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# Brain Electrical Activity of Film Directors Engaging in Initiating Imagination: Comparisons between Different Levels of Creativity

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**Abstract**

*Creativity is necessary to be a successful film director. By using electroencephalography, the present study analysed differences in the brain electrical activity of film directors of different levels of creativity while initiating imagination. Thirty directors were recruited to participate in a three-stage experiment. On the basis of measurements collected using established scales, the top and bottom thirds of the participants were divided into high- creativity (HC) and low-creativity (LC) groups and for further neural comparison. The following results were obtained: (i) the brain activity of the film directors increased in the frontal and parietal regions compared to the baseline; (ii) the spectral power of the HC directors was generally higher than that of the LC directors; (iii) regarding the novelty indicator, the right temporal and right frontal regions of the HC directors were more activate than were those of the LC directors; and (iv) regarding the productivity indicator, all of the component regions of the HC directors were more activate than were those of the LC directors.*

**Keywords:** *Creativity; Electroencephalography; Film director; Initiating imagination; Production design.*

## Introduction

Filmmaking demands imagination and creativity to achieve the intersubjective task of developing a film through what is currently completed, what is possibly missing, and what can potentially be added. Members of the film production team must know how to tell stories and visualise their audience's reaction. Highly imaginative individuals can offer new conditions of meaning and conjure new realities (Liu & Noppe-Brandon, 2009). This capacity, which is known as initiating imagination, is the capability to explore the unknown and productively originate novel ideas (Liang & Chia, 2014). Two indicators are used to evaluate this capacity, namely novelty and productivity. Novelty refers to an individual's ability to create uncommon ideas, and productivity refers to an individual's ability to productively generate ideas.

In the context of film production, a director typically acts as the chief designer. Wille (2015) emphasised that design thinking could clarify the analytic treatment of film production. Designer preparedness for a creative process requires them to possess high-level visual literacy because most effective stimuli for enhancing design creativity are visual, particularly abstract images (Cila, Hekkert, & Visch, 2014). Creativity is a desirable characteristic of production design, and exceptional designers are creative thinkers. Numerous neuroscientific studies related to cinematic imagination and filmmaking creativity have concluded that the prefrontal and frontal lobes—particularly the right hemisphere—are crucial in design conceptualisation and creative cognition (Alexiou, Zamenopoulos, Johnson, & Gilbert, 2009; Fink & Benedek, 2014). However, Aziz-Zadeh and colleagues (2013) indicated that robust parallel activity in the left hemisphere supports creative processing. Additionally, Goel and Vartanian (2005) reported that engaging in creative problem-solving tasks elicited activation in the left dorsal lateral and right ventral lateral prefrontal cortices.

Recent studies have further supported the relevance of the default mode network (DMN) regions in divergent thinking (Benedek, Schickel, Jauk, Fink, & Neubauer, 2014; Jung, Mead, Carrasco, & Flores, 2013). Furthermore, Beaty and colleagues (2014) revealed greater connectivity between the left inferior frontal gyrus (IFG) and the DMN in a high-creativity (HC) group. Benedek et al. (2014) indicated that creative idea generation was associated with extended activations in the left prefrontal cortex and the right medial temporal lobe and with deactivation of the right temporoparietal junction. The left inferior parietal cortex and left prefrontal regions may promote the flexible integration of past knowledge to construct new and creative ideas. Moreover, Mayseless and colleagues (2014) indicated that the left temporoparietal region is part of a neural network involved in evaluating creativity and thus may act as an inhibitor of creativity.

Bringing imaginative liveliness to film production, which ties in closely with the lives of audience members, has become a critical problem, compelling us to examine imagination more seriously. In addition, current scientific evidence identifying the effects of visual stimuli on filmmakers or production designers is insufficient, warranting further research. To address these research gaps, the present study applied a neurological approach based on the identified indicators of imaginative capacity possessed by film directors. By using electroencephalography (EEG), this study analysed differences in the brain electrical activities of film directors of different levels of creativity engaging in initiating imagination. The specific research questions were as follows:

(i) Which brain regions are particularly activated when film directors engage in the tasks that involve initiating imagination?

(ii) What are the differences in brain electrical activities between HC and low-creativity (LC) film directors in terms of two indicators of initiating imagination (i.e., novelty and productivity)?

## Methods and Materials

The present study was approved by the Research Ethics Office of National Taiwan University and conducted using the following three-stage experimental procedure.

### Stage 1: Familiarisation with the Experiment

To investigate the differences in the brain electrical activities of film directors of different levels of creativity, 30 film directors (18 male and 12 female, aged 21–43 years) were invited to participate in an EEG experiment. Some of the participants had worked in the filmmaking industry for more than 15 years, whereas some of them were college students recognised for their excellent short films. This inclusion allowed for a degree of diversity in the sample, various levels of seniority, and, thus, a broad range of directors' experiences was explored. Although the participants were diverse, they had all received awards in national or international filmmaking competitions.

The experimenter briefly described the study purpose and procedure, and informed consent letters were signed by the participants. Before the experiment, the participants were asked to describe the aim and imagined outcome of a filmmaking project. During the experiment, a prerecorded presentation of visual stimuli was displayed to each participant. The visual stimuli used for imagination stimulation in this study were paintings of two internationally prominent artists (Picasso and Miró). The artworks were selected because of robust evidence of the effects of abstract images on design creativity (Cila et al., 2014; Liu, Yang, & Liang, 2017). Four pieces from each artist were selected and randomly assembled into four groups. Each group consisted of two pieces, with one from each artist. These four groups were then randomly presented during the experiment.

### Stage 2: EEG Measurement

The EEG headset used in this study was a 32-channel inflatable system designed by Brain Rhythm Inc., Taiwan. The headset has two dry foam-based EEG sensors that are used only for the forehead Fp1 and Fp2 sites in the international 10-20 system. This wearable system has 16-bit quantisation and a sampling rate of 250 Hz. Both the ground and reference electrodes were placed on the mastoids behind the ears and the electrode impedance was kept as low as possible (≤ 5 KΩ). EEG data were wirelessly received through a Bluetooth protocol without needing external cabling. Four groups of visual stimuli with questions corresponding to the indicators of initiating imagination (i.e., novelty and productivity) were sequentially presented on a 46-inch TV monitor.

Regarding the novelty indicator, the participant was asked to select an item from the presented group and answer the question: 'What innovative ideas does this painting stimulate and inspire for the project you just mentioned?' The participant was asked to remain silent while responding to each question, and EEG data were recorded for 60 seconds. Subsequently, the participant verbalised their response for 120 seconds. The 120-second narration task was aimed at acquiring qualitative data and was treated as an intertrial interval to avoid recording overlapping brain responses. The qualitative data were collected for validity triangulation rather than for scientific comparison between brainwave activations and narrative contents. To ensure the quality of the experiment, the experimenter then repeated the same procedure for the novelty indicator with another group of visual stimuli.

Regarding the productivity indicator, the participant was also asked to select an item from the presented group but answer the different question: 'What various types of analogues does this painting stimulate and inspire for the project you just mentioned?' The procedure for this session was the same as that for the earlier sessions, and two runs of the experiment were also conducted for this indicator. Through this series of four 6-minute sessions, each group of artworks was presented and the two indicators of initiating imagination were enquired about. In total, the EEG measurement lasted 24–30 minutes. The experimental process was identical for all participants to ensure enquiry quality.

## Stage 3: Self-Report Measurement

After completion of the EEG measurements, the participant began the self-report measurement. The two scales used in this study were the creative personality scale (CPS; Gough, 1979) and the creative capability scale (CCS; Lin, Hsu, & Liang, 2014). The CPS contains 18 positive items (e.g., being capable, clever, egotistical, humorous, individualistic, insightful, and resourceful) and 12 negative items (e.g., being cautious, conservative, conventional, honest, and sincere). In this study, the CPS scores were also used to divide the participants into HC and LC groups for further analyses. Responses to the CCS (12 items) were measured using a 6-point Likert-type scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). CCS measurement was used to confirm the aforementioned division into HC and LC groups.

## Data Analysis

Analysis of the data obtained from the scale measurement revealed that the coefficient alpha (internal consistency) of the present sample was .76. The CPS mean score of this study was 4.17 ($SD$ = 2.89). This value is close to that reported in Gough (1979, p. 1402) ($M$ = 3.88, $SD$ = 3.94), which provides evidence of the validity of this measurement. Because higher CPS total scores indicate HC, the top and bottom thirds of the participants (10 for each) were allocated into the HC ($M$ = 7.67, $SD$ = 1.89) and LC ($M$ = 1.50, $SD$ = .98) groups for further brainwave comparisons.

The mean CCS scores ranged from 3.58 to 5.67, with SDs ranging from .40 to .57. Principal axis factoring analysis with promax rotation was conducted to determine the CCS dimensionality. Two-factor solutions (eigenvalues greater than 1) explaining 48.12% of variance was considered the optimal factor structure. The Cronbach's α value of Factor 1 (originality) was .922, and that of Factor 2 (usefulness) was .846. This measurement was used to confirm the aforementioned division of the HC and LC groups. The mean score of the HC group was 5.64 ($SD$ = .48), and that of the LC group was 3.78 ($SD$ = .50).

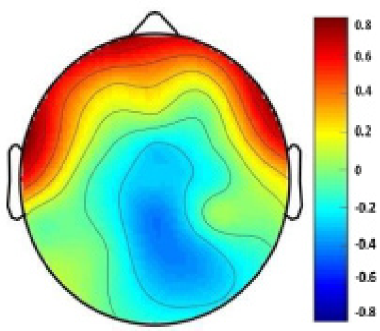
The acquired EEG signals were inspected to remove ill-functioning channels and were then split into 1.6-second signals. A low-pass filter with a cut-off frequency of 50 Hz and a high-pass filter with a cut-off frequency of 1 Hz were applied to all signals based on FIR filters to remove line noise and drifting artefacts, respectively. The filtered EEG signals were then decomposed into independent brain sources through independent component analysis (ICA), which is capable of reliably separating eye activities, such as eye blinking and lateral eye movements. All ICA computations, including the setup of the weights that remove the components related to blinking, were performed using EEGLAB.

Nonartefact independent component scalp topo graphies often strongly resemble the projection of a single dipole, enabling the location and orientation of the optimally fitting equivalent dipole to be easily determined. All ICA components were grouped into several clusters according to the similarity of outcomes using the *k*-means clustering method. The scalp topography of each independent component was used to plot the three-dimensional (3D) location of an equivalent dipole through the DIPFIT function. Time-domain data were then transformed into frequency-domain data by using the fast Fourier transform function. Finally, a paired-sample Wilcoxon signed-rank test was used to assess the differences in the brain activity spectra of the HC and LC directors.

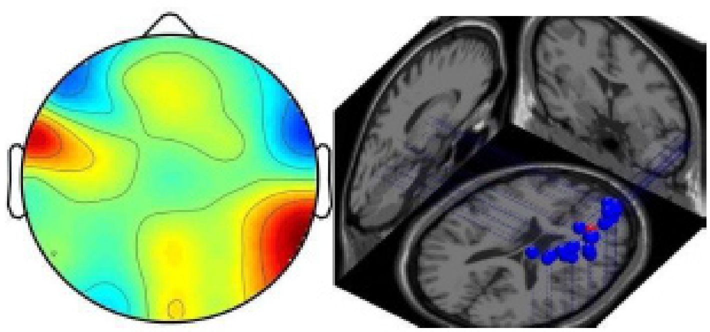
## Results

Regarding the novelty indicator, both the HC and LC directors had relatively high brain activations in the prefrontal and frontal cortices compared to the baseline when they engaged in the initiating imagination task (Figure 1). The scalp topographies and 3D dipole plots displayed in Figures 1a–1c reveal that these brain activations could be divided into three major component clusters, namely the right temporal, left frontal, and right frontal cortices. The 3D dipole plots indicate the equivalent dipole source locations with means and their projections onto average brain images.

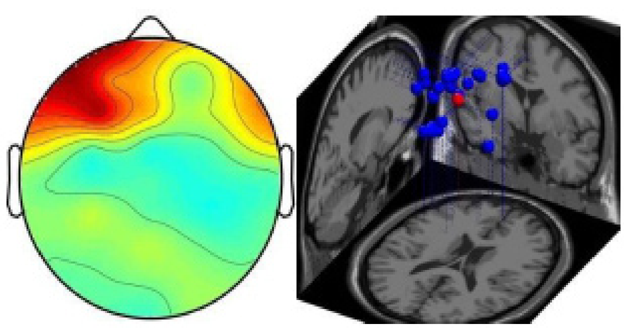
By using the results of the Wilcoxon signed-rank test, we clarified the differences in the spectral power of distinct indicators and experimental tasks between the HC and LC directors. The significance levels of the null hypothesis at different frequencies are shown as red dots in the plots of the spectra. The results indicated that the spectral power of the HC directors was generally higher than that of the LC directors. In the right temporal cluster, significant power differences were also observed in the beta and low gamma bands (Figure 2a). The largest differences appeared in the gamma band at 36 Hz and 40 Hz. Additionally, in the left frontal cluster, only one significant power difference was observed in the gamma band at 35 Hz (Figure 2b). Finally, in the right frontal cluster, significant power differences were observed in distributed bands (Figure 2c). The largest differences appeared in the gamma band at 42 Hz and the beta band at 19 Hz.



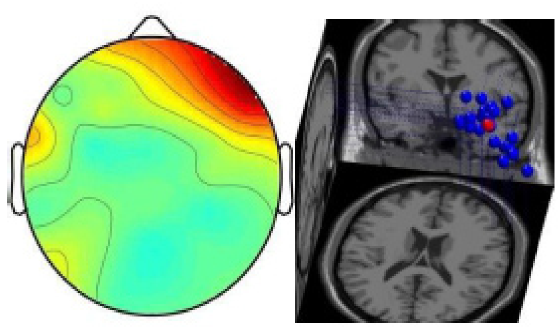

**1.** *Root cluster*



**1a.** *Right temporal cluster*

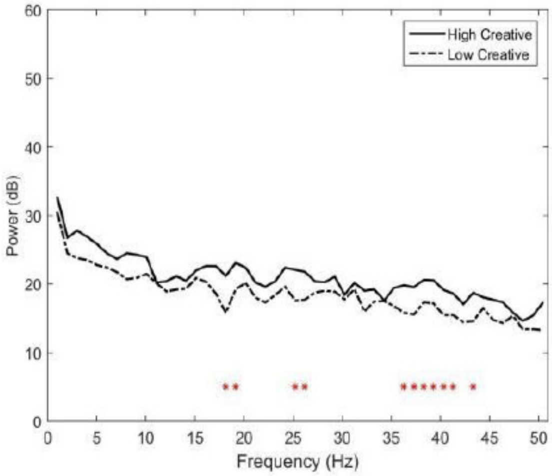


**1b.** *Left frontal cluster*

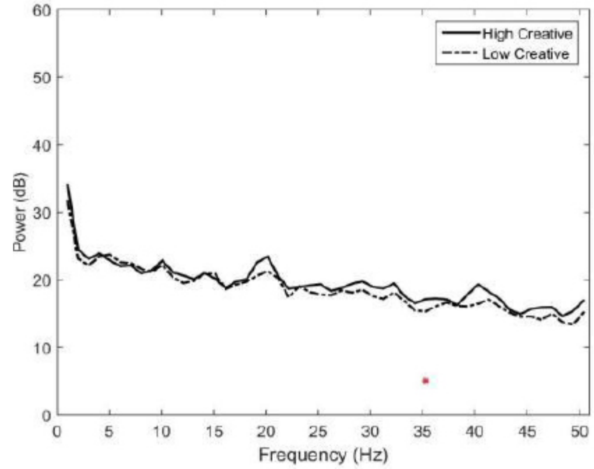


**1c.** *Right frontal cluster*

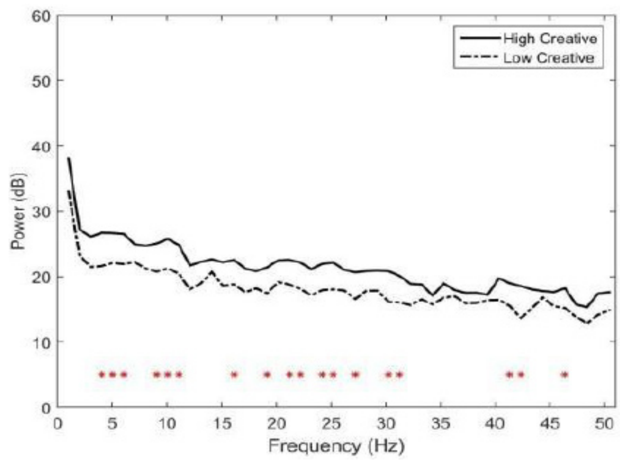
**Fig1.** *Scalp topographies and 3D dipole plots associated with the novelty indicator (1: scalp map for the root cluster; 1a–1c: scalp topographies for the component clusters and their 3D dipole source locations)*




**2a.** *Right temporal cluster*




**2b.** *Left frontal cluster*

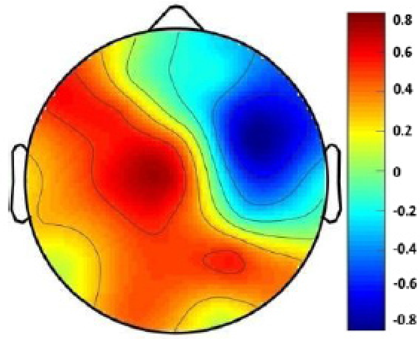



**2c.** *Right frontal cluster*

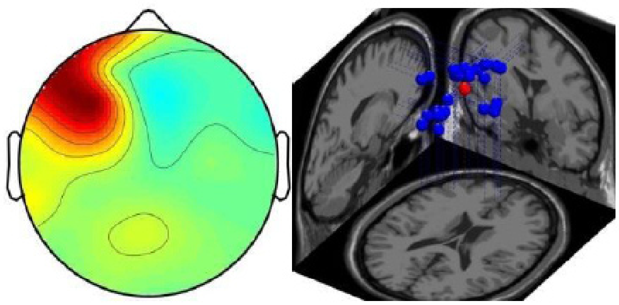
**Fig2.** *Spectral power and Wilcoxon signed-rank test results for the novelty indicator*

Regarding the productivity indicator, the director participants had relatively high brain activations in the left frontal and parietal cortices compared to the baseline when they engaged in the initiating imagination task (Figure 3). The scalp topographies and 3D dipole plots displayed in Figures 3a–3d reveal that these brain activations could be separated into four major component clusters: the left frontal, left parietal, left-biased middle frontal, and right medial parietal cortices. The left-biased middle frontal region is situated in the ACC, whereas the middle parietal region is located in the posterior cingulate cortex (PCC).

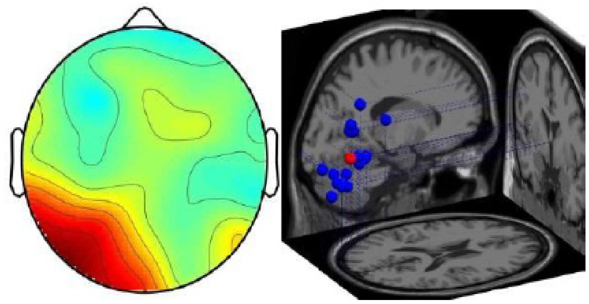
The results indicated that the spectral power of the HC directors was generally higher than that of the LC directors. In the left frontal cluster (Figure 4a), only four significant power differences were observed. The largest differences appeared in the alpha band at 10 Hz and 8 Hz. In the left parietal cluster (Figure 4b), significant power differences were observed for frequencies lower than 20 Hz. The largest differences appeared in the theta band at 7 Hz and the alpha band at 13 Hz. In the left-biased middle frontal cluster (Figure 4c), significant power differences appeared mainly in frequencies lower than 11 Hz. The largest differences appeared in the theta band at 3 Hz and 4 Hz. Finally, in the right medial parietal cluster (Figure 4d), significant power differences in the delta, theta, and alpha bands were identified. The largest differences appeared in the theta band at 5 Hz and 8 Hz.



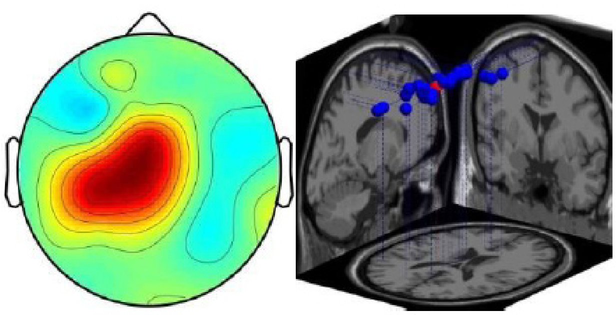

**3.** *Root cluster*



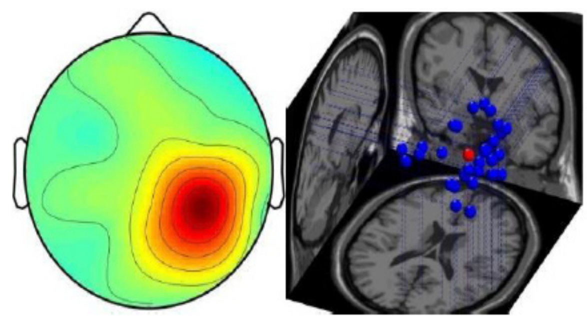
**3a.** *Left frontal cluster*



**3b.** *Left parietal cluster*

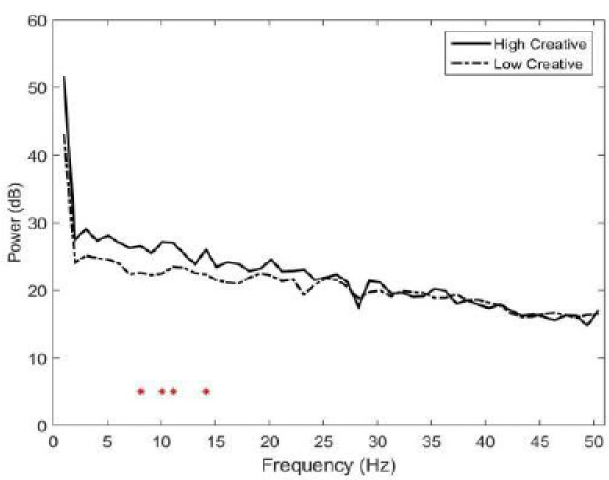


**3c.** *Left-biased middle frontal cluster*

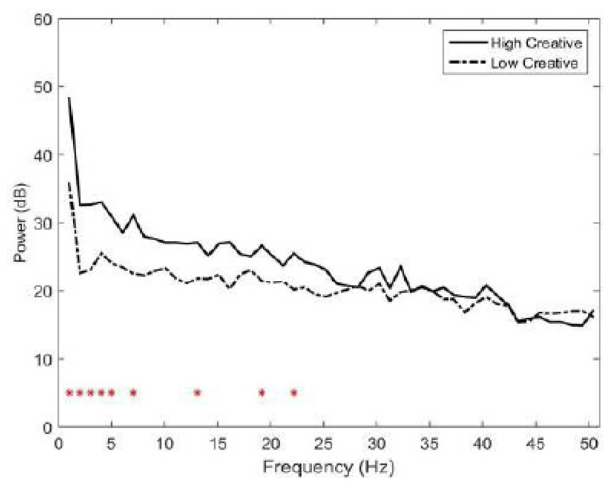


**3d.** *Right medial parietal cluster*

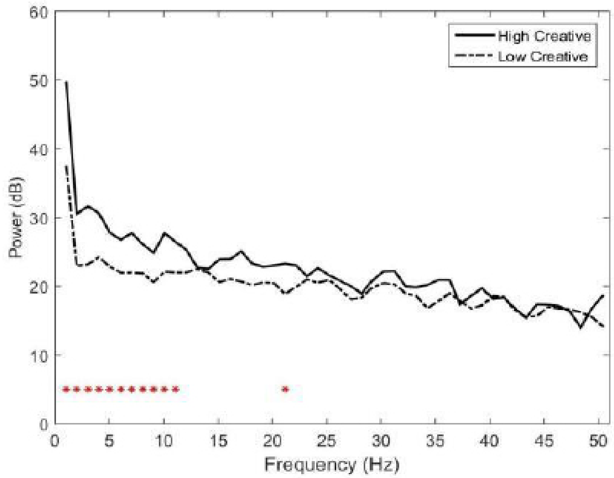
**Fig3.** *Scalp topographies and 3D dipole plots associated with the productivity indicator*



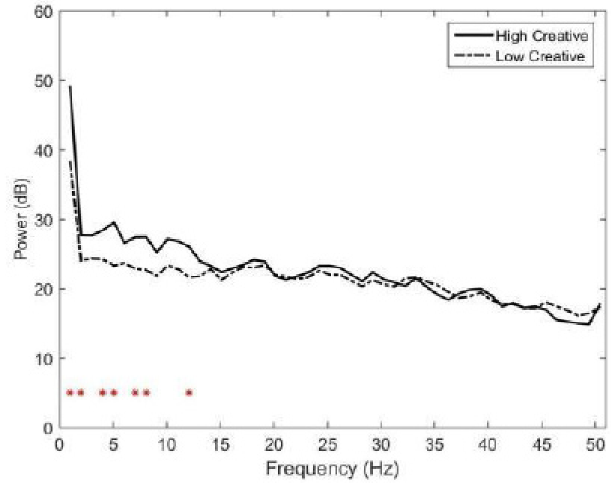

**4a.** *Left frontal cluster*




**4b.** *Left parietal cluster*




**4c.** *Left-biased middle frontal cluster*




**4d.** *Right medial parietal cluster*

**Fig4.** *Spectral power and Wilcoxon signed-rank test results for the productivity indicator*

## Discussion

Generally, the results indicated that the brain activations of the film directors increased in the frontal and parietal regions compared to the baseline when they engaged in the initiating imagination tasks; the spectral power of HC directors was generally higher than that of the LC directors. The differences in activations caused by different measuring indicators and experimental tasks varied between HC and LC directors. We discuss these differences in the following sections.

### Novelty Indicator for the Initiating Imagination Task

The EEG results indicated that the prefrontal and bilateral frontal regions were activated during the experimental task, concurring with prior research (Alexiou et al., 2009; Aziz-Zadeh et al., 2013; Fink & Benedek, 2014). In particular, the activations of the right temporal, left frontal, and right frontal cortices were noticeable. The major function of the right temporal cortex is nonverbal memory and communication (Wisniewski, Wendling, Manning, & Steinhoff, 2012) and the left frontal cortex is involved in the brain correlates of analogical reasoning, which are critical for making inferences and adapting to novelty (Aichelburg et al., 2016; Fine et al., 2009). The right frontal cortex is critical to the types of divergent semantic processing involved with human creativity (Giannouli, 2016), indicating that the directors underwent divergent semantic processing during the experimental task.

The largest power differences (HC > LC) in the right temporal cortex appeared in the beta and gamma bands. An increase in the beta and gamma power in the right temporal cortex can be understood as an indicator of conscious attention to nonverbal information processing (Wisniewski et al., 2012), which is also associated with creative idea generation (Benedek, Jauk et al., 2014; Liu et al., 2017). Additionally, the largest power differences (HC > LC) in the right frontal cortex also appeared in the beta and gamma bands. As stated earlier, the right frontal cortex is crucial for divergent semantic processing (Giannouli, 2016). These findings may indicate that the HC directors spend more cognitive resources than do LC directors in using abstract images and divergent semantic processing for design creativity than are the LC directors. According to Figure 2b, the spectral power of the HC and LC directors was similar and could be ignored. These results implied that, by optimising their visual-thinking capability and divergent semantic processing with abstract visual stimuli, LC directors can enhance their generation of novel ideas.

### Productivity Indicator for the Initiating Imagination Task

Widespread activities from the left frontal to right parietal regions were detected during the initiating imagination task for the productivity indicator. In particular, the activations of the left frontal, left parietal, left-biased middle frontal, and right medial parietal cortices were prominent. The left frontal cortex is involved in analogical reasoning, which is crucial for people to make inferences (Aichelburg et al., 2016; Fine et al., 2009). The left parietal cortex promotes the flexible integration of past knowledge to construct new ideas (Benedek, Jauk et al., 2014). These results implied that directors adaptably integrate prior knowledge for analogical reasoning to productively generate design ideas.

The left-biased middle frontal region is also associated with the ACC, which is involved in managing conflict detection and resolving (Bunge et al., 2004) and controlling emotions (Kang, Jeong, Kim, Kim, & Kim, 2014). Additionally, the PCC, which exhibits connectivity with a wide range of intrinsic control networks (i.e., the DMN), is located in the right medial parietal cortex. The activation of the inferior and superior parietal cortices is associated with internally directed cognition and that of the DMN is related to a high level of self-generated thought (Benedek et al., 2016; Liang et al., 2017). Together, these results implied that successfully managing mnemonic conflicts and focusing on internally directed thoughts could facilitate the fluency of director's idea generation.

During the initiating imagination task for the productivity indicator, the theta and alpha power of HC directors was generally higher than that of the LC directors in all the four major components. Previous studies have determined the critical role of EEG theta and alpha power in human creativity and have reported that greater theta and alpha power reflects higher internal processing demand (Fink & Neubauer, 2006). These results may indicate that, compared with the LC directors, the HC directors spent more cognitive resources than do LC directors in analogical reasoning and concept formation (the left frontal cortex). The HC directors seem more competent at flexibly integrating past knowledge for idea construction (in the left parietal cortex). Accordingly, the HC directors may be more competent at monitoring differential familiarity, managing mnemonic conflicts, and evaluating the emotional significance of external stimuli (left-biased middle frontal cortex). Furthermore, the HC directors spent more energy in performing internally directed tasks, particularly in the elaborateness of self-generated mental processes because alpha power increases in this region represent the depth of an ongoing process of mental imagination or internally focused thoughts (Benedek, Schickel et al., 2014; Von Stein & Sarnthein, 2000). All the aforementioned brain activities facilitate director productivity in initiating imagination.

## Research Limitations

Although wireless EEG is a promising neuroscientific tool, its use and experimental design result in several limitations that hinder research generalisations. First, neuroscience studies have typically examined simple cognitive processes by using repeatable tasks, but cinema imagination or filmmaking creativity is a multifaceted mental activity. Creating reliable and valid experimental settings in which the particular relationships between creative cognition and brain activity can be determined is challenging. Second, because of the limited spatial resolution of EEG, ascertaining the exact locations where brain signals fire during any experiment is impossible, particularly for those in the medial or orbitoregions related to human emotions. Third, the experimental stimuli used in this study were limited to the paintings of two artists (Picasso and Miró). Additional visual representations and other forms of stimuli (e.g., textual, music, tactile, video, and 3D objects) could be explored. Finally, the present study lacks behavioural data regarding participant imagination during the EEG recording. Additionally, we cannot completely exclude the possibility that the participants thought of multiple and mixed ideas, which may have hindered the interpretation of creative idea generation.

## Closing Remarks

In this study, we analysed the brain electrical activities of film directors while they were engaged in initiating imagination. The following five conclusions can be drawn: (i) The brain activations of the film directors increased compared to the baseline in the frontal and parietal regions. (ii) The spectral power of the HC directors was generally higher than that of the LC directors. (iii) Regarding the novelty indicator, the right temporal and right frontal regions of the HC directors were more activated than those of the LC directors during the initiating imagination task. (iv) Regarding the productivity indicator, all of the component regions of the HC directors were more activated than those of the LC directors during the initiating imagination task. (v) The idea novelty tasks mainly relied on the right hemisphere, whereas the idea productivity tasks largely depended on the left hemisphere.

Both imagination and creativity are essential for film directors; they play an increasingly crucial role as a source of organisational and cultural values and are becoming increasingly pervasive in the socioeconomic system. As demonstrated in the present study, neuroscience provides instruments and methods that can be applied to study cinema and design competencies. The results of this study provided new evidence to support studies of filmmaking imagination and provided new insights to differentiate the cognitive processes of film directors of different creativity levels. Studies combining the high temporal resolution of the EEG with the spatial accuracy of the fMRI would be of particular interest in this line of research. Clarifying the association of creative cognition with the activation of different brain regions may help in making more informed decisions regarding cultivation strategies for talent development in the film industry, as well as for the arts in general.

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