher mean values were detected in the group confronted with the individual condition (Figure 4a).

Concerning HRV, a significant effect was identified in the managers' group for the variable Condition (t(14)= 4.09, p = .01). Higher mean values were collected in the group compared to the individual condition (Figure 4b).

No other statistically significant effects were detected for these indices.

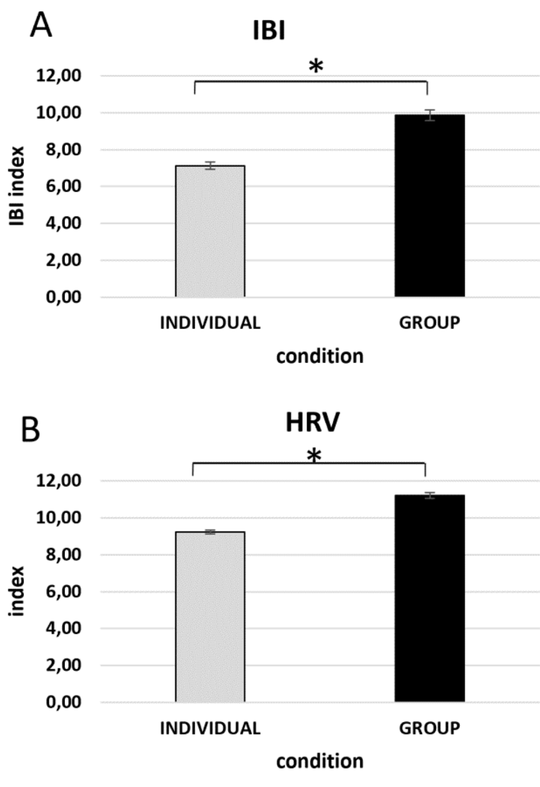

Figure 4ab. Cardiac variability indices outcomes. Bar graphs display a significant greater presence of IBI (a) and HRV (b) in the managers group in the group compared to the individual condition. For all charts, bars represent ± 1 SE; all asterisks mark statistically significant differences, with p ≤ .05

4. Discussion

The current research explored the psychophysiological correlates of managers, compared to a group of non-managers, during a creative problem-solving dynamic by exploiting autonomic measures recording. Participants performed a complex problem-solving task, the RCPT, which is a modified version of the problem exercise developed by Hall and Watson (1970) in two distinct conditions: individually or in groups of three participants. Two main patterns of findings were observed for the managers' group: first, EDA, both SCL and SCR, and cardiac variability (IBI and HRV) indices increased during the group compared to individual condition; second, cardiovascular indices, including HR, BVP, and PVA, decreased in the above-mentioned condition. No statistically significant results were observed for the non-managers group.

Concerning EDA indices, literature shows that skin conductance is one of the most accurate physiological indicators of emotional and empathic reactivity (Marci et al., 2007) and its assessment during interpersonal exchanges marks arousal variations (Lidberg & Wallin, 1981; Sequeira et al., 2009; Sohn et al., 2001). Moreover, former studies observed an increase of both SCL and SCR indices in organizational conditions featured by increased emotional engagement and positive rewarding feedback (Balconi, Venturella, Fronda, & Vanutelli, 2019; Balconi, Venturella, Fronda, De Filippis, et al., 2019). According to our hypotheses, greater values of these indices for the managers' group during the group compared to the individual condition could be in line with the increase of emotion and empathic responsiveness due to perceived social support experienced during the sharing of the creative ideas and the selection of the creative solutions.

This EDA effect was accompanied by an increase in cardiac variability indices (IBI and HRV) during the group compared to the individual condition for the managers' sample. Greater values of HRV suggest the capability of the individual to positively face stress and potentially adverse conditions. In a recent study, Lee et al. (2022) showed that the presence of low HRV values connoted a stress condition, and this condition negatively impacted the business problem-solving creativity. Regarding creative functioning, it was previously suggested that cardiac variability might mark cognitive shifts in subject's direction toward and away from the environment (from more realistic to imaginal modes of thinking) and that the extent of such cardio-cognitive shifting is straightforwardly connected with imaginative production (Bowers & Keeling, 1971). Therefore, in the current study, it seems the group condition may have been the best ground for creative exchange needed for completing a realistic problem-solving task, at least for the group of managers.

Conversely, cardiovascular indices reflect the polarity of the emotional reaction and the metabolic adaptation to environmental requests (Sequeira et al., 2009). For instance, earlier studies linked HR acceleration with the perception of unpleasant versus pleasant images (Palomba et al., 1997; Solbakk et al., 2005) and stressful conditions (Lee et al., 2022; Nagai et al., 2004). Also, an increase in HR was observed in conditions of quantitative rating and unidirectional feedback in neuromanagement studies (Balconi, Venturella, Fronda, & Vanutelli, 2019), compared to qualitative rating and reciprocal feedback in which HR was lower.

In this study, we observed how in the group condition, lower values of cardiovascular indices were reported, compared to the individual condition, thus suggesting this was the condition perhaps attributable to a more positive emotional valence and less stressful. It is well known that the emotional state may have an impact on creative dynamics. In fact, positive attitude and affect promote divergent thinking, exploring alternative opportunities, and improving creativity (Frith et al., 2020). Positive emotional states are associated with information processing modalities that support creativity and flexible thinking (Wróblewska, 2015). Increased dopamine levels in positive emotional states improve creative thinking by facilitating the switching between several solution alternatives (Hao et al., 2017). Also, in the study of Lee et al. (2022), the non-stress group was the one with lower HR and with higher creative ideas in the business complex dynamic.

Thus, in addition to the existing body of knowledge, this study shows that the group of managers displays a physiological reaction suggesting the group condition would seem to be a more positive condition in which to solve a realistic problem-solving challenge. Previous studies discussed that managers are exposed to greater occupational stress associated with an altered autonomic profile (due to challenging situations, competitions, and other work-related conditions) that can be improved by different psychophysiological training (Munafò et al., 2016; Patron et al., 2020). However, it may be possible that their expertise even influences their autonomic profile "in a positive way", helping them to implicitly recognize "the best way" to face complex challenges, in this case by displaying a specific autonomic profile marking the group condition

It may be argued that managers could be able to "feel", even at a deeper and psycho-physiological level, which social condition (in this case, the group one) is more suitable for solving a complex problem in a creative way. Whether this ability to "feel" consists of an individual difference of trait or status, or is a skill learned in relation to the occupational role held, must be determined by further studies. This specific autonomic profile showed by the professional category of managers opens new avenues for managerial skills training that could be also based on the recognition of one's own bodily responses in different working conditions.

This study presents some caveats. The sample size, obtained through a convenience sampling method, and the recruitment site, which was a specific company and university in Italy, can limit the generalizability of our findings. Also, this study relied on autonomic measures only, while future research in the field could benefit from the addition of self-report measures measuring for instance individual differences in generating creative ideas, especially if considering specific target groups, such as managers. Or again, managers' responses could be explored during tasks that measure the creative decision making process (Angioletti et al., 2024), combining them with psychophysiological measures.

Despite recent studies in the neuromanagement and clinical field (Angioletti et al. 2019, 2020), highlighted the intrinsic and ecological value of considering the peripheral responses associated with cognitive and emotional processing in different applied contexts, like during a professional assessment (Balconi, Venturella, Fronda, & Vanutelli, 2019; Balconi, Venturella, Fronda, De Filippis, et al., 2019) or during a business case problem solving (Lee et al., 2022), others stressed the need of a multi-methodological approach, integrating techniques collecting the neural markers of the creative process in business contexts (such as EEG and functional Near Infrared Spectroscopy; Balconi et al., 2017, 2021).

Future studies could also adopt more complex experimental implant and calculation approaches, like hyperscanning paradigm, that permit for evaluating the progress of brain and body dynamics while individuals are engaged in an interactional exchange (Balconi et al., 2017; Balconi & Vanutelli, 2017b).

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