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Article

Influence of flavored jelly beverage consumption on emotions during video game performance: An electroencephalographic study

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Abstract: The relationship between food consumption and emotional sensitivity has attracted considerable attention recently. This study aimed to examine the impact of routine consumption of a flavored jelly beverage on performance in a video game task. We included 19 healthy Japanese male participants aged 20–44 years. Using normalized γ-wave power values and an emotional state estimation model based on electroencephalography, we found that the routine consumption of flavored jelly beverages increased γ-wave power, which may be related to arousal. During the pre-performance quiet period, the winning group exhibited a lower positive probability in the emotional state model than the losing group, suggesting that reduced positive emotional states may enhance performance. Similarly, the routine group demonstrated a low positive probability, which aligns with the emotional state of the winners. After the task, the winning group exhibited decreased γ-wave power, which may reflect reduced arousal and a calmer emotional state. Our findings suggest that optimal performance is associated with a low positive probability, which may be linked to arousal-related emotional states. Routine consumption of a flavored jelly beverage may induce this low positive probability. Thus, this study established a correlation between flavored jelly beverage intake and emotional sensitivity, which could contribute to the development of foods that are not only enjoyable and healthy but also enhance overall well-being, including mental health.

Keywords: choking under pressure; electroencephalography; emotional state estimation; emotional arousal; jelly beverages

1. Introduction

Everyday emotions are influenced by internal and external stimuli, particularly through social interaction. One notable emotion triggered by social factors is choking under pressure (Baumeister, 1984), which occurs in situations that cause social anxiety (Leary and Kowalski, 1997), competitive anxiety (Jones, 1995), test anxiety (Sarason and Sarason, 1990), and stage fright (Steptoe and Fidler, 1987). Pressure, defined as psychological stress arising from the significance of an event, can sometimes enhance performance (Hardy and Parfitt, 1991) but often leads to a decline in performance (Baumeister, 1984; Lewis and Linder, 1997). Therefore, it is essential to identify effective strategies for managing pressure.

Psychological skills training is widely employed in sports, for example, to mitigate choking under pressure by promoting emotional self-control and fostering an optimal mental state for improved performance (Birrer and Morgan, 2010; Hardy et al., 1996). The concept of optimal arousal (Hardy et al., 1996), a cognitive and physical response to stimuli, is crucial for high performance (Birrer and Morgan, 2010). Since optimal arousal levels vary based on situational factors, cognitive and affective sensations (Hardy et al., 1996), individual preferences (Hanin, 2000), and the specific demands of the task or sport, managing arousal is both complex and challenging (Seiler, 1992). Additionally, its assessment is important.

Recently, pre-performance routines (PPRs), physical and psychological preparations prior to performing a task, have gained popularity for reducing stress and improving concentration (Cotterill, 2010). PPR has exhibited significant effects in both sports (Cotterill, 2010; Lonsdale and Tam, 2008; Rupprecht et al., 2024) and musical performances (Hawkes, 2021; Tief and Gröpel, 2021), suggesting that it may be a generalized performance-enhancing intervention. Various PPR methods have been proposed (Gröpel and Mesagno, 2019; Orbach and Blumenstein, 2022); however, few studies have examined the effects of food on this behavior, although flavored jelly beverages were often used before performance.

Hiraishi (2017) investigated the effects of PPR in dart games using electroencephalogram (EEG) measurements and found that PPR significantly stabilizes concentration, with similar results observed in skilled players. This finding underscores the importance of incorporating both psychological evaluations and physiological metrics that are independent of conscious awareness. Regarding the assessment of factors independent of conscious awareness, Gu et al. (2025) investigated EEG-based emotion recognition and achieved high modeling accuracy. Horikawa et al. (2020) reliably predicted a variety of visually evoked emotional states from different brain regions using functional magnetic resonance imaging.

Given this diverse research, we explored the relationship between food consumption and emotional sensitivity, a topic that has recently attracted considerable attention (Matsui et al., 2024; Schütte and Marco-Almagro, 2022). We developed an emotional state estimation model through visual evocation, following Horikawa et al. (2020). We investigated the effects of flavored jelly beverage consumption, which is commonly used as a pre-performance food whose effects have not been examined, using a model and γ-wave power values, which represent arousal (Fitzgibbon et al., 2004; Fukuma et al., 2022), a critical factor in high-stakes situations and high performance (Birrer and Morgan, 2010; Hardy et al., 1996). The aim of this study was to examine the impact of routine consumption of flavored jelly beverages compared to the absence of such practices on performance in a video game task under pressure. The potential of using food to enhance performance during high-pressure events, which could be a viable option for PPR in the future, was also assessed.

2. Materials and methods

2.1. Test system and participants

This study followed the ethical guidelines for medical research involving human participants as outlined by Japan's Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labor and Welfare on December 22, 2014 (partially revised February 28, 2017) and February 9, 2015 (partially revised March 8, 2017). The study was approved by the Ethical Review Board of PGV Inc. (P2304-01).

The eligibility criteria were as follows: (a) no history of smoking within the past year and (b) no ongoing dental treatment or medication use. Eligible participants were also required to have regularly consumed Morinaga's commercial "in Jelly Energy" (trade name) approximately once a week over the past 1 to 2 months as routine practice. Participants were included if their response to at least one of the main questionnaire items (**Table 1**) regarding their consumption of "in Jelly Energy" was "situation under pressure."

Table 1. Questionnaire options for the occasions when participants consumed "in jelly energy".

Main items	Sub-items
Before studying for an examination	When you want to fill your stomach
Before an examination	When you are not feeling well
Before training	As a substitute for a meal
Before a match	When you want nutrients for health
Before a presentation	When you want to recover from fatigue
Before an operation	
When you need energy and motivation	
When you need to concentrate	

2.2. Experimental procedure

Nineteen healthy Japanese men aged 20–44 years participated in this study (mean age: 32.1 years; standard deviation: 7.3 years). Participants were fully informed of the study's purpose and conditions and gave their written consent before participating. To minimize the influence of external stimuli, participants adhered to the following guidelines during the study period:

(1) Maintain existing living habits (sleep, diet, and general lifestyle) and avoid binge drinking, extreme dietary changes, travel-related dietary changes, abrupt changes in exercise routines, sleep deprivation, and altered drinking habits.
(2) Refrain from using over-the-counter drugs, quasi-drugs, foods for specified health objectives, foods with functional claims, health foods, and supplements.
(3) Refrain from consuming large meals or drinks the night prior to examination.
(4) Ensure adequate sleep and avoid late nights prior to examination.
(5) Abstain from alcohol for 12 h before the examination.
(6) Avoid using scented products (e.g., perfumes, hair products, hand creams, and fabric softeners) on examination day.
(7) Refrain from consuming caffeine-containing products (e.g., coffee, tea, and energy drinks) and other stimulants (e.g., spices) on examination day.
(8) Avoid strenuous exercise until examination is complete.
(9) Do not consume anything except water for 2 h before examination.

Test parameters were measured once daily between 10:00 and 11:30 a.m., with three to five participants being measured simultaneously. Each participant was randomly assigned to either consume or refrain from consuming the test sample. The measurement protocol is illustrated in **Figure 1**.

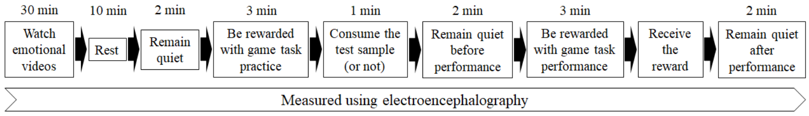

Figure 1. Measurement protocol of electroencephalography to evaluate the effects of consuming the test sample.

During the test, participants entered the designated test room post-urination. The test procedure and precautions were explained to the participants while seated. A patch-type EEG device (HARU-2, PGV Inc.; Araki et al., 2022) was placed on each participant's forehead to record signals from Fpz, Fp1, and Fp2 (**Figure 2**). Participants were asked to remain still during the measurements. Data recording began once the EEG signals were stable. After 2 min of baseline recording, participants watched emotion-inducing videos while EEG measurements continued.

Figure 2. Patch-type electroencephalography device, HARU-2.

The participants were randomly assigned to one of two groups. In one group, the participants watched videos that elicited positive emotions, followed by videos that elicited negative emotions; in the other group, the participants watched videos that elicited negative emotions first. Following a 10-min rest period, we recorded the participants' resting EEG for 2 min. Next, the participants practiced playing the video game Tetris on a smartphone for 3 min after receiving gameplay instructions. After that, to place them under pressure, we informed them that they would be awarded a 1,500-yen gift certificate if their performance in the final task surpassed their practice scores. Eight participants in the test group consumed the test sample within 1 min before the final task, while the non-consumption group (11 participants) omitted this step. Prior to starting the rewarded game task, the participants underwent a quiet period for 2 min, after which they performed the final video game task, identical to the Tetris practice, for 3 min. Participants who exceeded their practice scores were notified and rewarded. A final resting EEG was recorded for 2 min post-performance.

2.3. Test sample

Morinaga's commercial "in Jelly Energy" (trade name) was used as a test sample for a "flavored jelly beverage." It contained 180 g of the sample in a pouch with a spout (**Figure 3**).

The aroma components of the test sample were analyzed as chemical quality factors (Kinta et al., 2024; Kinta et al., 2025b); 1 g of the sample, which was diluted fivefold with water, and 1 g of water were prepared in a glass vial for analysis. The aroma components of the sample were extracted using headspace–solid phase microextraction and then measured by gas chromatography/mass spectrometry. Quantification was performed using the absolute calibration method in selected ion monitoring mode. The analytical equipment and conditions are listed in **Table 2**, the reagents are presented in **Table 3**, and the results are shown in **Table 4**.

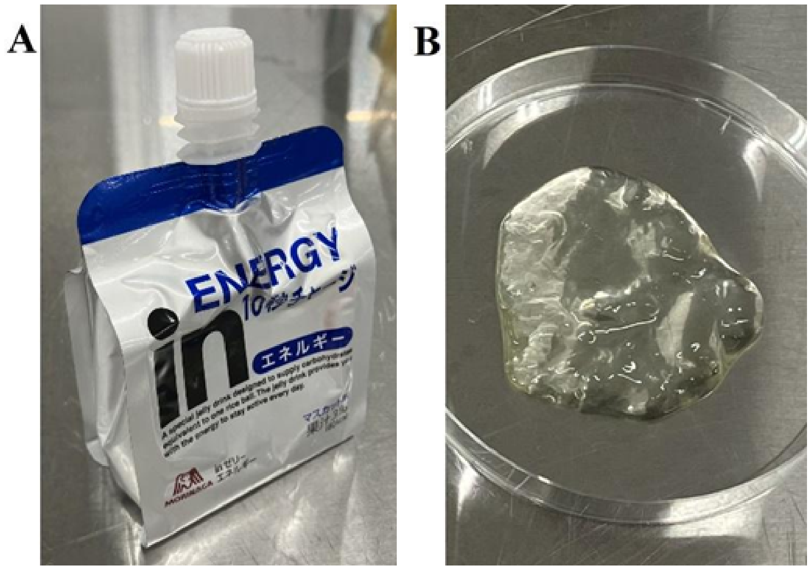

Figure 3. Images of the sample.

Note: A: Pouch container with a spout. B: Content of the pouch container.

Table 2. Analytical equipment and conditions.

Analytical equipment	**SHIMADZU GCMS-TQ8040, SHIMADZU AOC-6000**	
HS-SPME	Fiber	DVB/Carbon WR/PDMS, 80 µm (SHIMADZU)
	Incubation temperature/time	60 °C/20 min
	Sample extraction time	20 min
	Sample desorb time	3 min
Gas chromatography	Column	ZB-5 ms (Phenomenex) 30 m × 0.25 mm internal diameter × 0.25 µm film
	Column temperature	40 °C (3 min), 10 °C/min to 280 ˚C (5 min)
	Carrier gas	Helium, 1 ml/min
	Injection	1 min, splitless, 230 °C
Mass spectrometry (MS)	Interface temperature	280 °C
	Ion source temperature	200 °C
SIM monitor ion	57, 74 m/z	Ethyl propionate
	71, 43 m/z	Ethyl butyrate
	67, 41 m/z	*cis*-3-hexen-1-ol
	102, 71 m/z	Ethyl 2-methylvalerate
	67, 82 m/z	*cis*-3-hexenyl acetate
	71, 93 m/z	Linalool
	122, 104 m/z	Styralyl acetate

Note: HS-SPME: headspace–solid phase microextraction; SIM: selected ion monitoring.

Table 3. List of reagents used in this study.

Compound	**Manufacturer**
Ethyl propionate	Tokyo Chemical Industry Co., Ltd.
Ethyl butyrate	Tokyo Chemical Industry Co., Ltd.
cis-3-hexen-1-ol	FUJIFILM Wako Pure Chemical Corporation
Ethyl 2-methylvalerate	FUJIFILM Wako Pure Chemical Corporation

Table 3. *Cont.*

Compound	Manufacturer
cis-3-hexenyl acetate	FUJIFILM Wako Pure Chemical Corporation
Linalool	FUJIFILM Wako Pure Chemical Corporation
Styralyl acetate	Combi-Blocks

Table 4. Aroma components of the test samples.

Compound	Flavored jelly beverage
Ethyl propionate	14
Ethyl butyrate	6
cis-3-hexen-1-ol	6
Ethyl 2-methylvalerate	0.6
cis-3-hexenyl acetate	0.2
Linalool	0.2
Styralyl acetate	3

Note: Parts per million, limit of quantitation = 0.1.

The textural properties of the test samples were analyzed as physical properties (Kinta et al., 2024; Kinta et al., 2025b). Puncture tests were performed at 16 °C using a rheometer (CR-500V, Sun Scientific, Ltd., Tokyo, Japan) equipped with a 10-mm-diameter cylindrical probe. Measurements were taken by peeling off only the front film of the pouch container without touching the jelly inside. The breaking force (Pa) and distance (mm) of the test samples were measured at an entry velocity of 60 mm/min (**Table 5**). Breaking force refers to the amount of force required to puncture the test sample and indicates the firmness of the sample. Conversely, breaking distance represents the distance traveled by the probe before piercing the test sample and indicates the brittleness of the sample.

Table 5. Breaking force and breaking distance of the four test samples at 16 °C.

Textural properties	Breaking force (Pa)	Breaking distance (mm)
Flavored jelly beverage	0.457 ± 0.042	7.73 ± 1.39

Note: n = 3, mean ± standard deviation.

2.4. Video selection

In this study, we used videos labeled with 34 emotion categories and their scores, along with 14 affective dimensions and their scores, to visually evoke emotions (Horikawa et al., 2020; Cowen and Keltner, 2017; Kinta et al., 2025a). Although each video was associated with multiple emotion categories, we selected the category with the highest score to represent the dominant emotion for each video. Consequently, we assigned each video a new label (positive or negative) (**Table 6**).

Table 6. Definition of the affective valence label.

Affective valence label	Emotion category
Positive	Admiration, adoration, aesthetic appreciation, amusement, awe, calmness, craving, excitement, interest, joy, relief, romance, satisfaction, and triumph
Negative	Anger, anxiety, awkwardness, confusion, disgust, empathic pain, fear, horror, sadness, and surprise

Affective valence correlates with arousal scores as a psychological measure (Kuppens et al., 2013). We divided the arousal scores from the affective dimension labels defined by Cowen and Keltner (2017) into five levels to minimize the impact of arousal levels on the discriminant results of the machine learning model. For each level, we selected 10 positive and 10 negative videos. Videos that were overly stimulating or ethically inappropriate were excluded, resulting in a final selection of 47 positive and 42 negative videos. As the window size for fast Fourier transform processing in the EEG analysis was set to 2 s (see Section 2.5), all the selected videos were at least 2 s long.

2.5. EEG analysis methods

The EEG analysis methods were in accordance with the study by Kinta et al. (2025a).

2.5.1. Pre-treatment

EEG was preprocessed with a band-pass filter (0.5–45 Hz) and noise cancelation to eliminate blink artifacts. Following a wavelet transform, the noise error was estimated for each wavelet coefficient using the method described by Islam et al. (2016). Wavelet coefficients exceeding the estimated noise error were identified as noise and set to zero. A threshold filter of 400 μV was applied to eliminate noise originating from body movements.

2.5.2. Feature calculation

EEG data were isolated using a Hamming window (2 s, 50% overlap), and 10 different frequency power values were calculated utilizing the fast Fourier transform. These included γ, 25–45 Hz; β, 14–25 Hz; High-β, 18–25 Hz; Low-β, 14–17 Hz; α, 8–13 Hz; High-α, 12–13 Hz; Mid-α, 10–11 Hz; Low-α, 8–9 Hz; θ, 4–7 Hz; and brain rate. Brain rate, which represents the spectral center of gravity of the EEG frequency, is higher as the content of the high-frequency components increases and is related to the brain arousal level (Pop-Jordanova, 2011).

2.5.3. Normalization

For data during video watching, to correct for individual differences between participants, all the data from watching positive and negative videos were normalized using a z-score transformation. For each participant and each video, the frequency power per second values, derived from the windowing process, were then summed and averaged.

For data from the game task, data collected during three key moments (immediately after consuming the test sample, during a quiet period before, and after task performance) were also normalized using z-score transformation. For each participant, frequency power values per second were summed and averaged over these periods using the windowing process.

2.5.4. Construction and validation of the emotional state estimation model by machine learning

We constructed an emotional state estimation model using data collected during video watching. In the machine learning model, LightGBM (light gradient boosting machine) was used to construct an AI model that distinguished positive and negative emotional valence labels. To evaluate model performance, we calculated the following metrics: accuracy, recall, specificity, positive predictive value, and negative predictive value (**Table 7**). The model produced estimated probabilities of the positive and negative affective states, with the estimated positive probability being used to assess affective valence.

Table 7. Evaluating a machine learning model.

Evaluation indices	Score (%)
Accuracy	86.8
Recall	73.7
Specificity	100
Positive predictive value	100
Negative predictive value	79.2

2.6. Statistical method

A two-way analysis of variance (ANOVA) was performed on the positive probabilities and normalized γ-wave power values, considering three factors: test sample consumption (with vs. without), task performance outcome (win vs. lose), and the interaction between these factors. The analysis was performed at three time points: immediately after test sample consumption, during the quiet period immediately before task performance, and during the quiet period after task performance. All the analyses, including the ANOVA and the calculation of the standard deviation of participants' ages, were conducted using JMP 17.0 (64-bit).

3. Results

The results of the emotion plots immediately after test sample consumption, with positive probability in the emotional state estimation model on the horizontal axis and normalized γ-wave power values on the vertical axis, are shown in **Figure 4**. The results of the two-way ANOVA for test sample consumption (with vs. without) and subsequent task performance outcome (win vs. lose) are presented in **Table 8**. In **Figure 4**, the group that consumed the test sample is visually plotted higher, indicating a higher normalized γ-wave power value compared with that in the group that did not consume the test sample. A significant difference at the 5% risk level was observed (**Table 8**). No significant difference in normalized γ-wave power values was observed between the winning and losing groups in later performance. No significant difference was found in positive probability on the horizontal axis, regardless of test sample consumption or the subsequent task performance outcome.

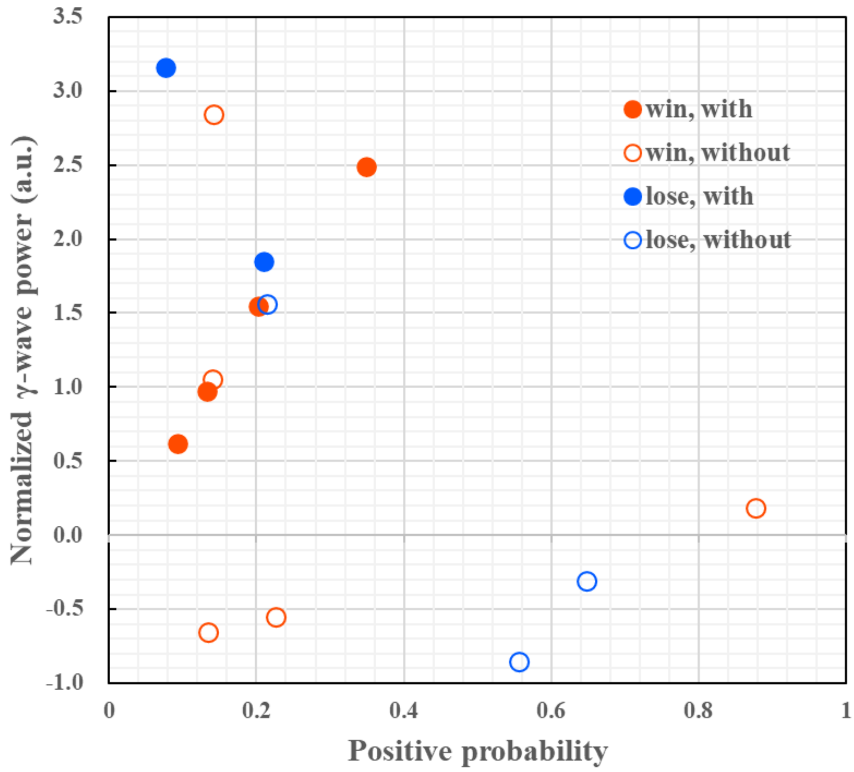

Figure 4. Post-consumption plots of emotions immediately after taking the test sample.
Note: a. u.: arbitrary unit.

Table 8. ANOVA results immediately after consumption of the test sample for test sample consumption (with vs. without) and subsequent task performance (win vs. lose).

	Normalized γ-wave power					Positive probability				
Factors	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**
With-without	1	1	8.00	5.58	0.0397**	1	1	0.150	2.65	0.135
Win-lose	1	1	0.335	0.234	0.639	1	1	0.0108	0.190	0.672
With-without × win-lose	1	1	1.85	1.29	0.282	1	1	0.0376	0.663	0.435

Note: $^{**}p < 0.05$. DF: degrees of freedom.

The results of the emotion plots during the quiet period immediately prior to task performance, with positive probability on the horizontal axis and normalized γ-wave power values on the vertical axis, are shown in **Figure 5**. The results of the two-way ANOVA for the test sample (with vs. without) and subsequent task performance outcome (win vs. lose) are presented in **Table 9** and indicate that the winning group had a significantly lower positive probability than did the losing group. The positive probability was significantly lower in the group that routinely consumed the test sample than in the group that did not consume the test sample during the quiet period prior to task performance. However, there was no significant difference in the normalized γ-wave power values between the test sample consumption and non-consumption groups, or between the winning and losing groups during the quiet period prior to task performance.

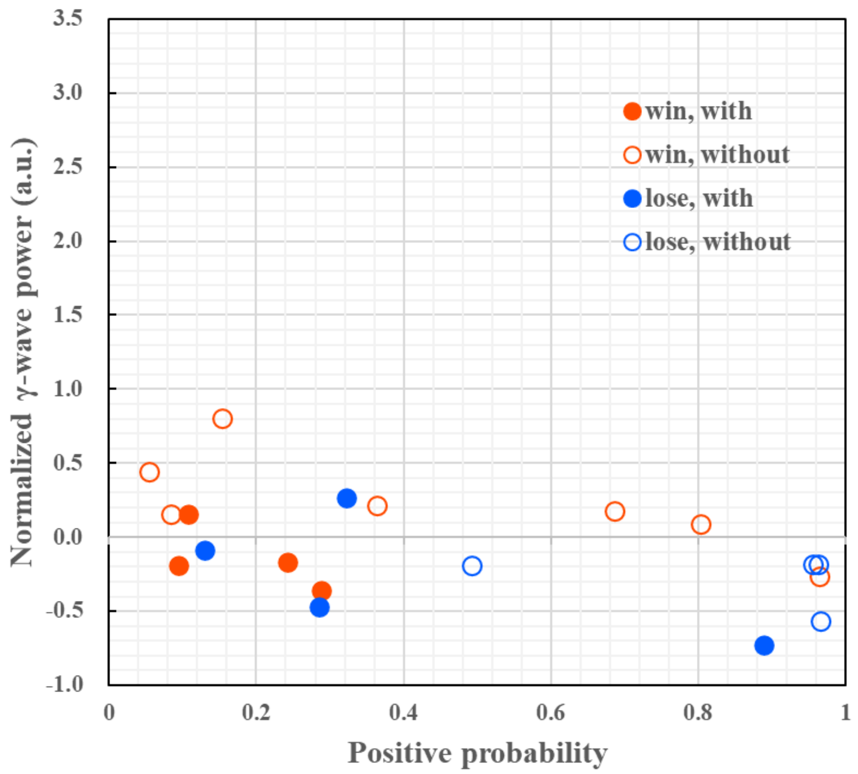

Figure 5. Plots of emotions recorded during a quiet period immediately prior to performing the task.

Note: a. u.: arbitrary unit.

Table 9. ANOVA results at a quiet period immediately prior to task performance for test sample consumption (with vs. without) and subsequent task performance (win vs. lose).

	Normalized γ-wave power					Positive probability				
Factors	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**
With-without	1	1	0.137	1.41	0.254	1	1	0.547	6.06	0.026**
Win-lose	1	1	0.442	4.53	0.05*	1	1	0.435	4.83	0.044**
With-without × win-lose	1	1	0.178	1.83	0.197	1	1	0.0349	0.387	0.543

Note: $*p < .1$, $**p < 0.05$. DF: degrees of freedom.

The results of the plots of emotions during a quiet period after task performance, with positive probability on the horizontal axis and normalized γ-wave power values on the vertical axis, are shown in **Figure 6**. The results of a two-way ANOVA for test sample consumption (with vs. without) and subsequent task performance (win vs. lose) are presented in **Table 10**, showing that the group that excelled in task performance had lower normalized γ-wave power values than did the group that did not succeed. No disparities were observed in positive probability on the horizontal axis, both with and without test sample consumption, as well as in subsequent wins and losses.

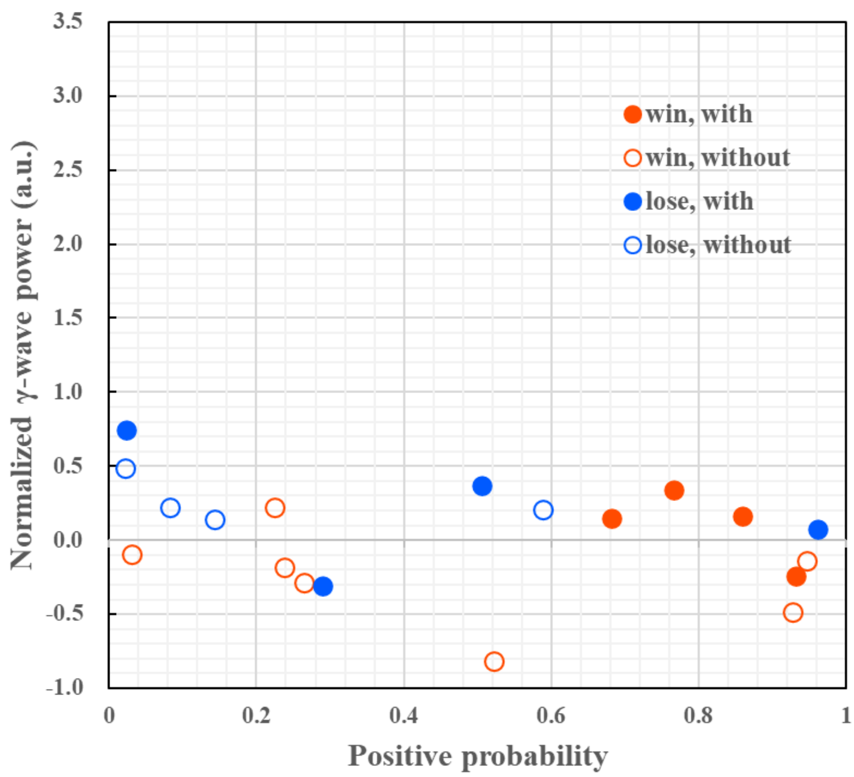

Figure 6. Plots of emotions recorded during a quiet period after performing the task.
Note: a. u.: arbitrary unit.

Table 10. ANOVA results at a quiet period after the task performance for test sample consumption (with vs. without) and subsequent task performance (win vs. lose).

	Normalized γ-wave power					Positive probability				
Factors	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**	***n***	**DF**	**Sum of squares**	***F***	***p* (Prob > F)**
With-without	1	1	0.110	1.11	0.309	1	1	0.396	3.98	0.065*
Win-lose	1	1	0.454	4.57	0.0495**	1	1	0.411	4.12	0.060*
With-without × win-lose	1	1	0.180	1.81	0.199	1	1	0.0170	0.171	0.686

Note: **p* < 0.1, ***p* < 0.05. DF: degrees of freedom.

4. Discussion

We first discuss the findings from the time series of EEG measurements. **Figure 4** illustrates the results of the emotion plots immediately after the consumption of the test sample. The group that consumed the test sample exhibited a significantly higher normalized γ-wave power value than the group that did not consume the test sample (**Table 8**). The γ-wave region is highly correlated with arousal (Fitzgibbon et al., 2004; Fukuma et al., 2022), suggesting that higher values in **Figure 4** correspond to increased arousal. Therefore, it can be inferred that routine consumption of test samples may elevate arousal levels immediately afterward. Kinta et al. (2024) measured psychological states during the consumption of flavored jelly beverages and reported that gelatinization produced arousal.

Kinta et al. (2025b) investigated the influence of flavored jelly beverage consumption on emotional sensitivity by examining heart rate variability. They reported that the presence of gelling agents suppressed the activity of the parasympathetic nervous system during consumption. They also examined correlations with subjective mood assessments and concluded that when the activity of the parasympathetic nervous system was suppressed, the arousal level increased during consumption. These results may support the possibility of an increase in arousal observed in our study.

The results in the quiet period immediately prior to task performance demonstrated that the winning group had a significantly lower positive probability than did the losing group, as presented in **Table 9**. These results suggest that a low positive probability in a quiet pre-performance period increases the likelihood of winning in subsequent performances. Considering the meaning of low positive probability in the context of emotional state estimation modeling, a high positive probability is closer to emotions defined as positive, while a low positive probability is closer to emotions defined as negative (**Table 6**), such as anger, anxiety, inspiration, confusion, disgust, empathic pain, fear, frustration, sadness, and surprise. These findings suggest that experiencing these emotions before the task increases the likelihood of winning subsequent tasks. In sports, psychological skills training has been utilized to address emotional self-regulation and to create optimal mental states that enhance performance (Birrer and Morgan, 2010; Hardy et al., 1996). Few studies support the hypothesis that negative thoughts and emotions hinder the achievement of ideal performance (Gardner and Moore, 2006). However, examples have been found where negative cognitive and somatic sensations, as well as competition anxiety, promote performance in preparation for an actual event (Hanton et al., 2005; Thomas et al., 2007).

The current findings indicate that certain negative emotions can enhance performance and that a low positive probability in the emotional state estimation model could indicate such performance. Conversely, the positive probability was also significantly lower in the group that routinely consumed the test sample than in the group that did not consume the test sample during the quiet period immediately before task performance. Prior studies have examined the effects of PPR on performance in athletes and proposed that its mechanism stabilizes individual mental states, enhances concentration, and releases excessive tension in the body and mind. However, it is unclear how it works (Cotterill, 2010). Hiraishi (2017) reported on dart games using EEG measurements and stated that PPR stabilizes concentration and improves performance in skilled players. This study found that participants who routinely consumed the flavored jelly beverage had a significantly lower positive probability, similar to the winning group. This suggests that routine consumption induced emotions that may be related to performance, considering the previous finding that the group that won in the subsequent performance had a significantly lower positive probability than did the group that lost.

The results of the quiet period after task performance showed that the winning group had lower normalized γ-wave power values, which may indicate reduced arousal compared to that in the losing group (**Table 10**). This may be owing to a decrease in arousal, which reflects post-performance feelings of relief and calmness. Although not significant, the positive probability tended to be higher in the winning group, suggesting that winning elicited positive emotions such as admiration, joy, relief, and satisfaction.

Similarly, the test sample consumption group exhibited a higher positive probability, though not significantly different, indicating that the test sample may have induced emotions similar to those experienced by winners.

From the perspective of performance management, the influence of emotions immediately after the consumption of the test sample and during the quiet pre-task period just before the performance is crucial for subsequent performance. There is an optimal state of arousal for high performance (Hardy et al., 1996). Arousal is defined as a cognitive and physical response to internal or external stimuli (Birrer and Morgan, 2010).

We found no significant differences in the normalized γ-wave power values, which may be related to arousal levels, either immediately after the test sample consumption or during a quiet period immediately before the main task, in relation to the effects on subsequent task performance. Therefore, we examined the relationship between positive probabilities, which exhibited a significant difference in their effects on subsequent task performance and arousal. **Figure 7** aggregates the data of **Figures 4–6**, plotting positive probability against normalized γ-wave power values across different time points. **Figure 7** exhibits a weak negative correlation between positive probability and normalized γ-wave power values, showing no high normalized γ-wave power values when positive probability is high. However, there are instances of high normalized γ-wave power values when positive probability is low. It is possible that the low positive probability included some elements of high normalized γ-wave power values that indicate arousal, which may have been associated with high performance. Additionally, **Table 9** presents that the normalized γ-wave power values at a quiet period immediately before task performance were not significantly different between winners and losers in the subsequent game task. However, the winning group exhibited a higher normalized γ-wave power value (level of significance: 0.0504), suggesting that higher normalized γ-wave power values that indicate arousal may contribute to winning.

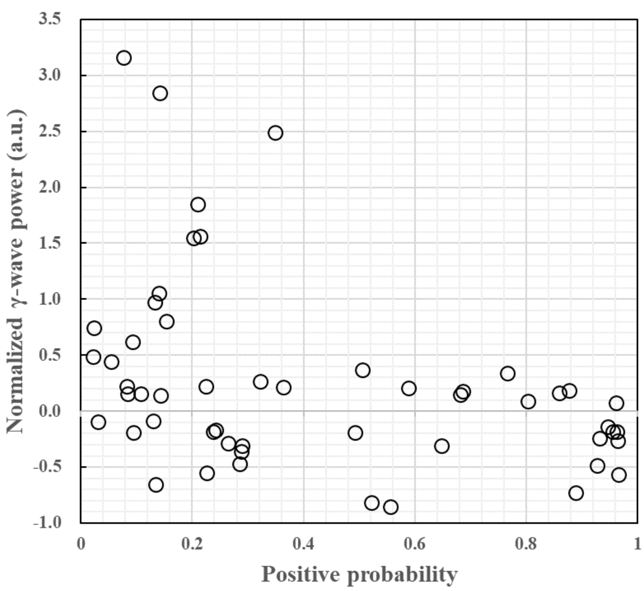

Figure 7. All the plots of emotions: immediately after the consumption of the test sample, during a quiet period immediately prior to the task performance, and in a quiet period after the task performance.
Note: a. u.: arbitrary unit.

Our method for estimating emotion state using EEG measurements indicated that the low positive probability associated with high normalized γ-wave power values, which may indicate arousal during a quiet period immediately prior to task performance, could be an indicator of performance improvement. Additionally, routine consumption of flavored jelly beverages also exhibited a similarly low positive probability, suggesting that this routine may be associated with the emotional state related to performance. Conversely, although several strategies have been proposed to control arousal appropriately (Hardy et al., 1996), most have been shown to reduce anxiety (Page et al., 1999); none have demonstrated a clear effect on performance itself (Gardner and Moore, 2006). Tief and Gröpel (2021) compared PPR with a control goal-setting intervention and reported higher self-efficacy in a post-test but found no significant difference in performance.

The group that won in the subsequent task performance had a lower positive probability during the pre-performance quiet period, and the same was true for the group that performed routine consumption; however, the latter group was not more likely to win in the subsequent performance. Although it was identified that a low positive probability, along with a high normalized γ-wave power value indicating the arousal factor, may affect performance, this low positive probability during the pre-performance quiet period may not be sufficient; rather, it is a necessary condition for performance. Other factors and indicators need to be examined to elucidate their relationships with performance. We hope that the development of these indicators and methods for controlling emotions through intervention conditions will lead to improved management of enhanced performance, including better food utilization. This study also established a correlation between flavored jelly beverage intake and emotional sensitivity, suggesting that foods that taste good and promote physical health may also influence mental well-being.

5. Conclusion

In this study, we evaluated the effect of routinely consuming flavored jelly beverages using a model for estimating emotion state based on measuring EEG during a video game task. During the quiet period immediately prior to task performance, the group that won the subsequent game exhibited a lower positive probability in the emotional state estimation model than did the group that lost. This lower positive probability was associated with an increased likelihood of winning. Similarly, during the pre-performance period, the group that consumed the test sample also exhibited a lower positive probability, suggesting that their emotional state was similar to that of the winning group. A low positive probability was considered indicative of an optimal emotional state that may be associated with arousal for high performance, and the effects of routine consumption may be related to the induction of those emotions.

We established a correlation between flavored jelly beverage intake and emotional sensitivity, which could contribute to the development of foods that are not only enjoyable and healthy but also enhance overall well-being, including mental health. However, this study has some limitations. First, the sample is relatively small and homogeneous. Second, it did not disentangle the factors that may influence routine effects, such as brand, sample quality, and methodological variables (e.g., behavioral routines). Third, EEG channels are limited and the analysis focuses mainly on gamma waves. Fourth, the model used for emotional state estimation may be overfit. Future studies should address this by including effect size reporting and controlling for potential confounding variables. Finally, it is unclear whether a model built on EEG data recorded during video viewing can be applied to EEG data collected under other conditions.

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