EmotivChat: Toward Emotion-Aware AI Agents: A General Framework for Real-Time EEG-Driven Human–Agent Collaboration

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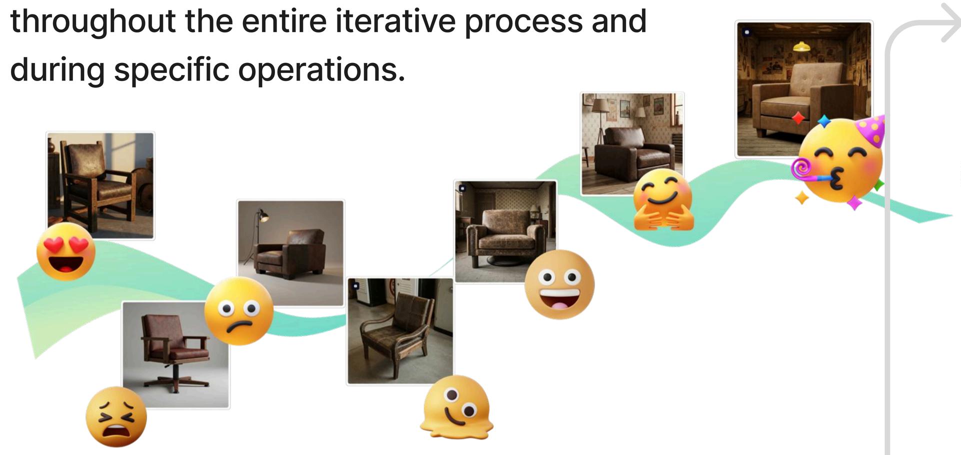
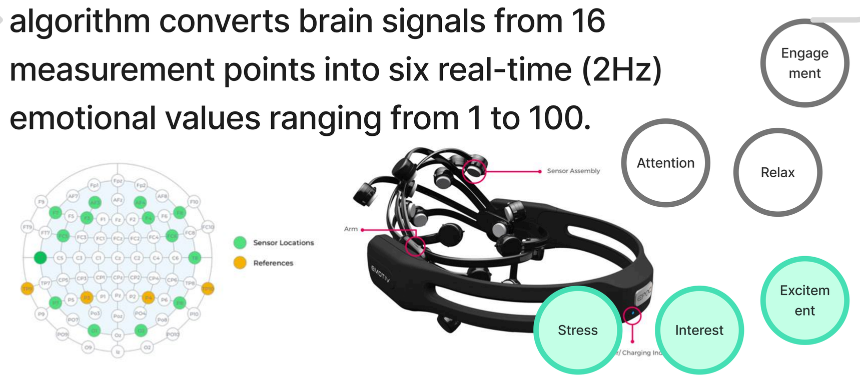
1. Background information

①Collaborative creation using generative AI through conversational methods for creative tasks has become quite commonplace.

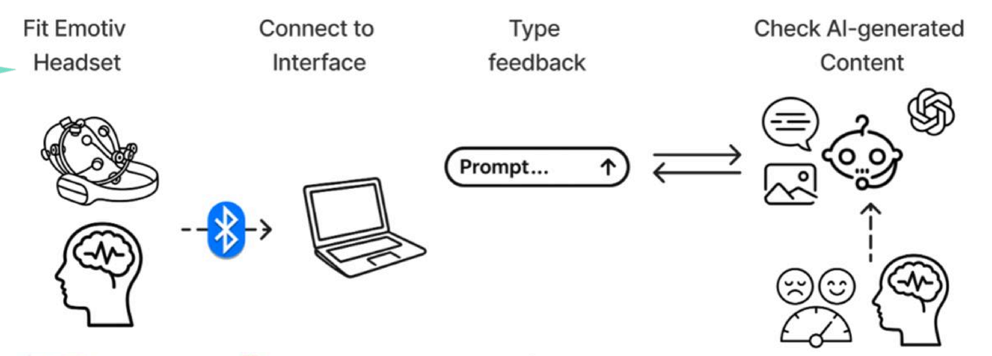
Emotion plays a significant role in creative tasks. It subtly influences users' strategic choices throughout the entire iterative process and during specific operations.

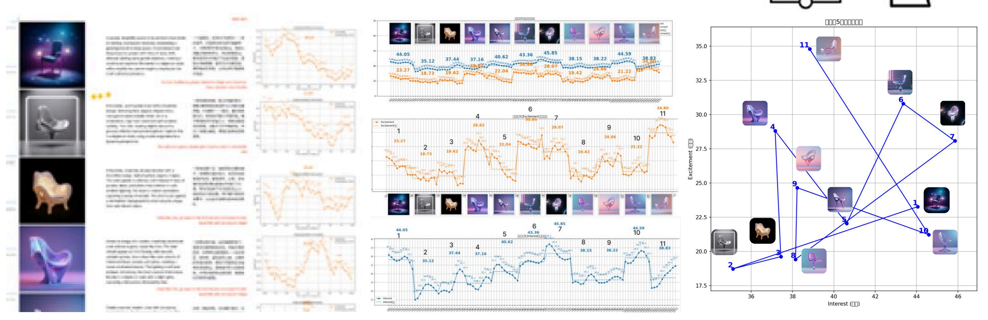


③Emotiv is a wet-electrode brain signal testing instrument whose built-in signal processing algorithm converts brain signals from 16 measurement points into six real-time (2Hz) emotional values ranging from 1 to 100.



④If the implicit emotional shifts occurring during user-AI co-creation were measured using Emotiv and transmitted to the AI, could this assist the AI in adjusting its response strategy, thereby enhancing the user experience? Based on this, the EmotivChat framework is proposed.





⑤Using this framework for a pilot study (N=6), we mapped the logical connections between emotions and tasks, as well as the methods for linking emotional signals to AI. This converged into the two user tests outlined below.

2. System Design

Study A：Co-creating Images with AI: Visual Generation Driven by Real-time Excitement and Interest (N=31)

Experimental Design

Experimental group： Users co-create product visuals with Image GenAI. Throughout the process, the system measures two emotional metrics in real time: arousal and valence, reflecting the user's response to newly generated images. Based on these metrics, the AI determines whether the user favours the latest image, thereby selecting the next strategy: either fine-tuning the previous prompt or generating a new prompt.

Control group： Without this strategy adjustment, images are generated using a fixed strategy and user interaction.

Experimental Arrangements

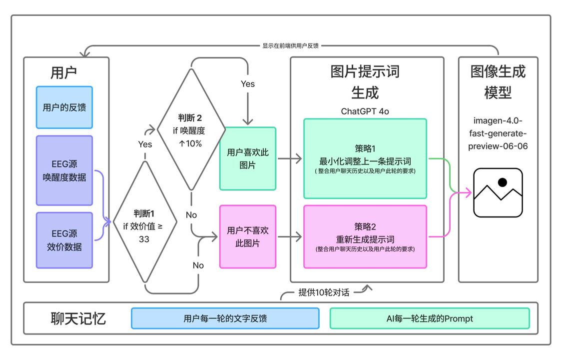
Consent & Headset Setup	Design Topic 1	User Survey 1	Design Topic 2	User Survey 2	Interview
10min	10min	3min	10min	3min	10min

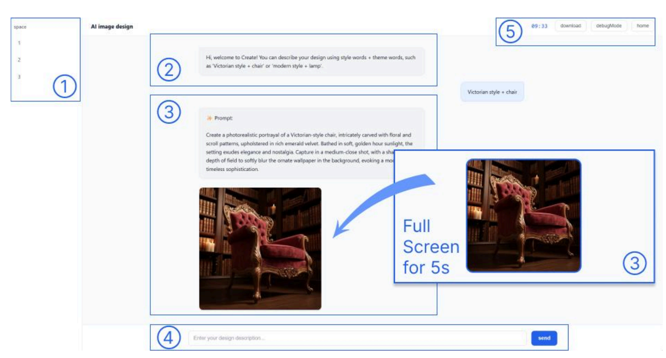
Interface

1. Enter the experimental chat interface①
2. AI generates a welcome message outlining the experiment's objectives and procedure②
3. Upon user input, AI generates the corresponding prompt and image③
4. Image displayed full-screen for 5 seconds to collect EEG signals for emotional analysis③
5. User provides typed feedback, transmitting EEG-based emotional preferences for AI iteration④
6. Countdown timer with debugging button⑤

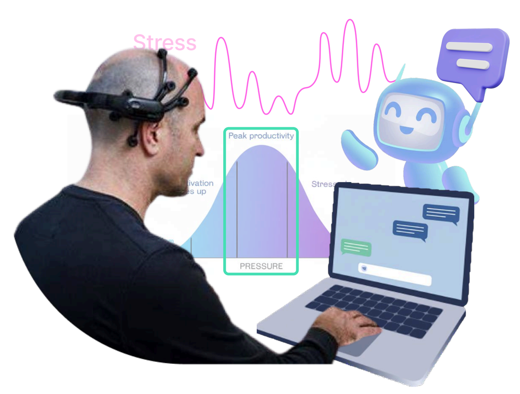
System Logic

1. Acquire brainwave-based emotional data from the user terminal and employ binary code analysis to determine user preferences.
2. AI determines the prompt logic for generating rear-wheel images based on preferences.
3. Generate images to be displayed on the front end for users to view.
4. User typing feedback, EEG transmission preferences, AI next iteration





Study B： Co-creating Text with AI: A Creative Dialogue Regulated by Stress Signals (N=29)



Experimental Design

Experimental group： Users engage in brainstorming sessions with the AI to generate creative ideas. The system continuously monitors users' stress levels in real time, reflecting their subjective perception of task difficulty. The AI dynamically adjusts its feedback strategy based on this stress level—providing greater support when users experience higher stress, while increasing challenges or reducing constraints when stress levels are lower.

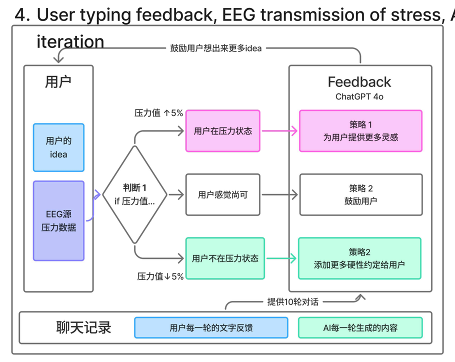
Control group： Without employing dynamic adjustment, the AI consistently interacts with users to generate creative content using a fixed strategy.

Experimental Arrangements

Consent & Headset Setup	Ideation Topic 1	User Survey 1	Ideation Topic 2	User Survey 2	Interview
10min	3min	3min	3min	3min	10min

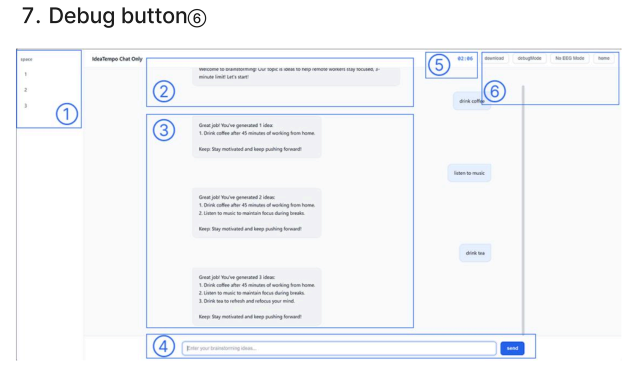
System Logic

1. Acquire brainwave stress signals from the user terminal to determine the user's stress state.
2. AI determines the prompt logic for rear-wheel encouragement based on the current state.
3. Generate encouragement, displayed on the front end, to guide the next steps.
4. User typing feedback, EEG transmission of stress, AI next iteration



Interface

1. Enter the experimental chat interface①
2. AI-generated welcome message outlining the experimental objectives and procedures②
3. After the user inputs their thoughts, the AI generates corresponding motivational phrases.③
4. User typing feedback: Continue inputting your thoughts.④
5. Transmitting brainwave stress states, AI adjusts stimulation strategies accordingly.
6. Countdown time⑤
7. Debug button⑥



3. Experimental results

Study A：Co-creating Images with AI (N=31)

A total of three distinct types of data were obtained:

1. Objective sentiment：Brain signal emotional data (Excitement & Interest) corresponding to each image during the iteration process
2. Subjective experience：User satisfaction ratings, corresponding to each image and the overall experiment
3. Interview data：Post-experiment interview with participants

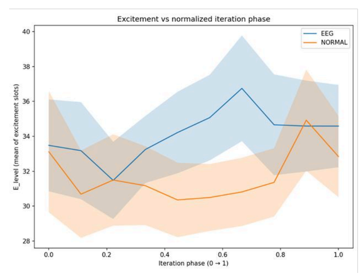
Objective sentiment

Macroscopic level: Calculate the overall arousal, affective valence, and the relationship between the presence or absence of EEG base strategy adjustments.
Microscopic level: Following turn-by-turn normalisation, compute the emotional changes throughout the entire process.

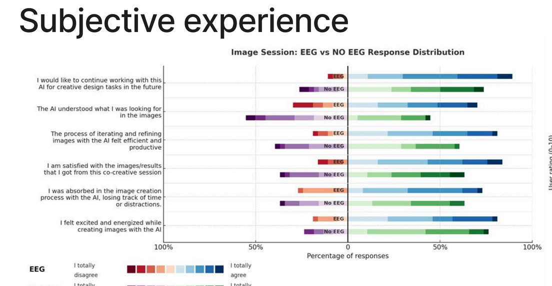
Outcome variable	EEG vs Normal	Topic	Order	R^2	Outcome variable	EEG vs Normal	Topic	Order	R^2
User_rate_score	$\beta = +0.50^{*}$ [0.10, 0.91]	n.s.	n.s.	0.012	E_peak (peak)	n.s.	n.s.	$\beta = +8.61^{***}$ [5.47, 11.75]	0.059
E_level (mean)	n.s.	n.s.	$\beta = +6.30^{***}$ [3.78, 8.83]	0.049	I_level (mean)	n.s.	$\beta = -2.28^{**}$ [-3.69, -0.87]	n.s.	0.027

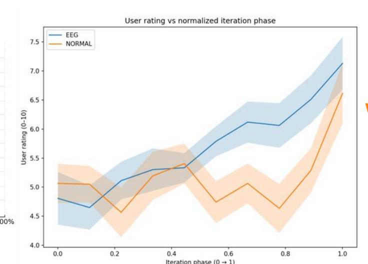
Note: Entries are coefficient estimates (β) with 95% CIs in brackets. n.s. = not significant. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Results: As shown in the figure on the right, chats employing the EEG strategy reached maximum arousal levels more rapidly.



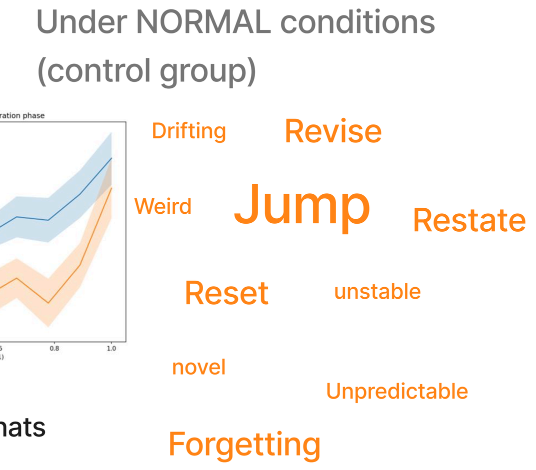
Subjective experience





Results similar to EEG arousal levels were observed, with chats employing EEG strategies reaching peak satisfaction more rapidly. Overall satisfaction levels were higher.

Interview data



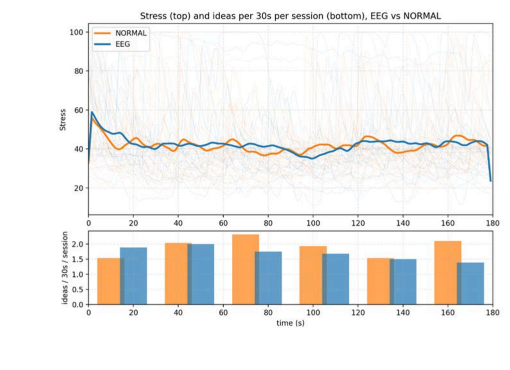
Study B：Co-creating text with AI (N=29)

A total of three distinct types of data were obtained:

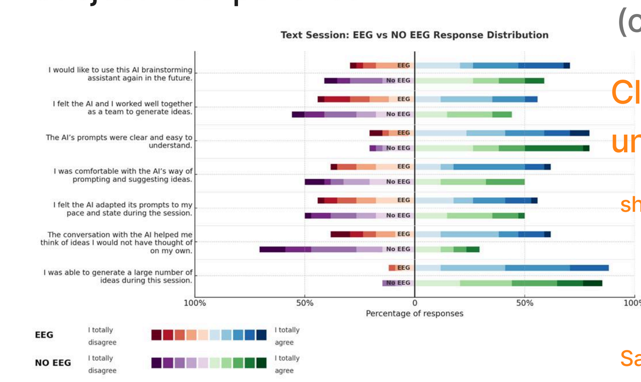
1. Objective pressure：Brain signal stress data throughout the creative dialogue process
2. Subjective experience：User satisfaction rating, corresponding to the overall experiment
3. Interview data: Post-experiment interviews with users

Objective pressure

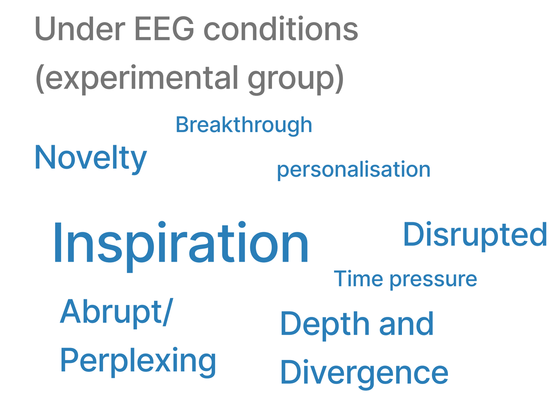
Macro level: Calculate overall arousal, emotional valence and

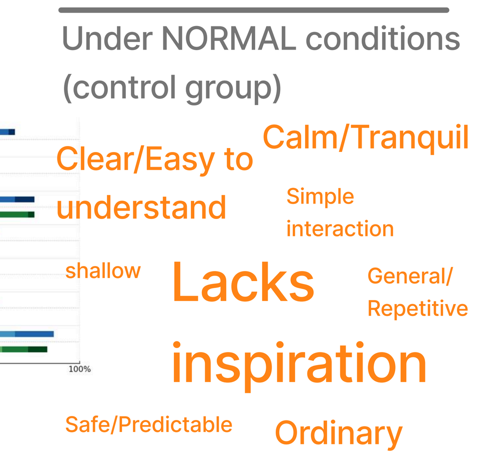


Subjective experience



Interview data





4. Summary

RQ1: What impact does a real-time EEG adaptive system have on human-AI collaboration quality?

Study A：
Both the objective emotional assessment and subjective rating tests have jointly validated that the real-time EEG adaptive system enables users to achieve their most satisfactory results more rapidly (with fewer iterations).

Study B：
No significant differences were observed under objective stress conditions. In subjective ratings, the real-time EEG adaptive system demonstrated clear advantages in creative assistance and team cohesion.

RQ2: How does the effectiveness of the EEG adaptive system differ across various creative tasks and contexts?

Study A (co-creating images with AI) ：demonstrated superior performance.
Reason:
Electroencephalogram (EEG) signals can be directly mapped to visible, immediate actions ('refinement/regeneration'), whereas in text-based tasks, they primarily modulate the 'intensity/style of prompts', which relies more heavily on timing and rhythm.

RQ3: What are the key design considerations when constructing an adaptive human-AI collaborative system using electroencephalography?

1. **Physiological signals → Discrete labels**
Convert continuous electroencephalogram (EEG) signals into a small number of auditable states (e.g., excited/calm/unresponsive) rather than raw numerical values, to ensure stability and reproducibility.
2. **Emotional Type Matching Interaction Scale**
Short-term, event-related emotions (e.g., excitement) → Guide immediate content hierarchy adjustments. Long-term states (e.g., stress, engagement) → Modulate overall conversational rhythm and cadence.
3. **Hidden Metrics, Revealed Logic**
Do not display raw emotional scores to users; instead, present only minimal reasoning ('Why this branch was selected'), while retaining full logs for auditing and debugging.

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