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Right Cortical Activation During Generation of Creative Insights: An Electroencephalographic Study of Coaching

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Coaching as a human development methodology has been demonstrating its results for more than four decades. Even so, the level of confusion about its essence and its lack of a definitive theoretical and methodological framework has caused its effectiveness to be questioned. Although studies on coaching with neuroimaging methodologies have been developed, there is no recent evidence about the brain changes in electroencephalographic (EEG) activity during a coaching session. The present research aims to make a comparison between EEG measurements of three different conditions, namely, rumination (R), directive (DC), and non-directive coaching (NDC), during the process of problem solving and goal achievement. Our hypothesis was that the use of the meta-competencies of NDC should induce a higher activation of brain mechanisms that facilitate the insight process, therefore causing an improvement in creative capacity. Results showed significant changes in alpha and theta frequencies in the right temporal region, and alpha, theta, and gamma in the right parietal region in the NDC condition compared to other experimental conditions. The correct use of the meta-competencies of NDC facilitates the rise of insight and the generation of creativity processes at the brain level. Thus, the application of the methodological framework of the NDC was related, in a specific way, to the creativity and the development of human knowledge.

Keywords: creativity, insight, EEG, non-directive coaching, coaching

HIGHLIGHTS

- Meta-competencies of non-directive coaching increase the frequency of creative insights.
- Meta-competencies of non-directive coaching induce higher levels of creative ideas.
- Creative insights are associated with changes in alpha and theta frequencies in the right temporal region.
- Creative insights are associated with changes in alpha, theta, and gamma in the right parietal region.

INTRODUCTION

Since the publication of the book "The Inner Game of Tennis" (Gallwey, 1979), coaching has undergone changes and transformations, leading us to a professional environment of confusion and ambiguity regarding its essence and theoretical and methodological framework (Ravier, 2016). Hence, the methodology of coaching has been frequently questioned, providing some confusion regarding its main methodological differences and identity with respect to others' care processes and therapies (Segers et al., 2011; Grant, 2015).

Coaching has emerged as a synthesis of various fields of knowledge, such as consulting, philosophy, the humanist movement, psychology, sports training, and systems theory (Ravier, 2005; Rock and Schwartz, 2006). This uncertain origin is one of the main obstacles to finding a clear and differentiated definition that can explain what coaching is. Although according to Rock and Schwartz (2006), different investigations explained how coaching works at brain level by neuroimaging techniques (Jack et al., 2013; Boyatzis and Jack, 2018). Despite this progress, none of them was neither based on non-directive coaching (hereinafter NDC) approach and its theoretical framework nor was employed with psychophysiological techniques for measuring brain activity during a coaching session. Electroencephalographic (EEG) techniques are widely used to provide an objective evaluation of brain correlates that occur during cognitive processes (e.g., deductive and inductive reasoning, generation of creative ideas, and metacognition) that could take place during a coaching session. In this sense, they would also allow us to compare the effectiveness of different coaching approaches to generate creative insights during problem solving and goal achievement. It is important to note that EEG can provide valuable data on the NDC approach's (i.e., where the coach does not make judgments or transfer knowledge or experiences about what is treated by the client) ability to generate insights compared to other conditions, such as the directive coaching (DC) approach (i.e., where the client receives clues and suggestions on how to solve their situation) or the ruminant state (Watkins, 2008) (i.e., in which the client thinks by himself repeatedly about the solution to the problem or goal).

From the perspective of non-directivity, understood as the non-transference of knowledge or experience, or the issuance of judgments by the coach, we can define coaching as a non-directive process: (a) where the coach is the person who accompanies the client through a professional client-centered relationship without interpretations or judgments; (b) it is a self-directed process, wherein the client is who determines the direction of the process; (c) which is established under conversations oriented to reflection, called dialogic; (d) it seeks to enhance and/or develop the tacit knowledge of individuals, in a creative way, where the client discovers or creates new knowledge in order to achieve their goals or solve their problems (Ravier, 2016). According to Ravier (2016), following the NDC approach and into the conversational field, we can distinguish three conversational meta-competencies: (a) paying phenomenological attention, which would mainly include observing and listening to the client's verbal, para-verbal, and non-verbal information; (b) mirroring faithfully, faithful return of what the client says and/or does in direct relation to the goal and coaching process; and (c) asking focused questions in order to enhance the client's capacity for association and reflection. Concerning the structural meta-competencies, two levels are distinguished: the first level is related with (1) the conversation structure represented by the GROW model (Whitmore, 2002; Alexander, 2005; Fine, 2010) within the conversation held in the coaching session. This model takes the form of a 4-phased model starting off with: (a) the goal design (G), (b) the exploration of reality (R), (c) the options generation (O), and finally (d) the design of actions (W). The second level is related with (2) the monitoring structure, marked by the model of the process scheme and monitoring of results obtained from actions carried out between sessions in order to achieve the overall coaching process goal.

One of the main characteristics of the coaching process mentioned in its definition is that it allows to enhance the creative capacity of the human being. The first studies on creativity began in the 1930s (e.g., Patrick, 1935, 1937, 1938), but it did not reach a consensus until, at least, 1953 (Stein, 1953). Focusing on the definition of creativity, Runco and Jaeger (2012) points out the need for a bipartite standard definition, in which creativity requires both originality and effectiveness. This means that the character of novelty and adaptation are the two differentiating elements within any definition of creativity. According to Fink and Benedek (2014), creativity implies the process of generating some original ideas to open problems, but as a cognitive process, considers the recovery of both existing knowledge in memory and the combination of various aspects of existing knowledge to convert them into new ideas (Paulus and Brown, 2007). Oliverio (2008) notes and emphasizes that the essential aspects of creativity are the ability to combine and mix in a new "capital" preexisting form and comparing it with knowledge that we already have at our disposal to create new associations.

However, Kounios and Beeman (2015) defined creativity as the ability to reinterpret something, decomposing it into its elements and recombining those elements in a surprising way to achieve a goal or solve a problem. Problem solving through divergent thinking is one of the most demanded skills in the professional and personal sphere due to how most of the challenges and problems that we face in our day-to-day life do not require logical thinking for their resolution. If they do not, they can only be solved through divergent thinking and through a generation of insights.

The concept of creativity cannot be dissociated from the phenomenon of insight (Duncker, 1945) since creativity is characterized by the solution of a problem not from a convergent reasoning or approach, but in an abrupt and spontaneous way. Insight can be defined as a transformative and non-incremental step during the solution of a problem that requires a successful restructuring or reformulation (Duncker, 1945). According to Sheth et al. (2009) we can identify the insight in two different ways. The first is to trust the feeling of "Aha!" of the subject once solved. The other way is to objectively classify a solution on the basis of cognitive processes. In order to identify insight from a cognitive process and not based on the individual subjectivity, it is important to focus on the following elements: a mental deadlock or impasse in which the subject is subjected to a situation in which he/she feels "stuck" and unable to continue (Fleck and Weisberg, 2004), and a restructuring or creation of a cognitive representation that was new or not obvious until then (Ohlsson, 2008). Regarding the psychophysiology of the cognitive process of insight, previous studies have identified local patterns of neural activity associated with "Aha!" experience based on electroencephalographic recording and event-related potential techniques (Jung-Beeman et al., 2004; Mai et al., 2004; Sheth et al., 2009). The cerebral cortex brain has the ability to generate different EEG frequency waves according to the mental activity that it is performing at that moment with an excellent temporal resolution. Therefore, EEG techniques offer us an opportunity to study the neurophysiological correlates that occur during a cognitive process (attention, learning, information retrieval) (Silva et al., 1999), or in this case, the efficiency of three different conditions [rumination (R), DC, and NDC] in the generation of insight during the emergence of creative solutions.

AIM AND HYPOTHESIS

The general purpose of this study was to compare the effects of different conditions, namely, R, DC, and NDC, in the EEG activation of electrode sites related to the processes of generation of creative insights during problem solving and achievement of goals. Our specific objectives were as follows:

(1) To evaluate the functioning of the GROW model (goal, reality, options, and will) as a structural competence for the effective application of the NDC.
(2) To compare the capacity of the NDC to enhance the creativity and generation of insights compared to other conditions (rumination and directive coaching).
(3) To identify the NDC meta-competences that have a greater impact on the EEG activation of electrode sites related to the enhancement of creativity and the generation of insights.
(4) To measure the regional pattern of EEG wave frequencies associated with the generation of insights during NDC.

Brain regions of interest in other EEG studies have been directed to the analysis of the right cortical parietal and temporal activity (Kounios and Beeman, 2009; Sheth et al., 2009; Fink and Benedek, 2014) because they have shown significant activity changes when insights arise and creative cognitive processes are generated. Our hypothesis predicts that the use of NDC meta-competencies could induce the activation of right temporo-parietal regional patterns of EEG wave frequencies associated with creative cognitive processes of divergent thinking (insights) during problem solving and goal achievement.

MATERIALS AND METHODS

Participants

A sample of 16 voluntary participants (50% female) between 25 and 65 years old (M = 42; $SD \pm 11.26$) were anonymously recruited through social media advertising to participate in the study. According to previous works, the sample size to consider is between 10 and 20 participants with 30–60 events per participant (Badcock et al., 2013, 2015; Larson and Carbine, 2017). We developed three tests per participant, and the average number of events (insights) per test was 45. Power analyses using the derived effect size estimates for EEG measures were calculated using Cohen's d with d = 0.8 and alpha = 0.05, indicating a medium effect. The age range has been determined based on the years in which a worker had a management position within an organization/company in our country (Spain). All the participants were informed about the aim of the study and that they could withdraw from the study at any point without further explanation. They were not rewarded by economic incentives for the involvement in the study.

In order to participate in the study, the following inclusion criteria were selected: (a) to have a management position within an organization/company regardless the number of people they have in charge, (b) no previous experience in individual or team coaching sessions, and (c) to have three goals or problems of a similar difficulty to solve at this time within their scope of management at work. The exclusion criteria were as follows: (a) The goals or problems should not have a direct emotional implication that might be susceptible to be approached from a therapeutic perspective, (b) The participants has not started to solve problems or achieve goals before attending the coaching session. All coaching-related procedures were conducted by an experienced Master Certified Coach (MCC) by the International Coach Federation (ICF). All procedures were authorized by the university ethical committee in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Instruments/Measures

Emotiv EPOC+ Headset

An Emotiv EPOC+ EEG neuroheadset device of 14 receptor channels was used to carry out the registering of brain cortical activity. EEG recordings were acquired using the Emotiv Pro software. Data was continuously recorded at a sampling rate of 256 Hz through wet saline that registers cortical electrodes (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4) and placed according to the international 10–20 system and two references on the left and right mastoids bones. The wireless EEG device transmits data via Bluetooth through the 2.4 GHz band. It has a sampling rate of 128 bit/s, a bandwidth ranging from 0 to 64 Hz, automatic digital notch filters at 50 and 60 Hz, and the dynamic range referred to the input is 8,400 μV (pp). Moreover, we evaluated the good EEG signal quality to ensure the accuracy of EEG data collection before starting the EEG signal recording. We did not start the signal recording if its quality was less than 99%.

Creativity Self-Assessment Questionnaire

A creativity self-assessment *ad hoc* questionnaire based on a six-point Likert scale (null: 1, very low: 2, low: 3, acceptable: 4, good: 5, and very good: 6) was used to measure the subjective level of creativity of each subject during each experimental condition (R, DC, and NDC). The design of this scale has been based on the concept of creativity and self-perception indicated by Sheth et al. (2009) which, according to insight, can be identified in two ways: By relying on the feeling of "aha!" personal or subjective nature of the individual solving the problem, or by objectively classifying a solution based on a creative cognitive process. In this way, the six levels of the Likert scale sought to facilitate that the participants could more easily discriminate the subjective feeling of the creativity level generated by the different moments of "aha!" during the three experimental conditions (R, D, and NDC). This instrument is a simple scale that was administered at the end of each session to record the subjective level of creativity experienced by each participant during each experimental condition. Questions were configured through a mixed process following the introductory fundamentals and research objectives, and through experts' judgment (Camic et al., 2003).

Experimental Procedure

Individual coaching sessions were carried out in a quiet room (3.25 × 5.5 m) where electromagnetic radiations were minimized, except those of the EEG instrument itself, video camera, keyboard for subjects, and the computer necessary for data collection. Possible distractions in the room were withdrawn, but two comfortable chairs and a study table to place the computer were available.

The study design was single-blind. In this way, the subjects were not previously aware of the experimental procedure or the specific objective of the coaching session in order to prevent results to be conditioned during the experiments or by possible previous learning experience. Firstly, when each subject arrived, he/she was requested to sit on a chair. He/she was then informed that the three free-choice goals or problems will be addressed in the order that they choose. The researcher also explained the instructions and guidelines of the EEG procedure to ensure good recording (to control eye blinking, sudden movements, and to must keep their body still to avoid EEG recording artifacts). Participants were asked to sign the consent form and an authorization for video recording of the session before starting the experiment. The recording allowed to analyze the relationship between insights, GROW coaching model phases, and the different meta-competencies used. Before placing the neuroheadset on the scalp, the electrodes were slightly wet with saline solution (sodium chloride 0.9%) to improve skin contact and to increase conductivity. Next, the EEG device was over participant's head following the 10–20 standard positioning by the researcher, and the device connection was checked for 100% connectivity (**Figures 1A–C**).

Secondly, once the subject was ready to proceed with the experiment, the researcher started recording the EEG signals. EEG baseline was registered for 30 s with closed and open eyes. Then, the participant is asked to solve the first goal or problem by R (no coaching or interaction with the subject at this stage). After, the participant is guided to achieve the second goal or problem by DC. Finally, the participant is asked, without guidance, to resolve the third goal or problem by NDC (**Figure 1D**). As follows, we explain in more detail each intra-subject experimental condition based on the coaching approaches (**Figure 1D**):

- Rumination (R, no coaching): The subject is asked to think for as long as necessary, without any help or assistance and in silence of possible solutions on how to solve the first problem or goal that he/she has chosen.
- Directive coaching (DC): The subject is asked to raise the second problem or goal, during which the researcher holds a conversation with the subject. Suggestions for the goal, possible advice, and hints on how to arrive at the solution, together with closed questions with an implicit solution are offered while mirroring back the subject's comments with the researcher's own interpretations, without any structure or order designed.
- Non-directive coaching (NDC): The subject is asked to expose the third problem or goal chosen, and the researcher initiates a conversation following the structural competence of GROW and only making exclusive use of non-directive meta-competences (phenomenological perception, focused reflections and questions, all based on non-directivity principles). During this third condition, the researcher pays special attention on not transferring any type of judgment or knowledge to the subject.

During all experimental sessions, each subject was monitored with the Emotiv EPOC+ device, and EEG data were collected and recorded to identify every event of creative insight with one marker (press space bar) for subsequent analysis through EmotivPRO software, San Francisco, CA, United States (**Figure 1D**). As mentioned previously, according to Sheth et al. (2009), insight can be identified in two ways: by relying on the feeling of "aha!" personal or subjective nature of the individual solving the problem or by objectively classifying a solution based on cognitive processes. To identify insight from a cognitive process and not based on the subjectivity of the individual, the focus can be established on the following elements: a mental deadlock or impasse, where the participant is "stuck" and unable to continue (Fleck and Weisberg, 2004); and a construction or creation of a new or hitherto unobvious representation (Ohlsson, 2008). From the psychophysical point of view, in the 4 s prior to the indication of insight by the participants in the non-directive condition, we found significant differences that were observed in terms of the increase in power in the alpha and theta frequencies of the right temporal region. Significant differences were also found in the frequencies alpha, theta, and gamma of the right parietal region, in comparison with the results obtained in the ruminative and directive conditions. The brain regions and frequencies where significant power increases were recorded and coincide, for the most part, with previous studies on the different EEG patterns in the field of creative insight (Jausovec, 1997, 2000; Mölle et al., 1999; Razumnikova, 2000; Aftanas and Golocheikine, 2001; Herrington et al., 2005; Fink et al., 2006, 2011; Sandkühler and Bhattacharya, 2008; Gruzelier, 2009; Kounios and Beeman, 2009, 2015; Fink and Benedek, 2014; Rothmaler et al., 2017; Wokke et al., 2017, 2018; Oh et al., 2020). In addition, these EEG studies are reinforced by other neuroimaging studies that show

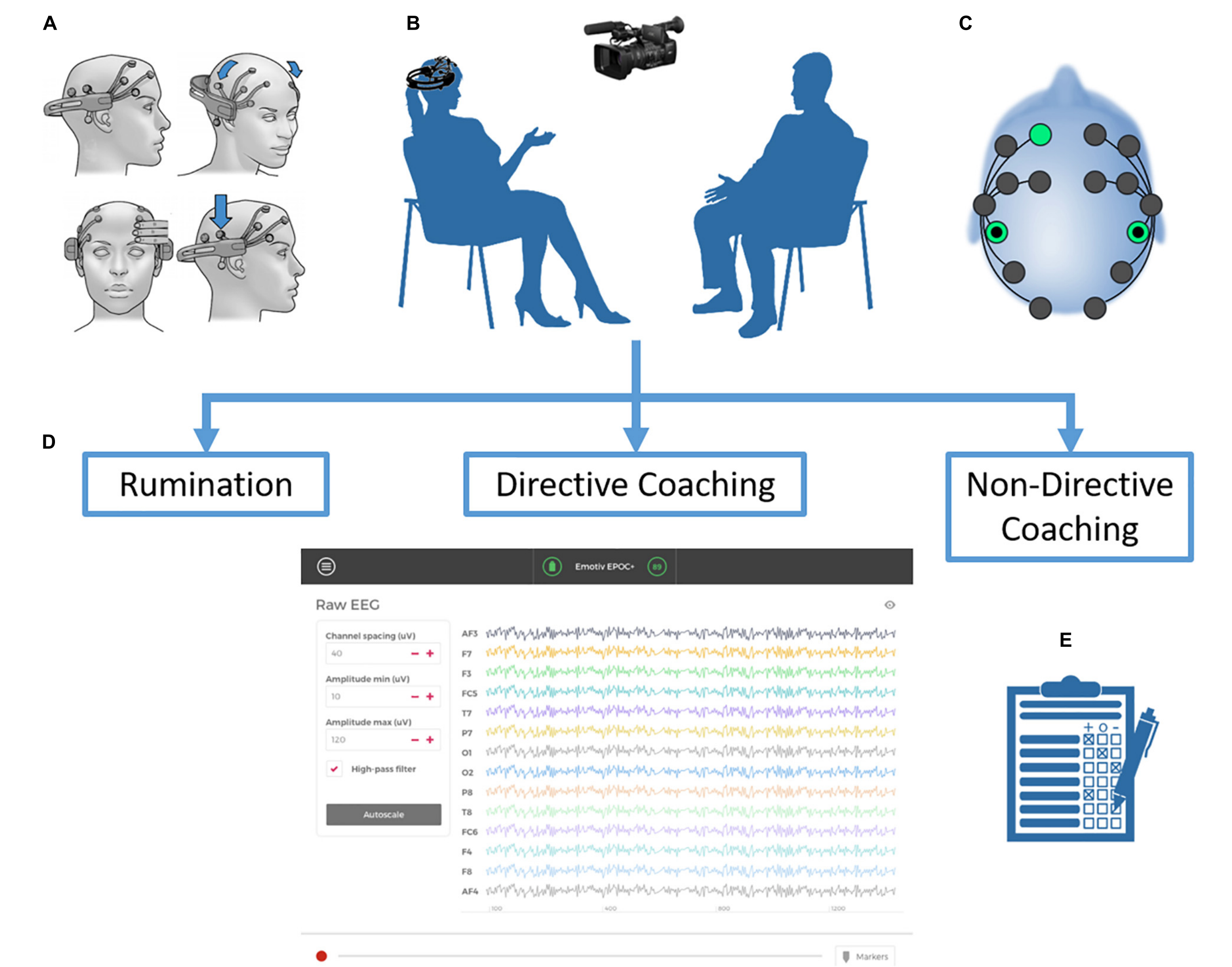

FIGURE 1 | Schematic illustration of the experimental procedure performed in each experimental session during electroencephalographic (EEG) acquisition data. **(A)** One wireless EEG device (Emotiv EPOC+) with non-invasive electrodes (14 channels) was placed on the forehead subject according to the International 10–20 system before data-collection. **(B)** Subjects were informed about the instructions, procedure followed during the session (free-choice and order of three goals or problems to resolve) and tips in order to ensure good EEG recording. Each session was video recorded to analyze the relationship between insights and goal, reality, options, and will (GROW) coaching model phases. **(C)** Spatial mapping of the electrodes' current connection status on the scalp (color code: green, good connection; black, not providing information). Data recording was started when all electrodes had good connectivity. EEG baseline was registered with closed and open eyes (both for 30 s). **(D)** Participants were guided during each individual session to resolve a problem by rumination (no coaching), directive coaching, and non-directive coaching approaches while EEG brain activity was recorded, identifying every moment of creative insight (even-related markers). **(E)** After EEG data acquisition, the creativity self-assessment scale was filled out.

evidence of neuronal activity during the generation of insight in the temporoparietal regions (Beeman and Bowden, 2000; Coney and Evans, 2000; Starchenko et al., 2003; Bechtereva et al., 2004; Kounios et al., 2006; Benedek et al., 2016). The basis for an objective consideration of the insight condition would be found in the joint use of these two mentioned parameters. That is, the marks in the EEG reading in which the participants indicated a new and useful idea after a "stuck" situation and an EEG correspondence of the 4 s prior to that mark with the frequencies and regions aforementioned.

Once the coaching session was finished, the recording session was concluded, and the device was removed from the subject's head. Finally, each subject assessed the levels of subjective creativity achieved for each coaching condition responding to the creativity self-assessment questionnaire (**Figure 1E**).

Statistical Data Analysis

The EEG data were analyzed using the JupyterLab platform. A specific program that works on Jupyter Notebook was created using the Python 3.8 language, which allowed us to perform the data analysis by applying a frequency-time analysis based on Discrete Wavelet Transform (DWT). Five frequency waves ranges were extracted (theta: 4–7 Hz, alpha: 10–13 Hz, low beta: 13–16 Hz, high beta: 16–28 Hz, gamma >32 Hz). To focus on

EEG activity during the three experimental conditions (R, DC, and NDC), the median of the maximum power for each electrode site and frequency waves was analyzed in epochs of 4 s prior to the marker activated (press space bar) by the subjects at the time of the perceived insights manifested in every condition. Additionally, a filtering was performed, eliminating data where the power exceeded $\pm 100\ \mu V$ and that were related to artifacts from blinks or facial muscle movements.

We ran different comparative analyses to assess the effect of the three experimental conditions (R, DC, and NDC) on dependent variables (number of insights, creativity self-assessment scores, and EEG frequency waves) using the SPSS 22.0 software for Mac. Once the statistical tests of normality were carried out, we used non-parametric statistical tests (Wilcoxon signed-rank test) due to the non-normality of the data. The significance level was set to $p < 0.05$.

RESULTS

Insights and Creativity Self-Assessment

When we compared the number of insights registered between experimental conditions (R, DC, and NDC), we found that the subjects showed a higher number of insights during the non-directive condition compared to the other conditions (Directive: $p < 0.003$; Rumination: $p < 0.009$, Wilcoxon signed-rank test) (**Figure 2A**). We also found statistically significant differences comparing the subjective perception of perceived creativity in the creativity self-assessment scale between conditions. Our results showed higher scores in the non-directive condition compared to the other conditions (Directive: $p < 0.047$; Rumination: $p < 0.011$, Wilcoxon signed-rank test) (**Figure 2B**).

Electroencephalographic Power

After having carried out a comparative statistical analysis between all the electrode sites of both cerebral hemispheres and the different frequencies, the analysis focused on observing the power differences for each EEG wave frequency range (theta, alpha, low and high beta, and gamma) generated in cortical brain regions (frontal, temporal, parietal an occipital) during experimental conditions. This allowed us to observe if there was any significant difference in EEG power between NDC, DC, and R situations during the 4 s before subject's marks of insights. In this channel-based EEG regional analysis, we found significant differences placed in different brain regions (parietal and temporal cortices) of the right hemisphere. The right parietal region (P8) showed a significant increase in EEG power in the alpha and theta frequency ranges between NDC vs. R and DC conditions (Alpha: $p = 0.003$, $p = 0.034$, respectively; Theta: $p = 0.005$, $p = 0.013$, respectively), whereas gamma frequency range also revealed a significant increase of high power between NDC vs. R and DC conditions ($p = 0.023$, $p = 0.041$, respectively) (**Figure 3**). However, although the results of the beta high frequency range in the right parietal region (P8) showed an increase of beta power in the NDC condition, it did not show a significant difference compared to the other conditions. Additionally, the right temporal region (T8) also showed a significant increase of EEG power in theta and alpha frequency ranges between NDC vs. R and DC conditions (Theta: $p = 0.011$, $p = 0.021$, respectively; Alpha: $p = 0.006$, $p = 0.034$, respectively) (**Figures 3**, **4**).

The boxplot analysis represents the median EEG power values associated to creative insights through different levels of activation frequency ranges (theta alpha, beta high, and gamma). We have selected the right parietal (P8) and temporal (T8)

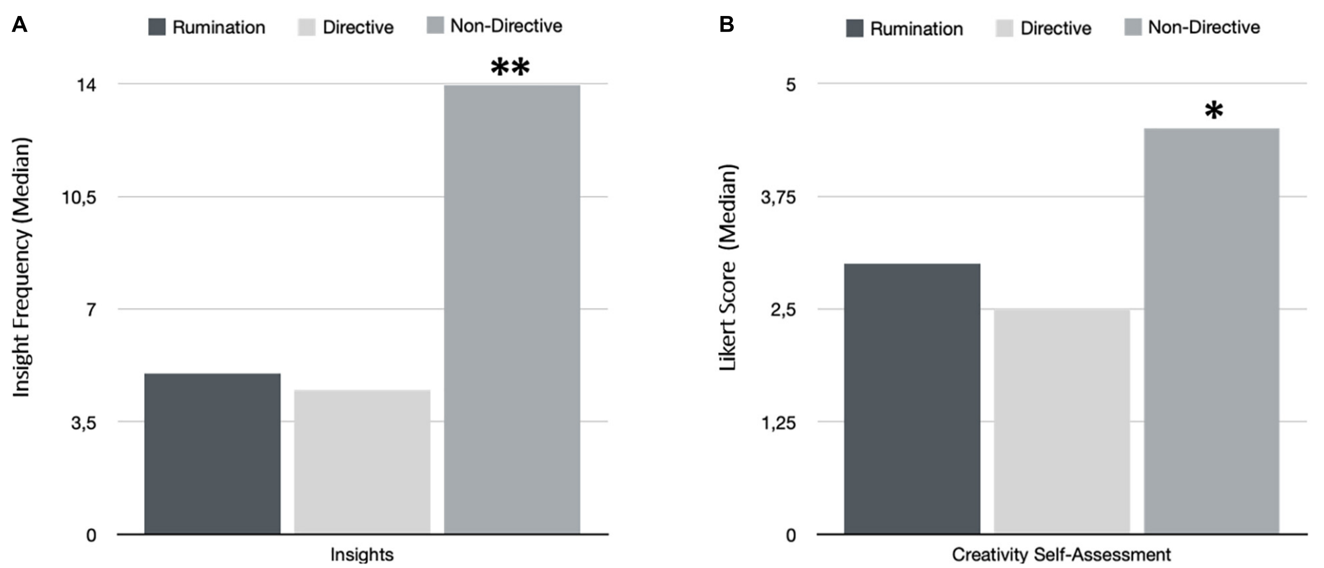

FIGURE 2 | Graphics showing the numbers of insights registered **(A)** and the levels of creativity perceived by the subjects **(B)** during each experimental condition evaluated after coaching session. Significant differences can be observed between the greater number of insights and the perception of higher levels of creativity in non-directive coaching condition compared to the other conditions (rumination and non-directive coaching). Insights: **$p < 0.01$; Self-assessment: *$p < 0.05$.

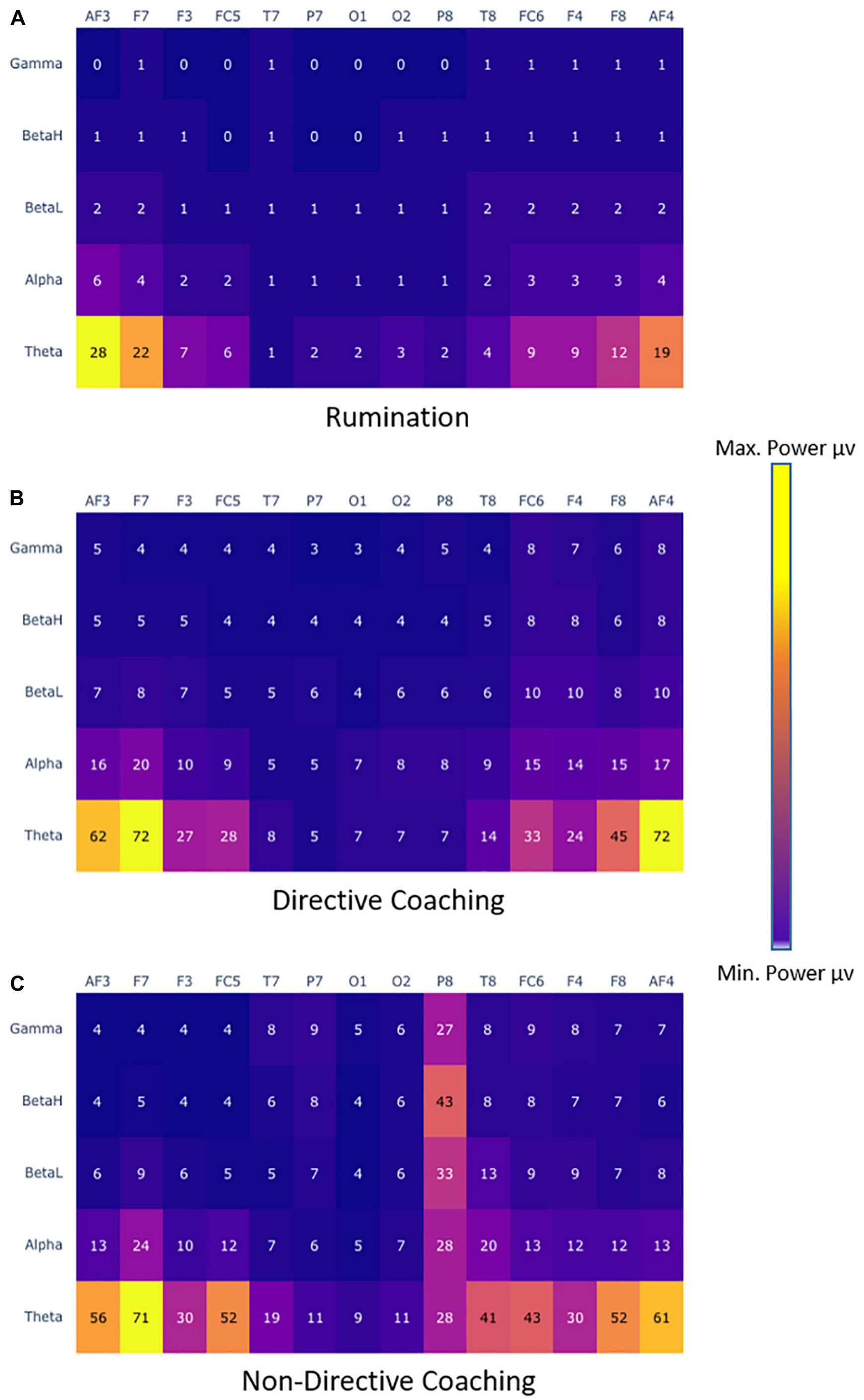

FIGURE 3 | Heat map of EEG power generated by insights in each experimental condition [**(A)** Rumination, **(B)** Directive coaching, and **(C)** Non-directive coaching]. Heat maps indicates the magnitude of the effect of EEG power at each frequency band (gamma, beta low and high, alpha, and theta) across 14-EEG channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4). Colors represent values resulting from the median of the power (µv) for epochs of 4 s prior to the marker activated (press space bar) by the subjects during each condition. Cold colors indicate decrease, whereas hot colors indicate increase in the median of the EEG power for each cortical region (electrode sites) and frequency wave bands.

channels because they showed high EEG power related to creative cognitive activity according to our previous hypothesis, while the right occipital (O2) channel has been selected as the control channel. We showed the distribution of the median EEG power values (µv) associated with events of creative insights during each experimental condition (R, DC, and NDC) placed in the

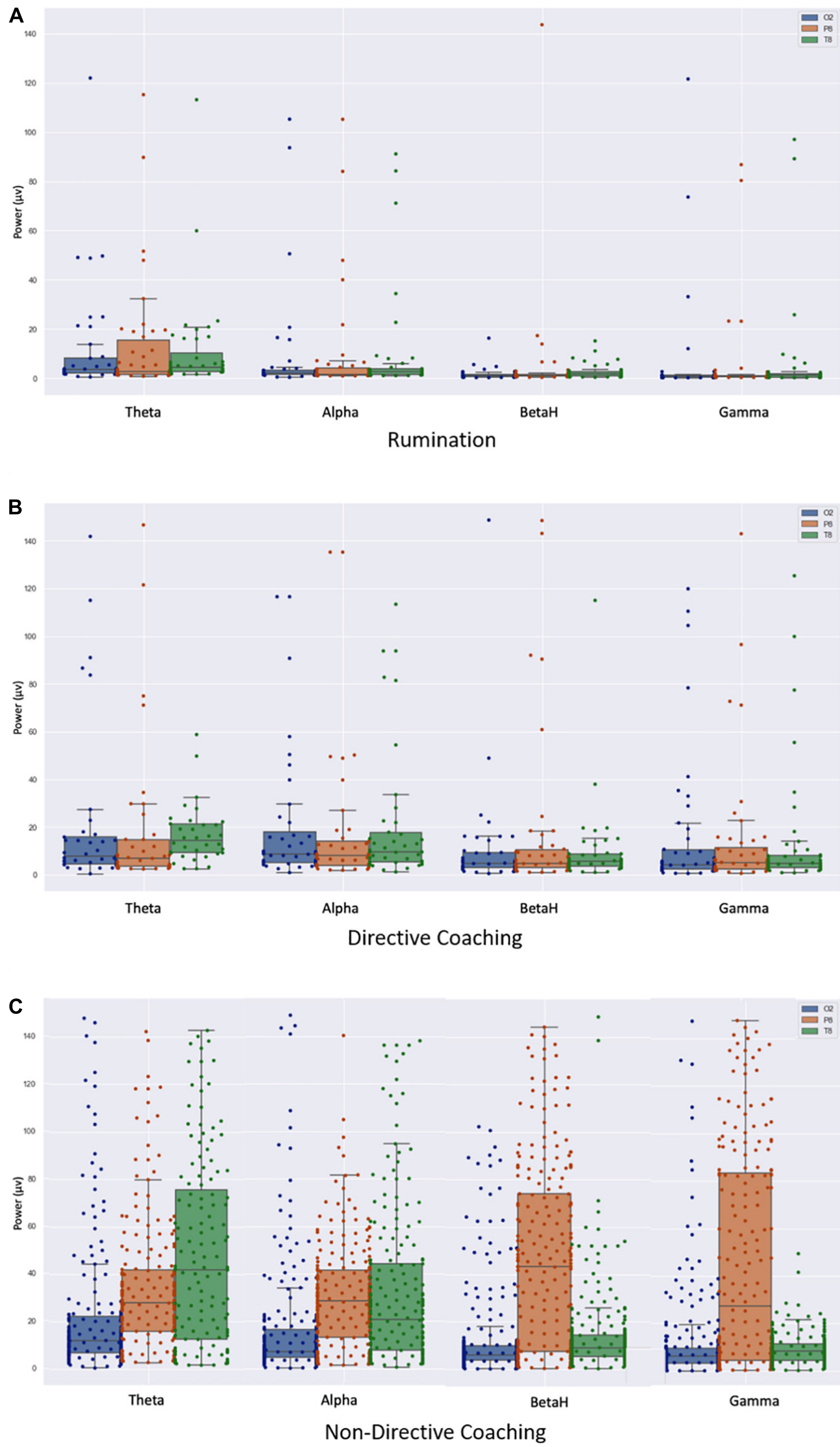

FIGURE 4 | Box plots represent medians, interquartile ranges (P25–P75), and min-max (whiskers) of the EEG power during insight time window (epochs) in occipito-parieto-temporal right channels in each experimental condition [**(A)** Rumination, **(B)** Directive coaching, and **(C)** Non-directive coaching]. The graphic shows the distribution of the EEG power associated to insights in the right occipital (blue), parietal (orange), and temporal (green) channels at the theta, alpha, beta high, and gamma frequency ranges during each condition. Creative insights during non-directive coaching condition induced higher EEG power in the alpha and theta frequency bands of the right temporal region (T8), and in the alpha, theta, and gamma frequency bands of the right parietal region (P8). No differences were found in the right occipital region (O2). Within the box, black line represents the median value. Color data points are shown for each selected channel (blue to occipital, O2; orange to parietal, P8; green to temporal, T8).

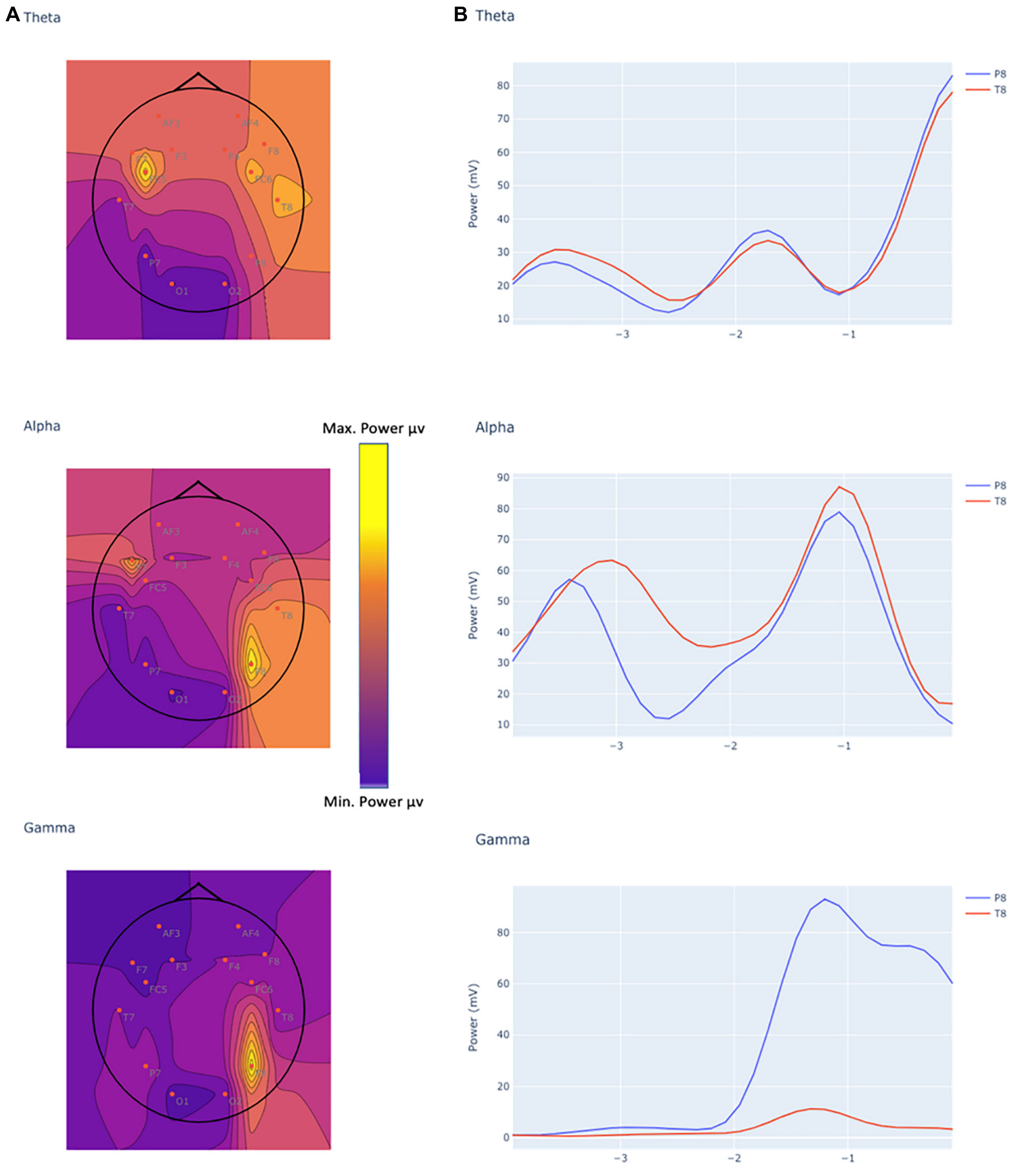

FIGURE 5 | Topographic distribution of scalp power to theta, alpha, and gamma frequency bands in the non-directive coaching condition **(A)** and EEG power wave form to alpha, theta, and gamma frequencies in the right temporal and parietal channels **(B)**. **(A)** Graphic showing the spatial distribution of theta, alpha, and gamma frequency bands in relation to their EEG power levels in the 4 s prior to the identification of insights by the subjects in the non-directive coaching condition. **(B)** Representation of the increase in power (µv) in the alpha, theta, and gamma frequencies in the right temporal (T8, red) and parietal (P8, blue) regions during the 4 s prior to the marker activated when one creative was identified by part of the subject.

right parietal (P8), temporal (T8), and occipital (O2) channels for the alpha, beta high, theta, and gamma frequency ranges. We found that there is a significant increase of EEG power in the right parietal (alpha, theta, and gamma) and temporal (alpha and theta) regions related to an increase in the generation of creative insights during the NDC condition (**Figure 4**). It can also be seen that the median values (alpha T8, 20 µv; alpha P8, 30 µv; beta high P8, 42 µv; beta high T8, 15 µv; gamma P8, 30 µv; gamma T8, 10 µv; theta P8, 30 µv; theta T8, 40 µv) associated with the insights fall within the EEG activation frequency ranges (alpha 10–200 µv; beta 1–50 µv; theta 5–100 µv; gamma 1–50 µv) (Tatum, 2008; Guyton and Hall, 2020).

Likewise, we also showed topographical representation of cortical EEG activity, specifically in the right temporo-parietal region associated with the creative insights during the NDC condition (**Figure 5A**). In this sense, we can observe an example of increased EEG power in the theta and alpha frequencies in the T8 channel (red line) and in the theta, alpha, and gamma frequencies in the P8 (blue line) for one epoch (4 s prior to the marker activated, from −3 to 0 s) corresponding to the generation of one creative insight during NDC condition (**Figure 5B**).

DISCUSSION

The present study aimed to analyze the possible relationship between the use of a NDC approach in solving problems or achieving goals and the generation of creativity/insight processes and their associations with specific patterns of cortical brain activity. Although there is no scientific evidence that analyzes the different coaching approaches while recording cortical activity by EEG, we can find current works that carry out studies of some basic characteristics of and approaches to coaching using functional MRI (fMRI) (Jack et al., 2013; Boyatzis and Jack, 2018). It is also possible to find some articles that develop the field of creativity from the perspective of insight using EEG (Jung-Beeman et al., 2004; Mai et al., 2004; Fink and Benedek, 2014; Stevens and Zabelina, 2019). Despite this, to date, this is the first work that analyzes the generation of creative insights under NDC approach and their relationship to cortical patterns of brain activity measured by EEG band frequencies.

Kounios and Beeman (2009) define insight as a sudden understanding that solves a problem or reinterprets a situation, but, due to its immediacy, seems to be disconnected from the immediately preceding thought. These authors consider insight as one of the essential elements necessary for the culmination of the creative process, which is also part of the basic abilities of the human being (Kounios and Beeman, 2015). Our results allow to relate the number of insights per condition and the levels of perceived creativity in the creativity self-assessment scale. The difference appreciated in these measures that compare the three experimental conditions is favorable in both cases in the NDC. The increase in the number of insights registered by the subjects and the increase in the level of creativity subjectively perceived by each participant seem to be related to the application of the GROW model as a structural competence for the effective application of the NDC condition. In a recent study, Oh et al. (2020) made a direct association between the gamma frequency activation and the moment before the insight starts with a greater reward sensitivity. We also found an increase in the gamma frequency placed in the right temporoparietal region that was related to the 4 s prior at the moment of insight. In this sense, it is deducible that the approach of the first phase of the GROW model, objective (G), to identify those positive and beneficial aspects that the subject wants to achieve, increases the reward sensitivity and therefore facilitates the path toward the generation of insights (Kounios and Beeman, 2015).

Regarding the field of insight and EEG activity, our results showed an increase in alpha power recorded in the right temporal and parietal region. Previous studies had also already confirmed the relevance of the alpha frequency range induced by processes of creative ideation (Mölle et al., 1999; Jausovec, 2000; Razumnikova, 2000; Agnoli et al., 2020). In this sense, Fink and Benedek (2014) claim that most studies reveal that the creative process can be characterized by an increase in alpha power in the prefrontal and posterior parietal regions of the right hemisphere, which partially coincides with the data recorded in this experiment. Furthermore, other studies from this same group suggested that alpha power range increases as a result of interventions aimed at increasing creativity (Fink et al., 2006, 2009, 2011). Our results also showed an increase in gamma power range in the right parietal region which was associated with the emergence of creative insights. Kounios and Beeman (2009) and Oh et al. (2020) showed how the EEG recording detected a significant increase in high frequency (40-Hz, gamma frequency band) 300 ms before the subjects pressed the button to indicate that they had found a new solution to the given problem. This increase in gamma frequency was placed in the registering electrodes located on the right anterior temporal lobe (Kounios and Beeman, 2009). Another study developed by Sheth et al. (2009) found an improvement in the gamma power band (30–70 Hz) placed in the right cerebral hemisphere (frontal, frontal-medial, and temporo-medial regions) when participants correctly solved one problem (verbal puzzles task) through insights and reported experiencing an “Aha!”. In our study, the increase in gamma power associated with creative insights is placed on the right parietal region. This apparent discordance may be due to the limitation of our EEG device, as it only had 14 channels receptors, or to the difference between both cognitive tasks. Despite this, there is a certain close proximity between the channels located in the temporo-parietal region and in both cases that are located in the right hemisphere.

Similarly, Sandkühler and Bhattacharya (2008) identified correlations in EEG activity between the four elements of the insight solution process, namely, (1) deadlock, (2) restructuring of the problem representation, (3) deeper understanding of the problem, and (4) “Aha!” feeling of immediacy and obviousness of the solution. This study shows considerable similarity to the results presented in our research. First, an intense response of the gamma power range was found in the parieto-occipital regions that were interpreted as an adjustment in selective attention processes (leading to a mental deadlock or a correct solution depending on the power level of the gamma band) and a coding of the recovery processes for the emergence of new spontaneous solutions. Second, they observed an increase in the high alpha power range placed on the right temporal regions (suggesting a suppression of the weakly activated solution of relevant information) for initially unsuccessful attempts that which after the presentation of a track led to a correct solution. The analysis of theta frequency power showed an increase in the right temporal and parietal regions associated with creative insights. In this sense, Wokke et al. (2017, 2019) showed how creative metacognitive and decision-making processes are orchestrated by oscillations of theta frequency in the prefrontal cortex. Moreover, this research group demonstrated that high creativity is associated with an improvement in long-range functional connectivity between the occipital and medial prefrontal cortex. Furthermore, Von Stein and Sarnthein (2000) described that during top-down processing of internal information, slow theta and alpha frequency ranges shows long-distance synchronization between the fronto-parietal regions. Other studies also support this approach by relating the increase in low-power waves with coherence in theta frequency range between long-distance connections (Aftanas and Golocheikine, 2001; Herrington et al., 2005). Thus, Gruzelier (2009), by relying on data provided by various investigations (Petsche, 1996; Aftanas and Golocheikine, 2001; Thompson et al., 2008), hypothesizes that creative cognitive associations arise from integration through the co-activation of activity slow waves, such as theta and low alpha frequency ranges of widely distributed neural networks.

In addition to the EEG studies mentioned above, we can also find some neuroimaging studies that provide evidence of neuronal activity during insight in the temporoparietal regions, emphasizing the importance of these regions over the frontal regions (Starchenko et al., 2003; Bechtereva et al., 2004; Kounios et al., 2006; Benedek et al., 2016).

CONCLUSION

In relation to the achievement of the specific objectives of this work study, our conclusions claim that: (1) The right application of the NDC meta-competencies together with the GROW structural competence facilitate the emergence of insights and, therefore, the generation of creativity processes; (2) There is a relationship between the generation of a greater number of insights and the subjective perception of greater creativity shown by the participants in the NDC condition compared to the other conditions (R and DC); (3) The application of the methodological framework of the NDC induced a higher EEG activation of electrode sites in the parieto-temporal cortical networks of the right hemisphere; and (4) Our results show significant changes in the right parieto-temporal cortical brain regions that are associated with the generation of insights during NDC. EEG power activity was higher in alpha and theta frequencies in the right temporal region, and alpha, theta, and gamma frequencies in the right parietal region during creative insights in NDC compared to other experimental conditions (R and DC). The study provides a new perspective on the application of NDC to insight into creative processes. It would be possible that the emergence of meta-cognitive processes allows the potentiation in the generation of creative insights to solve problems and to improve the development of human knowledge.

One of the aspects that has limited the possible scope of the results is produced by use of a commercial portable 14-channel EEG device. It is understood that although the device used has the scientific validation necessary for its use in experimental research (Badcock et al., 2013, 2015), it is very likely that having more receptor channels would have allowed us to specify more and better, especially regarding the spatial location of the EEG wave changes. It is also interesting to note that wired EEG devices have a higher level of precision than wireless ones, and that clinical EEGs have a higher level of reliability than commercial ones. All this could have facilitated obtaining results that are even closer to those of other studies previously carried out.

We believe that it could be interesting, as a future line of research, to transfer the object of the study to the scope of the coach's brain and analyze how the EEG patterns associated with creativity in performance influence the use of meta-competencies. In this way, it could be investigated if the elaboration of questions and reflections is based on a convergent thought dynamic or if, on the contrary, it is the result of divergent thinking and insight. Deepening in this area could provide very useful information to understand how to generate the meta-competencies of the NDC more effectively by the coach and lead to better practice in the profession.

Additionally, it is important to broaden the scope of this research to study the impact of the NDC process on the improvement of the creative capacity of people in the medium and long-term. It is also important to broaden the scope to study the possible developments of creative autonomy in the brain without having to depend on the external elements of the coach for the generation of creative solutions once the coaching process is finished. This study would help validate whether the NDC process can establish a habit in accessing the brain's mechanisms of creativity without the need to consciously generate the entire competence and structural process.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the CEIM – Hospital Universitari Arnau de Vilanova. Code: CEIC-2499. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EB and CT-N: conceptualization, writing – original draft preparation and reviewing and editing, formal analysis, and methodology. GB: writing – original draft preparation and reviewing and editing, formal analysis, methodology, and software. SV: methodology and software. All authors contributed to the article and approved the submitted version.

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