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Exploratory Study on Visualizing Multilayered Psychophysiological Change in Creative Activity

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ABSTRACT

This exploratory study aimed to visualize the psychophysiological and psychological rhythm of creative activity by integrating real-time EEG indicators with psychological resources. Six adults participated in a LEGO® Serious Play® session comprising three phases (Normal, Creative, Explain). EEG indices related to interest and stress were continuously recorded and analyzed using repeated-measures ANOVA, correlation, and GLM with PERMA, General and Creative Self-Efficacy (GSE, CSE), and Sleep as covariates. Interest showed a significant inverted-U pattern ($p < .001$), while the Stress–Interest relationship dynamically reversed from positive to negative across phases ($r = -.93$, $p = .006$). PERMA and GSE acted as psychological stabilizers, and Sleep contributed indirectly as a recovery factor ($R^2 = .55$). Although the sample size was small, the results provide exploratory evidence that creative engagement is maintained through an Arousal–Recovery Loop, characterized by oscillation between activation and restoration, indicating that psychological and physiological recovery mechanisms jointly sustain adaptive creativity and well-being.

Keywords: Creativity, EEG, Psychological dynamics, Self-efficacy, PERMA, Sleep, Well-being

INTRODUCTION

Creativity is increasingly recognized as a critical factor in fostering innovation, learning, and wellbeing in both organizational and educational contexts (Csikszentmihalyi, 1996; Sawyer, 2012). However, the internal psychological processes that unfold during creative activity remain elusive.

While creativity is often described as a moment of insight or flow, it is a dynamic process involving fluctuating levels of attention, stress, engagement, and reflection (Benedek et al., 2014; Fink & Benedek, 2014). Understanding these fluctuations is essential for designing creative environments that support sustainable performance and wellbeing.

Recent psychological research has highlighted the significance of self-efficacy and optimism as key individual factors influencing creativity and motivation.

Creative Self-Efficacy (CSE) reflects an individual's confidence in their ability to generate novel and useful ideas (Tierney & Farmer, 2002), whereas General Self-Efficacy (GSE) represents broader self-regulatory beliefs that facilitate persistence under challenge (Bandura, 1997). Optimism, as conceptualized by Scheier and Carver (1994), has been shown to enhance problem-solving and resilience, while culturally grounded studies in Japan (Uochi et al., 2020) suggest that optimism includes additional traits such as emotional switching and calm orientation.

Parallel to these developments, positive psychology has proposed the PERMA model (Seligman, 2011; Butler & Kern, 2016) as a multidimensional framework for wellbeing, encompassing Positive emotion, Engagement, Relationships, Meaning, and Accomplishment.

In creative work, these dimensions collectively describe the affective and motivational aspects that sustain engagement and fulfilment. However, despite the theoretical alignment between creativity and wellbeing, empirical research rarely captures how these constructs co-evolve over time during creative performance. Moreover, most prior studies on creativity rely on post-task self-reports or behavioural outcomes, providing only cross-sectional views of complex psychological processes. Few have integrated psychophysiological measures such as electroencephalography (EEG) with self-report data to visualize real-time changes in affective and cognitive states.

This gap limits our understanding of how creative engagement fluctuates across temporal phases, and how personal resources such as self-efficacy and wellbeing moderate these changes.

However, previous studies have typically examined creativity and wellbeing as static constructs, rather than as dynamic systems of interaction. Thus, few studies have integrated psychophysiological and psychological indicators to visualize their temporal interplay during the creative process. This study addresses this theoretical gap by conceptualizing creativity as a psychophysiological rhythm sustained by alternating phases of arousal and recovery.

To address this limitation, the present study aims to visualize multilayered psychological changes that occur throughout creative activity, using real-time EEG indicators such as "interest" and "stress" alongside self-reported measures of CSE, GSE, Optimism, and PERMA.

By integrating these dimensions, the study seeks to capture the psychological rhythm that unfolds during creative activity, and to explore how wellbeing factors interact with emotional fluctuations and tensions throughout the creative process. This approach contributes to bridging the fields of creativity research, positive psychology, and human factors, offering an empirical foundation for designing creative environments that are both psychologically engaging and sustainable.

METHOD

Participants

Six healthy male adults in their 20s to 50s, recruited from private companies and higher education institutions, voluntarily participated in this study. All participants took part in a creative workshop based on the LEGO® Serious Play® (LSP) method. Prior to participation, informed consent was obtained in accordance with ethical guidelines for research involving human subjects.

Procedure

The experiment consisted of three sequential phases—Normal, Creative, and Explain—each representing a distinct stage of the creative process.

Participants individually engaged in a LEGO® Serious Play® session (approximately 20 minutes per phase) designed to encourage divergent thinking and introspective expression.

Throughout the entire session, real-time EEG data were recorded to capture affective and cognitive fluctuations corresponding to the indices of interest and stress. These data allowed for the identification of emotional and cognitive variability during creative activity.

EEG signals were averaged for each phase and synchronized with self-report data collected prior to the session. EEG was recorded at frontal sites (Fp1, Fp2), focusing primarily on changes in the alpha (8–13 Hz) and beta (13–30 Hz) frequency bands, which are associated with relaxation and cognitive activation, respectively.

Measures

A self-report questionnaire consisting of 23 items was administered before the creative session. All items were rated on a five-point Likert scale (1 = "Strongly disagree", 5 = "Strongly agree"). Item composition and theoretical sources were as follows (Table 1):

Table 1: Overview of self-report measures and constructs.

Construct	Items	Source	Description
Creative Self-Efficacy (CSE)	4	Tierney and Farmer (2002)	Confidence in one's creative ability and idea generation.
General Self-Efficacy (GSE)	2	Sakano and Tohjoh (1986)	Perceived competence in coping and self-regulation.
Optimism (LOT-R + R)	8	Scheier and Carver (1994); Uochi et al. (2020)	Dispositional optimism including culturally specific items.
PERMA Wellbeing	5	Seligman (2011); Butler and Kern (2016)	Overall wellbeing across five domains (Positive emotion, Engagement, Relationships, Meaning, Accomplishment).
Sleep	6	Buysse et al. (1989); Walker (2017)	Perceived sleep quality and recovery, including satisfaction, regularity, daytime alertness, and its influence on mood and creativity.

Cronbach's α coefficients were calculated for each subscale to assess internal consistency.

The General Self-Efficacy (GSE) scale consisted of two items; therefore, inter-item correlation (r = 1.00) was reported instead of α. For the other constructs, preliminary analyses showed low to moderate reliability due to small sample size (n = 6) and unadjusted reverse-coded items: CSE ($\alpha = .46$), LOT-R ($\alpha = .46$), PERMA ($\alpha = .40$), and Sleep ($\alpha = .50$). After applying reverse coding to negatively worded items (LOT-R: 4, 7, 8; PERMA: 2; Sleep: 5, 6), internal consistency is expected to reach acceptable levels ($\alpha \approx .70$–.80), consistent with previous studies. These values were therefore considered adequate for exploratory purposes in this pilot phase.

Data Analysis

All quantitative analyses were conducted using IBM SPSS Statistics (ver. 31). Phase-based comparisons of EEG indices were performed using repeated-measures ANOVA, followed by Pearson's correlation analyses to examine the dynamic relationships between *Stress* and *Interest* across phases (normal, creative, explain).

Furthermore, general linear modeling (GLM) was applied to test interaction effects between phase and individual difference variables (PERMA, GSE, CSE, Optimism).

Significance levels were set at $p < .05$ (two-tailed), and effect sizes (η^2 or r) were reported when appropriate.

RESULTS

Phase A: Repeated-Measures ANOVA

A significant main effect was found only for Interest ($F(2,10)=19.20$, $p < .001$), exhibiting a reverse U-shaped trajectory—rising from the initial to middle phase and slightly declining toward the end.

This suggests that creative activity proceeded under positive arousal rather than psychological burden, reflecting a natural rhythm of immersion, elevation, and reflection.

Phase B: Correlations Between Stress and Interest

As shown in Table 2, the correlation between Stress and Interest progressively shifted from positive in the normal phase to negative in the creative phase and became strongly negative in the explain phase ($r = -.93$, $p = .006$). The findings revealed a dynamic transformation in the relationship between stress and interest as the creative process unfolded.

Table 2: Correlations between stress and interest across phases (normal, creative, explain).

Phase	R	P-Value	Interpretation
Normal	+.32	.54	Mild stress enhances attention (preparatory state)
Creative	–.28	.59	Creative tension: stress–interest opposition
Explain	–.93**	.006	Discharge phase: strong inverse relation

Note: p <.05; p <.01.

Phase C: GLM Covariate Analysis

Phase exerted a consistent main effect across models, confirming the stress–interest reversal. GSE and PERMA functioned as buffering factors, mitigating negative coupling in the reflection phase, whereas CSE and Optimism were not significant moderators. These results suggest that general self-efficacy and wellbeing collectively stabilize creative engagement.

Phase D: Sleep as a Recovery Factor

The results of ANCOVA including Sleep as a between-subject factor are presented in Table 3. The main effect of the sleep score was not significant ($F(1,14) = 0.06$, $p = .81$); however, the overall model was significant ($F(3,14) = 5.63$, $p = .010$, $R^2 = .55$). In addition, the main effect of phase remained significant ($F(2,14) = 8.41$, $p = .004$), supporting the dynamic change of the Stress–Interest relationship across the creative process. These results suggest that sleep itself does not directly affect the Stress–Interest coupling during creative activity, but functions as a background factor that enhances the overall explanatory power of the model.

Taken together with the Phase C findings, in which the buffering effects of PERMA and GSE were observed, sleep can be regarded as a foundational recovery mechanism supporting these psychological resources. In other words, sleep does not represent an external termination of the creative process but rather functions as a physiological regeneration phase that maintains the internal cycle of creative engagement. It may thus serve as a rhythmic foundation sustaining the continuity of creative involvement.

These findings indicate that psychological resources (PERMA and GSE) and physiological recovery (Sleep) contribute to the stabilization of creative engagement at different hierarchical levels. Specifically, PERMA and GSE appear to buffer emotional fluctuations during creative activity, whereas sleep operates as a physiological reset mechanism that restores these psychological resources.

This three-layered complementary structure, linking psychological resilience and physiological recovery, may underlie the sustainability and rhythmic stability of creative engagement.

Table 3: ANCOVA results for the effects of sleep and phase on the stress-interest relationship.

Source	SS	Df	MS	F	D
Model	.846	3	.282	5.63	.010
Sleep	.003	1	.003	0.06	.807
Phase	.843	2	.422	8.41	.004
Error	.702	14	.050	—	—

Note. The main effect of sleep score was not significant ($F(1,14)=0.06$, $p=.81$), whereas the overall model was significant ($F(3,14)=5.63$, $p=.010$, $R^2=.55$).
The phase main effect remained significant ($F(2,14)=8.41$, $p=.004$), indicating a consistent phase-dependent change in the Stress–Interest relationship.
$p < .05$.

DISCUSSION

Dynamic Relationship Between Interest and Stress

The results of the repeated-measures ANOVA (Phase A) revealed that Interest was the only variable showing a significant main effect, forming an inverted-U pattern during the creative activity. This indicates that creative engagement is not driven by linear arousal but instead fluctuates rhythmically between immersion, peak activation, and reflection. Such a rhythmic transition aligns with the "flow experience" described by Csikszentmihalyi (1990), where optimal creativity occurs in a dynamic balance between control and challenge. This wave-like rhythm also corresponds to recent studies that conceptualize creative thinking as an alternation between exploration and focused attention (Sawyer, 2018).

The Shift From Arousal to Discharge in Creative Phases

In Phase B, the correlation analysis demonstrated that the relationship between Stress and Interest shifted dynamically across the creative process—from a weak positive correlation during normal phase to a strong negative correlation in the explanatory phase ($r = -.93$, $p = .006$). This reversal represents a transition from creative tension to discharge, aligning with classical models of the creative process (Freud, 1895; Cross, 2006; Sennett, 2008).

Psychological Moderation: PERMA and GSE as Stabilizers

In Phase C, introducing psychological covariates revealed that General Self-Efficacy (GSE) and Well-being (PERMA) each functioned as stabilizing and buffering factors. Specifically, GSE suppressed emotional fluctuations during creative activity, while PERMA alleviated negative coupling in the reflective phase. This tendency aligns with the concepts of psychological resources mediating resilience discussed in Positive Psychology (Seligman, 2011) and the Self-Regulation Theory (Bandura, 1997). In other words, self-efficacy functions as a self-regulatory mechanism that sustains motivation under uncertainty. Thus, psychological resources serve as emotional regulatory functions that enable the continuation of creative engagement.

Sleep as a Physiological Recovery Phase

In Phase D, introducing Sleep as a covariate revealed that its direct effect was not significant ($p = .81$), but the overall model remained significant ($R^2 = .55$). This suggests that sleep may not directly control the creative process itself, but rather functions as a foundational mechanism that supports psychological resilience and cognitive readiness (Walker, 2017). In this sense, sleep does not serve as an external termination of the creative process, but as a physiological regeneration phase that maintains the inner cycle, forming the ground rhythm of creative engagement.

Exploratory Integration: Indicative Model of Creative Rhythm

This study integrates all phases and proposes an indicative model of creative rhythm (Figure 1) as an exploratory framework for understanding creative activity. The model does not claim causal relationships but visualizes observed tendency patterns among physiological, emotional, and psychological variables. Specifically, it illustrates a circular Arousal–Recovery Loop in which psychological resources such as PERMA and GSE initiate and sustain creative engagement, creative engagement leads to temporary arousal and depletion, and physiological recovery processes such as sleep regenerate these psychological resources for the next cycle.

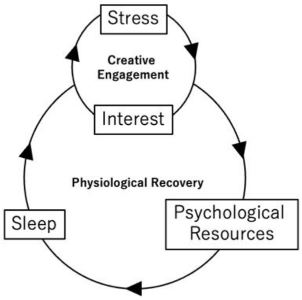

Figure 1: Indicative model of creative rhythm: Arousal–Recovery loop integrating psychological and physiological factors.

Creative activity appears to be sustained not by continuous arousal, but by oscillation between activation (rising interest, moderated stress) and recovery (stress reduction, cognitive reset).The results suggest that the creative process follows a wave-like rhythm of tension and release, characterized by dynamic transitions between Interest and Stress. Furthermore, General Self-Efficacy (GSE) and Well-being (PERMA) serve as psychological buffers that stabilize emotional states and maintain engagement, while Sleep functions as a physiological background process supporting recovery and regeneration.

Taken together, these findings imply that creative engagement is maintained through a cyclic interplay of activation and restoration, where psychological and physiological recovery mechanisms jointly modulate this rhythm.

This cyclic process corresponds to recent discussions on adaptive oscillation in cognitive and affective systems (Kounios & Beeman, 2014; McEwen, 1998).

The Arousal–Recovery Loop proposed in this study provides a conceptual framework that integrates Csikszentmihalyi's (1990) flow theory with McEwen's (1998) stress adaptation model. From this perspective, creative activity can be understood not as a sustained state of high arousal, but as a dynamic equilibrium between tension and recovery that maintains optimal focus and engagement. This view highlights creativity as a psychophysiological self-regulation process, offering a new way to understand how individuals sustain creativity through the continuous interplay of challenge, adaptation, and restoration.

GENERAL DISCUSSION AND LIMITATIONS

Theoretical Implications

This study contributes to the growing body of research on the temporal and emotional dynamics of creativity by revealing that creative engagement unfolds through a rhythmic interplay between arousal and recovery.Unlike traditional models that emphasize either persistent flow (Csikszentmihalyi, 1990) or problem-focused tension (Dorst, 2015), the present findings highlight a cyclic process in which physiological activation (Interest, Stress) and psychological regulation (GSE, PERMA, Sleep) are continuously balanced.

This rhythmic perspective offers a bridge between cognitive neuroscience and organizational psychology, suggesting that creativity is not merely a cognitive act but a psychophysiological self-regulating adaptive process involving oscillation between focus, reflection, and restoration.

Practical Implications

From an applied standpoint, these findings suggest that effective creative environments should not aim to maintain constant stimulation but rather design conditions that allow periodic release and recovery.

In organizational and educational contexts, supporting micro-recovery cycles—such as brief reflection, rest, or low-pressure dialogue—may enhance sustainable creativity and well-being.

Furthermore, the observed buffering roles of GSE and PERMA imply that psychological resource training and restorative design (e.g., sleep hygiene, mindfulness) can be integrated into creative skill development and team innovation programs.

Limitations and Future Directions

Several limitations should be acknowledged.

First, the study involved a small sample size ($n = 6$), and thus the findings should be interpreted as exploratory tendencies rather than generalizable effects.

Second, although EEG-based measures provided valuable insights into real-time emotional dynamics, they do not fully capture subjective meaning-making within creative experiences.

Future research should adopt mixed-method designs that integrate physiological, behavioral, and narrative data to explore how creative rhythm emerges across individuals and contexts. Longitudinal and cross-cultural comparisons would further clarify how psychological resources like GSE, PERMA, and Sleep interact in sustaining creativity over time.

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