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Frontal alpha asymmetry in adolescent video game players: Associations with executive functions, in-game performance, and flow state

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Abstract

This exploratory study aims to investigate the relationship between resting-state frontal alpha asymmetry (FAA) and executive functions in adolescent video game players, while also examining potential associations between post-game FAA, in-game performance, and self-reported flow state.

A total of 17 Dota 2™ players and 21 CS:GO™ players underwent EEG recordings before and immediately after a training match. FAA was calculated as the difference between the alpha power at frontal electrodes (F3 and F4). Executive functions were assessed via the Behavior Rating Inventory of Executive Function-2. Post-game data included the team game outcome (win or loss) and measures of flow state.

The results revealed a significant positive association between relative left-sided frontal activity and behavioral regulation, and a tentative positive association between relative right-sided frontal activity and emotional regulation. Given the role of left-sided activity in emotional regulation, it may be assumed that regulatory control is selectively involved in suppressing impulsivity. The relationship between FAA and executive functions was inconsistent across recording conditions, highlighting a need for further methodological consideration of this issue.

FAA was not associated with team performance or flow state. However, a positive trend emerged between FAA and autotelic experience. These findings challenge the existing literature linking success in sports, approach motivation, and positive emotions to left-frontal activity, highlighting the need for further investigation.

Keywords: frontal alpha asymmetry, electroencephalography, executive functions, adolescents, video games, Dota 2, CS:GO, flow state

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Фронтальная альфа-асимметрия: связь с исполнительными функциями, игровым результатом и состоянием потока у подростков, играющих в компьютерные игры

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Резюме

Исследование рассматривает взаимосвязь между фронтальной альфа-асимметрией (ФАА) в состоянии покоя и исполнительными функциями у подростков, играющих в компьютерные игры. Также оценивается взаимосвязь ФАА после игры с игровой производительностью и состоянием потока.

В исследовании приняли участие 17 игроков в Dota 2™ и 21 игрок в CS:GO™. Электроэнцефалограмма регистрировалась до и после тренировочного матча. ФАА рассчитывалась как разница между альфа-мощностью в лобных электродах (F3 и F4). Исполнительные функции оценивались с помощью опросника Behavior Rating Inventory of Executive Function-2. После игры фиксировался командный результат матча (победа или поражение) и состояние потока.

Результаты выявили значимую положительную взаимосвязь между относительной левосторонней фронтальной активностью и регуляцией поведения, а также тенденцию к усилению эмоциональной регуляции с ростом относительной правосторонней активности фронтальной области. Учитывая роль левой лобной зоны в регуляции эмоций, можно предположить, что регуляторный контроль избирательно участвует в подавлении импульсивности. Связь между ФАА и исполнительными функциями оказалась неодинаковой в разных условиях записи ЭЭГ, что указывает на необходимость дальнейшего методологического изучения этого вопроса.

Значимые взаимосвязи ФАА с командной игровой эффективностью и состоянием потока не выявлены. Однако наблюдается тенценция к росту ФАА с ростом значений аутотелического опыта. Эти данные противоречат большинству исследований, связывающих успех в спорте, положительные эмоции и мотивацию приближения с активностью левого полушария, что подчеркивает необходимость дальнейших исследований.

Ключевые слова: фронтальная альфа-асимметрия, электроэнцефалография, исполнительные функции, подростки, компьютерные игры, Dota 2, CS:GO, состояние потока

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Introduction

Executive functions (EFs) are a set of top-down processes that facilitate goal-directed behavior by integrating working memory, inhibitory control, and cognitive flexibility. EFs can be divided into two distinct domains. The first, known as «*cold*» EFs, regulates mechanistic and affect-neutral cognitive operations, such as abstract problem-solving. The second, referred to as «*hot*» EFs, is engaged in contexts involving emotion, reward, punishment, and motivational salience (Salehinejad et al., 2021). Rather than being confined to specific cognitive domains, EFs are best conceptualized as a metacognitive, supervisory system (Ward, 2019; Salehinejad et al., 2021). The EFs enables individuals to regulate attention, manipulate information in working memory, suppress prepotent responses, and adapt to dynamically changing task demands.

Research into the neurobiological foundations of EF has consistently identified the prefrontal cortex (PFC) as its central hub (Ward, 2019). One prominent correlate of the PFC functioning, as measured by electroencephalography (EEG), is the frontal alpha asymmetry (FAA). The FAA is defined as the difference in frontal alpha power between the left and right hemispheres (Smith et al., 2017).

Two predominant research approaches for treating the FAA can be identified. The first approach conceptualizes the FAA as a stable, trait-like characteristic of an individual, typically assessed during resting-state conditions. Conversely, the second approach views the FAA as a dynamic, situation-sensitive marker of individuals' state-dependent shifts in emotional responses and motivational direction. Both lines of research reveal that reduced alpha power (an indicator of the greater cortical activation) over the left frontal hemisphere is associated with approach-oriented motivational situations, while reduced alpha power in the right frontal site correlates with withdrawal-related traits and states (Harmon-Jones, Gable, Peterson, 2010; Smith et al., 2017).

Regarding more stable individual characteristics, the resting-state FAA relates to distinct EFs. Reduced alpha power in the left hemisphere (relative to the right one) has been associated with poorer performance on a «*hot*» EF task-strategic long-term decision-making in emotionally charged, reward-based contexts — in children with neurodevelopmental differences (Edmunds et al., 2023). Greater relative left frontal activity has also been linked to fewer difficulties in emotion regulation, mainly in the impulse control domain (Zhang et al., 2020).

A meta-analysis by Kuper, Käckenmester, Wacker (2019) found FAA associations with personality traits (extraversion, neuroticism, impulsivity, anger, and defensiveness) are either absent or too weak to be practically meaningful. Given that the EF system comprises control processes that regulate behaviors and thoughts, a more comprehensive consideration of relevant individual characteristics will yield more robust relationships. As previously noted, the FAA is predominantly conceptualized as a neurophysiological index of motivational direction (approach vs. withdrawal) and emotional processing (Harmon-Jones, Gable, Peterson, 2010; Smith et al., 2017). Therefore, we hypothesized that the FAA would be associated with EF specifically in emotionally and motivationally salient contexts.

This FAA-affect relationship motivates examining this EEG marker in video game players. Given the pervasive engagement of adolescents with video games, investigating the neural correlates of EF in this population is particularly pertinent and may deepen understanding of the factors influencing behavioral adaptability in gaming contexts.

Video games are complex, dynamic activity that requires high levels of cognitive and emotional regulation for effective performance (Cregan, Toth, Campbell, 2024). This is especially true in ranked matches, where players face high-pressure situations demanding concentration, strategic thinking, and self-control. Engagement in adaptive emotion regulation strategies is linked to a reduced likelihood of experiencing *tilt* (Cregan, Toth, Campbell, 2024), an emotionally dysregulated state characterized by frustration, rage, and diminished gameplay performance (Wu, Lee, Steinkuehler, 2021). Despite the central role of emotional regulation in video game performance, the empirical literature regarding this phenomenon within the context of video games remains highly inconsistent. Studies reported a range of effects on emotional outcomes — negative, positive, and neutral — which appear to depend on factors such as the game's genre and the duration of gameplay (Lapteva, 2024).

The debate extends to the role of EF as potential markers differentiating adaptive, high involvement from problematic engagement. Another meta-analysis found that individuals with gaming disorder tend to exhibit lower inhibitory control (Argyriou, Davison, Lee, 2017). However, other researchers argue that engagement in video gaming represents a heterogeneous phenomenon not necessarily linked to deficits in EF (Brevers, King, Billieux, 2020).

Sustained EF engagement during play may include long-term neuroplastic changes. Evidence from studies employing EEG, event-related potentials, and magnetic resonance imaging (Bavelier, Green, 2019; Huang, Cheng, 2022) supports this view, identifying neural markers that distinguish successful players. However, to date, there is a notable lack of research examining the FAA as a predictor of gaming performance across genres. Game characteristics can vary considerably across genres, which may influence both the player's immediate experience (Jin, 2012) and the long-term impact on EF (Brevers, King, Billieux, 2020).

Accordingly, our aims are twofold: (1) to investigate the relationship between the resting-state FAA and the «*hot*» EFs in adolescent video game players; (2) given that frontal alpha activity may be modulated by affective state (Smith et al., 2017), to examine whether the FAA following gaming can serve as an indicator of video game performance and player immersion.

We adopt an exploratory approach for two reasons. Firstly, methods in the extant literature vary, with studies reporting the FAA for the eyes-open condition, the eyes-closed condition, or an average of both (Kuper, Kckenmester, Wacker, 2019; Luo, Tang, Fan, 2025). Accordingly, we examine potential associations for each condition individually. Secondly, we did not propose strict a priori hypotheses concerning the relationship between FAA, EFs, in-game performance, and the players' immersion; therefore, multiple possible associations are considered.

Methods

Sample

The sample consisted of 38 teenage video game players (one female, mean age 15.02 ± 1.68 years): 17 Dota 2™ players and 21 CS:GO™ players (all male). Participants reported varying levels of gaming experience, ranging from less than one year to over nine years, with a median experience exceeding nine years. Weekly gaming time varied substantially, ranging from five to more than thirty hours per week; the median indicated >30 hours weekly. Furthermore, game-specific experience (Dota 2™ or CS:GO™) ranged from 190 to 8000, and a mean of M(SD) = 1947.90 (1867.02) hours. There were no significant differences in age, overall gaming experience, weekly gaming duration, or game-specific experience between Dota 2™ and CS:GO™ players (Mann-Whitney U, *p*s > 0.05).

Only participants without video game addiction (according to the Game Addiction Scale for Adolescents; Lemmens, Valkenburg, Peter, 2009) were included in the study. According to self-report, all participants were right-handed, had normal or corrected-to-normal vision and no history of brain trauma or mental illness. Participants provided verbal informed consent, and written informed consent was obtained from the legal guardians of minors. The experimental protocol was approved by the Sirius University ethics committee. Due to technical difficulties, the post-game resting state FAA data were missing for four participants, resulting in a sample size of 34 individuals for the analysis requiring post-game EEG data.

Design and Procedure

The experiment was conducted within a 14-day e-sports kids camp residential session in August 2022. The camp is aimed at school-aged children with an interest in e-sports. It offers sessions focused on specific games, including CS:GO™ and Dota 2™. During each session, players trained under coaches' supervision and participated in a local championship. On the very first day of the session, teams were formed to balance well-qualified and novice players. During the session, each team is supervised by the same trainer.

The data collection process for each team in which at least one member was a study participant was conducted over two distinct days. On the first day, participants completed screening questionnaires designed to gather demographic information and assess eligibility for the study, including the presence of gaming addiction. Additionally, participants completed the Behavior Rating Inventory of Executive Function-2 (BRIEF-2). On the second day, participants played the training game while EEG data and game statistics were collected. Immediately after the game, the participants filled out the Flow State Scale-2 (FSS-2). During the second day of data collection, the research team made no changes to the training or gameplay process.

This study uses resting-state EEG recordings obtained before and immediately after games (Dota 2™ or CS:GO™). The matches were played in a standard 5-on-5 format. The average length of a game was approximately 40 minutes. The matches were part of the typical training process, where players competed as part of their teams, sharing the same physical space with both teammates and opponents without the opportunity to view opponents' actions. EEG data were collected simultaneously from up to five participants, while other players in the room might not have been a part of the study and simply proceed with the training process with their coaches. During the EEG recording, participants were seated in a comfortable gaming chair and were asked to remain relaxed. Both before and after the game, EEG was recorded for 1.5 minutes with eyes open, then for 1.5 minutes with eyes-closed.

Following the acquisition of post-game EEG data, the outcomes of the match were documented via screenshots of the game interface. These screenshots indicated team victory or defeat.

Dota 2™

Dota 2™ (v. 7.31 d) is a free-to-play multiplayer online battle arena (MOBA) game on personal computers. Two teams of five players each compete to destroy the enemy team's «Ancient» structure. Players choose from over 100 heroes, each with unique abilities, and use items from a vast in-game shop to enhance performance. Matches involve real-time strategy, leveling up, earning gold, and coordinating across three lanes. The average match lasts approximately 35-45 minutes and typically is uninterrupted. Players can manually pause a match; however, any player can unpause it after five seconds.

CS:GO™

CS:GO™ (v. 1.38.3.8) is a team-based first-person shooter. In its main competitive mode, two teams of five players face off in fast-paced rounds. One team aims to plant a bomb, while the other tries to prevent or defuse it. Each round lasts about two minutes, and eliminated players respawn in the next round. After each round, players earn money based on performance, and use it to buy equipment, adding a layer of strategic resource management. The first team to win a set number of rounds (usually 16 out of 30) wins the match (Gostilovich et al., 2023).

Questionnaire data

The Game Addiction Scale for Adolescents

The Game Addiction Scale for Adolescents (Lemmens, Valkenburg, Peter, 2009) assesses problematic gaming behaviors in adolescents. The scale includes 21 items corresponding to seven core addiction criteria derived from the DSM-IV criteria for pathological gambling. Validation was conducted on two independent samples of Dutch adolescents aged 12—18, each with > 350 people. Confirmatory factor analysis supported a second-order factor structure, with all factor loadings exceeding 0.50. Construct validity was further demonstrated by the scale's ability to differentiate between high engagement and pathological use. The authors provided diagnostic thresholds for identifying at-risk individuals. The scale demonstrated high reliability estimates across two different samples (Cronbach's $\alpha = 0.94$ in Sample 1 and 0.92 in Sample 2).

BRIEF-2

The BRIEF-2 is a standardized informant-report questionnaire designed to assess everyday executive functioning in children and adolescents aged 5—18 (Gioia, Isquith, Roth, 2018). We used a self-report form for ages 11—18, which evaluates a wide range of self-regulatory behaviors across seven clinical subscales. These subscales form three indices — Behavior Regulation (Inhibit and Self-Monitor), Emotional Regulation (Shift and Emotional Control), and Cognitive Regulation (Task Completion, Working Memory, and Plan/Organize) — and a Global Executive Composite score that reflects overall executive functioning. Items are rated on a 3-point Likert scale, and raw scores are converted to norm-referenced T-scores, with higher scores indicating greater executive dysfunction (Gioia, Isquith, Roth, 2018). In the present study, only the Behavior Regulation Index (BRI), Emotional Regulation Index (ERI), and their corresponding subscales were considered.

The BRIEF-2 was normed on a large, nationally representative U.S. sample of children and adolescents, matched by age, gender, ethnicity, and parent education. It demonstrates strong psychometric properties, with Cronbach's α ranging from 0.81 to 0.88 for its subscales and test-retest reliability for the self-report form of r = 0.85 over 3—4 weeks (Gioia, Isquith, Roth, 2018). The Russian adaptation of the BRIEF-2 on a sample of 486 participants (aged 15—8) confirmed the original 7-factor structure and demonstrated satisfactory internal consistency (Chumakova et al., 2022).

The Flow State Scale-2

The FSS-2 is an instrument developed to assess the flow experience across nine core dimensions (Cziksentmihalyi, 1990): challenge — skill balance, action — awareness merging, clear goals, unambiguous feedback, concentration, sense of control, loss of self-consciousness, time transformation, and autotelic experience (Jackson, Martin, Eklund, 2008). The scale includes 36 items, with four items per dimension, rated on a 5-point Likert scale of agreement. In a sample of 499 physically active Australian participants (M = 26 years, SD = 10.55; 37% male), confirmatory factor analyses supported both a first-order nine-factor model and a higher-order global flow factor, with subscales' reliability ranging from Cronbach's = 0.76 to 0.90 (Jackson Martin, Eklund, 2008).

Although originally validated in physical activity settings, the FSS-2 is conceptually suitable for use in video games research with teenagers, as video game playing similarly involves high levels of skill, real-time feedback, clear goals, and intense concentration — conditions conducive to flow. In the present study, the global flow factor, together with subscales describing shifts in subjective experience, was considered: challenge — skill balance, action — awareness merging, concentration, sense of control, loss of self-consciousness, time transformation, and autotelic experience.

EEG Data Acquisition and Signal Processing

Neural activity was recorded using a 32-channel LiveAmp x32 mobile EEG system *(Brain Products GmbH)* with Ag/AgCl active electrodes positioned according to the international 10-20 system. The montage included FCz as the reference, with all electrode impedances maintained below 10 kΩ throughout the recording session. EEG signals were acquired at a sampling rate of 500 Hz and were transmitted via a LAN connection to the LiveAmp Connector and recorded using LabRecorder software (*Brain Products GmbH*). The recorded data were stored via the Lab Streaming Layer protocol.

The raw EEG data were preprocessed using MNE-Python 1.7.1 (Gramfort et al., 2013). The preprocessing pipeline comprised the following steps. The continuous data were initially band-pass filtered between 1 and 40 Hz using a finite impulse response filter to remove slow drifts and high-frequency noise. Channels exhibiting low signal quality, including those identified as bridged electrodes, were detected and subsequently interpolated. Additionally, segments of the recording containing excessive noise were manually marked and excluded. Next, the data were re-referenced to the common average reference. Independent Component Analysis was performed to correct ocular artifacts. Components were identified based on MNE-ICALabel (Li et al., 2022) results, and those with a probability score above 0.8 were corrected.

Frontal Alpha Asymmetry Analysis

The FAA was calculated as the difference between the log-transformed alpha (8—13 Hz) power at frontal electrodes, expressed as follows: FAA = log(F3) — log(F4). Prior to this, continuous EEG data were segmented into fixed-length 1-second epochs with 0.75-second overlap. Power spectral density (PSD) in the alpha band was computed using Welch's method, with PSD estimates averaged across epochs via the median to reduce the influence of outliers. The alpha power values were log-transformed to normalize their distribution. The FAA was computed in three variants: eyes-open, eyes-closed, and the mean of both conditions.

Statistical Analysis

Statistical analysis was performed in R (v. 4.4.0) using RStudio (2024.04.01). Univariate outliers were excluded prior to analysis. For non-normally distributed variables ($p < 0.05$ in the Shapiro—Wilk test), outliers were defined as values exceeding 1.5 times the interquartile range within fame-specific groups. For normally distributed data, the exclusion criterion was set at 2.96 standard deviations from the group mean. Furthermore, predictors were z-scored.

This investigation was exploratory, as there was no strong a priori evidence to select specific EEG conditions or questionnaire subscales. Consequently, a multi-stage analytical approach was employed. For every stage involving multiple tests, the False Discovery Rate (FDR) was controlled across all models using the Benjamini—Hochberg procedure.

First, separate multiple linear regression models were fitted (using the lm() function in base R) to assess the bivariate relationships between FAA and measures of emotional and behavioral regulation, while controlling for age. The dependent variable in each model was FAA under one of three recording conditions (eyes-open, eyes-closed, or the average of both states). The independent variables were age and one of the six EF indices or subscales derived from the BRIEF-2 questionnaire: the BRI, the ERI, and the Inhibit, Self-Monitor, Shift, and Emotional Control. This resulted in 18 regression models (3 FAA conditions 6 EF metrics).

A second stage was conducted to investigate whether models incorporating both a behavioral regulation component and an emotional regulation component would better explain FAA variance. Based on the results of the first stage, the EF metrics that exhibited the strongest association with FAA (as indicated by the smallest adjusted *p*-values and largest adjusted *R* values) were selected for further analysis. Finally, a post hoc model was specified for illustration, including the specific combination of predictors that showed the strongest association in the previous stage.

To investigate the reliability of the post-game FAA as an indicator of video game performance, we developed three multiple linear regression models with the post-game FAA under one of three recording conditions as the dependent variable. The independent variables included the game outcome (team win or loss). Additionally, we controlled for the participants' age and the pre-game FAA values in the analysis.

To account for the specific characteristics of the gameplay activity that contribute to immersion, we examined the potential relationship between the flow state and the FAA utilizing a multiple linear regression analysis. The post-game FAA served as the dependent variable, while the scores from FSS-2 (Global Flow Factor, and Challenge — Skill Balance, Action — Awareness Merging, Concentration, Sense of Control, Loss of Self-Consciousness, Time Transformation, and Autotelic Experience subscales) acted as predictors. Additionally, we controlled for the game (Dota 2™ or CS:GO™), age and the pre-game FAA values. Thus, 24 models were considered (3 FAA recording conditions × 8 FSS-2 metrics). The final model was specified, including the specific combination of predictors that showed the strongest association with the FAA.

In all final models, multivariate outliers were identified utilizing the Mahalanobis distance test. Observations showing significant deviation (p-value < 0.01) were excluded from further analyses. The assumptions underlying multiple linear regression were assessed for all final models, including evaluations of homoscedasticity, multicollinearity, and the normal distribution of residuals.

Results

Initial analyses fitted 18 regression models to explore relationships between six EF metrics and FAA across three recording conditions, while controlling for age. After FDR correction, no significant associations between any EF metric and any FAA measures were found (all $p_{FDR} > 0.05$; Supplementary Table 1). Given the theoretical rationale for combining different aspects of executive regulation, a second-stage of analysis was conducted.

This stage tested models that included both one metric of behavioral regulation (BRI or Self-Monitor) and one metric of emotional regulation (Shift, Emotional Control, or the ERI), in addition to age. This yielded 18 subsequent models (3 FAA recording conditions 2 behavioral regulation metrics × 3 emotional regulation metrics). Again, no significant relationships between EF predictors and FAA were observed after FDR correction (all $p_{FDR} > 0.05$; Supplementary Table 2).

Finally, a post hoc model was fitted for illustrative purposes using the strongest predictors from prior stages. After excluding one multivariate outlier (one CS:GO™ player), this model identified significant negative associations between the FAA and ERI, and significant positive associations between FAA and the BRI (Table 1). It should be noted that the final model is conditional on the results of the exploratory screening, so its findings should be interpreted with caution.

To visualize the association between FAA and EF, topographic maps of alpha-band power were plotted over frontal and fronto-central regions for the eyes-open condition using MNE-Python 1.7.1. (Fig.). We generated topographic maps by grouping participants by their median BRI and ERI scores, creating separate visualizations for high and low scorers on each index.

To evaluate whether post-game FAA was related to a video game performance, we modeled its association with team outcome (win or loss). No significant association was observed in any of the three FAA recording conditions (all $p_{FDR} > 0.05$; Supplementary Table 3). Similarly, no significant associations were observed between FAA (across all recording conditions) and any flow state metric after controlling for pre-game FAA and age (all $p_{FDR} > 0.05$; Supplementary Table 4). However, a trend toward significance emerged for the relationship between the Autotelic Experience and FAA under eyes-closed conditions ($p_{uncorrected} = 0.01$; $p_{FDR} = 0.16$; adjusted R for the model = 0.68). These results are presented for illustrative purposes and should be interpreted with caution due to the exploratory study design (Supplementary Table 5).

Table 1 / Таблица 1

The relationships between the pre-game FAA and EFs
Взаимосвязь между ФАА перед игрой и ИФ

Pre-game FAA (eyes-open) / ФАА перед игрой (открытые глаза)			
Predictors / Предикторы	**Beta coefficients (CI) / Бета-коэффициент (ДИ)**	**p-value $_{uncorrected}$ / p-значение $_{исходное}$**	**p-value $_{FDR}$ / p-значение $_{FDR}$**
(Intercept) / (Свободный член)	−0.01 (−0.07 — 0.06)		
Age / Возраст	−0.10 (−0.16 — −0.03)	0.01	0.08
BRI / ИПР	0.15 (0.07 — 0.24)	0.01	0.02
ERI / ИЭР	−0.12 (−0.21 — −0.03)	0.01	0.14
Observations / Число наблюдений	37		
R^2 / $R^2_{adjusted}$ R^2 / $R^2_{скорректированный}$	0.44 / 0.39		

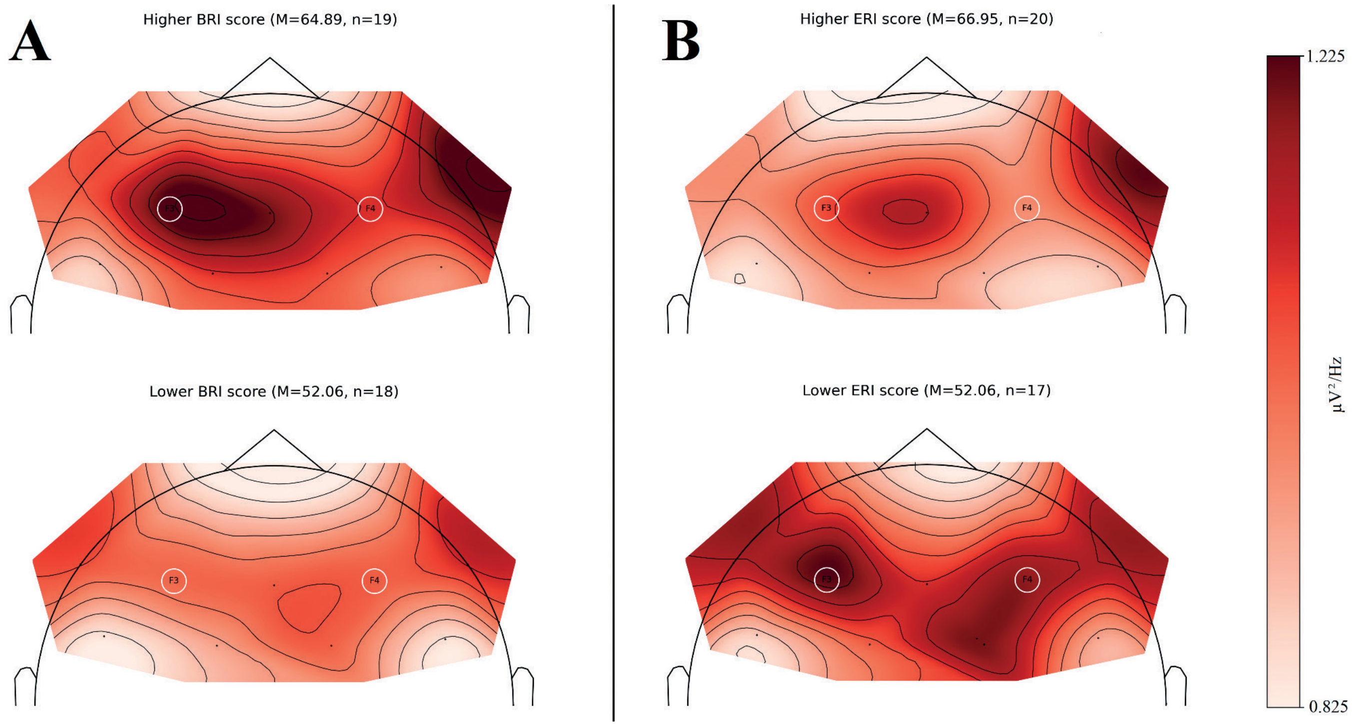

Fig. Topographic distribution of alpha-band (8—13 Hz) power (μV²/Hz) stratified by BRI (A) and ERI (B) scores

Discussion

Frontal Alpha Asymmetry and the Executive Function

Employing an exploratory screening methodology, this study provides preliminary evidence regarding the association between the FAA and the «hot» EFs in adolescent video game players. The results indicate a positive correlation between FAA scores and BRI, alongside a trend toward a negative correlation with ERI. This pattern of results suggests that an increase in relative right frontal activity (i.e., an FAA increase indicating a relative increase in left-side alpha power) might be associated with reduced behavioral regulation. Conversely, an increase in relative left frontal activity (i.e., a decline in the FAA) might be associated with impaired emotional regulation.

The negative association between right frontal activity and behavioral regulation aligns with findings by Zhang et al. (2020), who reported a similar relationship between FAA and impulse control under emotional distress. Although this study's focus was emotional regulation, we draw a parallel with our results on behavioral regulation due to the conceptual proximity of the considered constructs. Behavioral regulation (as stated in the BRIEF-2) involves monitoring overt behavior, inhibiting impulses, and awareness of the impact of one's own behavior on other people and outcomes (Gioia, Isquith, Roth, 2018). In turn, the instrument used by Zhang and colleagues — the Difficulties in Emotion Regulation Scale (Gratz, Roemer, 2004) — defines emotional regulation as a process that involves the ability to behave in accordance with desired goals when experiencing negative emotions, thereby distinguishing it from expressive control or emotional avoidance (Gratz, Roemer, 2004). This conceptualization largely aligns with the operationalization of behavioral regulation in the BRIEF-2.

A positive correlation between FAA and BRI is also consistent with the results of another study (Mikolajczak et al., 2010) that found an association between greater relative left frontal activity and higher trait emotional intelligence scores, predominantly with sociability (interpersonal utilization and management of emotions) and self-control (regulation of emotions and impulses). This confirms that BRI encompasses the regulation of the impact of one's actions on others, and its implementation is not feasible without adequate emotional intelligence.

As for the other group of «*hot*» EFs, the relationship between FAA and ERI was insignificant after applying the correction for multiple tests. Therefore, for emotional regulation, one can only assume a tendency to decrease with an increase in left-sided frontal activity. These findings align with prior evidence linking relatively greater left frontal activity to diminished executive functioning in emotionally valenced contexts, particularly under conditions requiring strategic decision-making for receiving an award (Edmunds et al., 2023).

ERI assesses the ability to regulate emotional responses, including those changing situations. Poor ERI can be expressed as emotional lability or emotional explosiveness, difficulties in switching and perseverative behavior (Gioia, Isquith, Roth, 2018).

Notably, impulsivity has also been linked to left frontal brain activity. The findings of Gable et al. (2015) showed that individuals with higher trait positive urgency — the tendency to engage in impulsive behaviors when in a positive mood — exhibit reduced right frontal activity. Other facets of impulsivity, including positive urgency, negative urgency, lack of premeditation, and lack of perseverance, were also associated with relatively greater left frontal activity (Neal, Gable, 2016;

Neal, Gable, 2017). In the context of the ERI, impulsivity traits may indicate increased reactivity to emotional triggers, thereby creating more challenging conditions for executive control, which can manifest as deficits such as emotional explosiveness and affective lability.

Although the association (or tendency toward association) of the FAA with the two groups of EFs is consistent with some studies, it is important to emphasize the opposite direction of the two associations. With a relative increase in right-sided frontal activity, behavioral regulation worsens, while emotional regulation tends to improve. The divergent relationship can be explained by considering the processes involved. The BRI assesses the capacity to inhibit impulses and self-monitor behavior, including observing and evaluating one's actions as experienced by others (Gioia, Isquith, Roth, 2018). A reduction in BRI may simultaneously reflect both diminished inhibitory control (manifesting as increased impulsivity) and impaired self-monitoring. This combination can result in elevated impulsivity that is not necessarily accompanied by a subjective awareness or perceived need to inhibit such impulses. Therefore, individuals with worse behavioral regulation (higher BRI score) might not report or experience the same urgency to control impulsive behaviors as those with difficulties in emotional regulation (higher ERI score), where emotional triggers explicitly drive the impulsivity.

Neal and Gable (2017) conceptualize impulsivity as a manifestation of impaired regulatory control over motivational impulses. The findings of the present study can be elucidated by incorporating an additional dimension into this relationship. Impulsivity may be more accurately understood as one of the components of regulatory control operating as a bottom-up process. In contrast, inhibition of impulses operates as a top-down process, initiated by a subjective need — reflecting that individuals are not invariably motivated to suppress their impulses; hence, impulsivity should not be construed solely as indicative of diminished regulatory control.

The association between the FAA and EF was only observed during the eyes-open state and not when eyes were closed or when data were averaged, which indicates that this relationship may be state-specific. Despite the apparent distinction between the presence and absence of visual input conditions, recent meta-analyses (Luo, Tang, Fan, 2025; Kuper, Kckenmester, Wacker, 2019) have incorporated studies utilizing each of the three approaches. However, the rationale and potential confounding effects of integrating data from these varied neurophysiological states remain unexamined. This specificity remains to be clarified and is a significant area for future research.

Frontal Alpha Asymmetry, Post-Game State, and Game Performance

The present study found no statistically significant associations between the post-game resting-state FAA and either team performance (i.e., game outcome) or players' self-reported flow state. One potential explanation is the limited statistical power. The analysis lacked a robust *a priori* effect-size estimate. The modest sample, further split across two game genres, may have been insufficient to detect a small effect, if present. Genre structure may influence FAA — performance or immersion associations. CS:GO™ employs a round-based format, in which each round is an independent experience. Conversely, Dota 2™ offers continuous gameplay experience, without clearly delineated rounds. Consequently, the failure to reject the null hypothesis, while not confirming the absence of an effect, may be attributable to the methodological constraints. Future research should use larger samples to definitively ascertain the relationship between FAA and game performance.

Beyond sample size, the timing of the FAA measurement is crucial. The FAA was assessed during a resting-state condition subsequent to the game session. This approach conceptualized the post-game FAA as a residual state marker reflecting the affective and motivational tone elicited by the performance or player immersion. However, the most pertinent neural correlates of game performance or experience are the FAA dynamics that occur during the game itself in response to specific events (Ding et al., 2018). It is suggested that future research employing EEG recording during gameplay could elucidate whether dynamic, time-locked changes in the FAA are more strongly associated with game performance or immersion outcomes than a post-game state. Future studies should address the apparent contradiction between the right-lateralized activity observed in League of Legends™ players during combat (Ding et al., 2018) and the links between left-frontal activity and superior athletic performance, positive affect, and approach motivation (Chen et al., 2019).

Although no significant associations were found, a trend suggested a potential positive relationship between FAA and Autotelic Experience — an intrinsically motivated, process-oriented state (Cziksentmihalyi, 1990). This contrasts with much of the literature linking right frontal activation to withdrawal motivation but aligns with research connecting it to sensation seeking (Neal, Gable, 2016). The findings of the current study may reflect by the specific context of team-based gaming. In such environments, heightened engagement may increase emotional experiences due to the social and competitive dynamics, affecting the significance of the outcome of the game. Increased right-hemisphere activity has also been linked to positive arousal. We propose that initial withdrawal responses to in-game challenges were later positively reassessed as exciting. This positive assessment serves as a motivation for playing digital games. As a result, games that elicit stronger emotional reactions are often seen as more enjoyable (Salminen et al., 2009).

This study has several limitations that may impact the interpretation and generalizability of the findings. First, the sample size was relatively small, especially after dividing participants by the games. Additionally, there were no strict criteria regarding the level of gaming experience and expertise required for participants' inclusion in the study. Furthermore, indicators of experience and expertise were not included as covariates in the analysis, which could have provided valuable insights into their potential effects on the results.

In accordance with prevailing methodologies, our analysis interpreted activity at the F3 and F4 electrodes as indicative of processes in their underlying prefrontal regions. The use of a 32-channel EEG system limited the analysis to scalp electrodes, as source localization requires higher electrode densities for precise anatomical mapping. The elucidation of the neuroanatomical sources is a prospect for future research. Furthermore, adopting an individualized approach to defining the alpha frequency band for each participant would improve the precision of future findings.

Conclusions

Employing an exploratory approach, this study examined the relationships between the FAA, EFs, gaming performance, and flow state in video game players. The analyses revealed that the relationships between EFs and FAA were heterogeneous across EEG recording conditions. As the field lacks a clear rationale for selecting specific conditions, these findings underscore the necessity for more targeted studies to establish an empirical basis for such choices. Furthermore, results showed a significant negative association between relative right-sided frontal activity and behavioral regulation, and a tentative positive association with emotional regulation. These divergent patterns may indicate differences in regulatory functions between hemispheres. Given the role of left-sided frontal activity in emotional regulation, we propose that regulatory control is selectively involved in suppressing impulsivity. Specifically, behavioral control may be shaped by the interplay between impulsivity and the subjective need to suppress impulses. However, these conclusions are preliminary and must be validated through independent replication studies with larger sample sizes.

The present study found no association between post-game resting-state FAA and either game performance or flow state. However, the findings suggest a potential association between heightened levels of autotelic experience and a relative increase of activity over the right frontal area. The implications of this result remain unclear, since most of the literature links relatively greater right frontal activity to withdrawal motivation. Therefore, additional research is necessary, as our findings challenge the existing literature suggesting that success in sports, approach motivation, and positive emotions are predominantly linked to greater relative left-frontal activity.

Краткое изложение содержания статьи на русском языке

Введение

Исполнительные функции (ИФ) представляют собой комплекс нисходящих процессов, обеспечивающих целенаправленное поведение. ИФ целесообразно концептуализировать как метакогнитивную контролирующую систему, не ограничиваясь рассмотрением отдельных когнитивных процессов (Ward, 2019; Salehinejad et al., 2021). Согласно одному из подходов, ИФ подразделяются на «холодные», отвечающие за реализацию когнитивных процессов в эмоционально-нейтральном контексте, и «горячие», связанные с реализацией исполнительного контроля на фоне различных эмоциональных состояний (Salehinejad et al., 2021).

Фронтальная альфа-асимметрия (ФАА), рассчитываемая на основе данных электроэнцефалографии (ЭЭГ), является одним из показателей функционирования префронтальной коры — области, которой отводится ключевая роль в реализации ИФ (Ward, 2019). ФАА вычисляется как разница между мощностью альфа-ритма в левой и правой лобных областях (Smith et al., 2017). Можно выделить два подхода к изучению ФАА: первый рассматривает ее как коррелят устойчивых индивидуальных характеристик, второй — в качестве коррелята эмоционально и мотивационно окрашенных состояний. Оба подхода сходятся в том, что снижение мощности альфа-ритма (отражающее рост активности) в левой лобной области отражает мотивацию достижения, а аналогичные изменения в правой лобной области — мотивацию избегания (Smith et al., 2017).

Исследования указывают на связь ФАА с индивидуальными характеристиками, в том числе относящимися к ИФ (Zhang et al., 2020; Edmunds et al., 2023). Однако в рамках метаанализа было выявлено, что связь ФАА с такими чертами, как экстраверсия, нейротизм, импульсивность, является слабой либо отсутствует вовсе (Kuper, Käckenmester, Wacker, 2019). Предполагается, что комплексный учет различных аспектов ИФ может способствовать обнаружению более выраженных связей индивидуальных характеристик с ФАА. Учитывая имеющиеся данные о ФАА как ЭЭГ-корреляте мотивации и эмоциональных состояний, следует ожидать, что ФАА будет связана с «горячими» ИФ (Smith et al., 2017).

Компьютерные игры представляют собой сложную деятельность, требующую высокого уровня саморегуляции, особенно в соревновательных матчах (Cregan, Toth, Campbell, 2024). При этом эмпирические данные о влиянии компьютерных игр на эмоциональную сферу остаются противоречивыми и варьируются в зависимости от игрового жанра, длительности игры и других факторов (Лаптева, 2024), которые, среди прочего, определяют состояние вовлеченности в процессе игры. Также наблюдается недостаток исследований, рассматривающих ФАА в качестве коррелята игровой результативности.

Настоящее исследование носит эксплораторный характер и имеет две основных цели: 1) изучить взаимосвязь между ФАА в покое и «горячими» ИФ у подростков, играющих в компьютерные игры; 2) рассмотреть взаимосвязь ФАА в покое после игры с игровой результативностью и состоянием потока.

Методы

Сбор данных проводился в киберспортивном детском лагере. Выборку исследования составили 38 подростков (одна девушка, средний возраст 15,02 ± 1,68 года): 17 игроков в Dota 2™ и 21 игрок в CS:GO™ (все юноши). Все участники были правшами, имели нормальное или скорректированное до нормального зрение, не имели черепно-мозговых травм, психических заболеваний и игровой зависимости.

Выполнялась регистрация ЭЭГ в состоянии покоя (1,5 минуты с открытыми глазами и 1,5 минуты — с закрытыми) до и после игрового тренировочного матча. ФАА рассчитывалась как разность логарифмов мощности альфа-ритма (8—13 Гц) в лобных отведениях: ФАА = log(F3) — log(F4). Расчет производился отдельно для записи с открытыми глазами, закрытыми глазами, а также усредненно по этим условиям записи.

За день до игры участники заполнили опросник для оценки исполнительных функций (Behavior Rating Inventory of Executive Function-2, BRIEF-2). На второй день участники приняли участие в тренировочном матче по Dota 2™ или CS:GO™, в ходе которого были собраны ЭЭГ-данные, а также зафиксирован итоговый командный результат (победа или поражение) по итогу игры. После игры участники заполняли опросник состояния потока (Flow State Scale-2, FSS-2).

Эксплораторный статистических анализ выполнялся методом линейной регрессии и предусматривал моделирование множества возможных взаимосвязей между ФАА и шкалами опросников, игрой, командной результативностью при учете возраста участников и игры.

Результаты и обсуждение

Полученные результаты указывают на то, что повышение относительной активности в правой лобной области (по отношению к активности в левой лобной области) связано с ухудшением поведенческой регуляции (β = 0,15, p_{FDR} = 0,02). Кроме того, повышение относительной активности в левой лобной области может быть связано со снижением эмоциональной регуляции (β = –0.12, p_{FDR} = 0,14).

Установленная взаимосвязь между относительной активностью в правой лобной области и индексом поведенческой регуляции (ИПР; более высокий балл соответствует более низкой способности к регуляции поведения) концептуально согласуется с данными о связи ФАА с саморегуляцией, преимущественно в части контроля импульсов (Zhang et al., 2020). Результаты также согласуются с ранее выявленной положительной связью между относительной активность левой лобной области и эмоциональным интеллектом (Mikolajczak et al., 2010). Поскольку ИПР указывает на контроль за последствиями действий в социальном контексте, успешная поведенческая регуляция будет зависеть от уровня эмоционального интеллекта.

Связь между ФАА и индексом эмоциональной регуляции (ИЭР) оказалась незначимой после применения поправки на множественные сравнения, однако наблюдалась тенденция к снижению эмоциональной регуляции при увеличении относительной активности в левой лобной области. Этот результат согласуется с данными о взаимосвязи между повышением активности префронтальной коры и снижением результативности в задаче на принятие решений в эмоционально окрашенном контексте (Edmunds et al., 2023).

Примечательно, что относительно большую активность в левой лобной области ассоциируют с импульсивностью. Gable et al. (2015) показали, что склонностью к импульсивному поведению в позитивном настроении связана с относительным снижением активности правой лобной доли. Другие аспекты импульсивности имели аналогичную связь (Neal, Gable, 2016; Neal, Gable, 2017).

Дефицит эмоциональной регуляции может выражаться в эмоциональной лабильности, вспыльчивости и навязчивых переживаниях (Gioia, Isquith, Roth, 2018). Высокая импульсивность в данном контексте может указывать на повышенную реактивность в ответ на эмоциональные триггеры, затрудняющую реализацию исполнительного контроля.

Несмотря на согласованность результатов с рядом исследований, важно подчеркнуть разнонаправленную связь ФАА с ИПР и ИЭР. Так, относительная активность в правой лобной области связана негативно с поведенческой регуляцией, но положительно — с эмоциональной. ИПР может отражать не только снижение тормозного контроля, но и нарушение процессов мониторинга собственного поведения, включающих способность оценивать свои действия через призму восприятия окружающих (Gioia, Isquith, Roth, 2018). Такое сочетание может привести к повышенной импульсивности, которая не обязательно сопровождается субъективной необходимостью корректировать поведение. Напротив, трудности в эмоциональной регуляции можно считать более осознаваемыми в силу субъективной значимости триггеров.

В рамках второй цели исследования не удалось обнаружить значимых связей ФАА после игры с победой или поражением команды и состоянием потока. Однако наблюдалась тенденция к взаимосвязи ФАА с аутотелическим опытом (β = 0.09, p_{FDR} = 0,16) — состоянием повышенной внутренней мотивации, ориентированной на процесс, а не на результат деятельности (Cziksentmihalyi, 1990). Это противоречит большинству исследований, связывающих активность правой префронтальной коры с мотивацией избегания, но согласуется с результатами, указывающими на ее связь со стремлением к поиску ощущений (Neal, Gable, 2016). Данное противоречие может быть объяснено спецификой командных компьютерных игр. Повышенная вовлеченность может усиливать эмоциональные переживания из-за социальной и соревновательной динамики. Можно предположить, что изначальные реакции избегания, возникающие в ответ на игровые ситуации, впоследствии могли переоцениваться и способствовать вовлеченности в игровой процесс. В пользу этого свидетельствуют выводы о том, что игры, вызывающие более сильные эмоциональные реакции, часто воспринимаются как более увлекательные (Salminen et al., 2009).

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Ethics statement

The study was reviewed and approved by the Ethics Committee of Sirius University of Science and Technology (dated 15 April 2021, with amendments adopted on 20 June 2022)

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I.O. Tkachenko: methodology, investigation, writing of the original draft.

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Conflict of interest

The author declares no conflict of interest.

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Supplementary

Table 1/ Таблица 1

The relationships between the pre-game FAA and executive functions (models with one predictor)
Взаимосвязь между ФАА перед игрой и исполнительными функциями (модели с одним предиктором)

X2	Intercept estimate / Свободный член	Age / Возраст		X2		N	$R^2_{Adjusted}$ $R^2_{Скорр.}$
		Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}	Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}		
		Dependent variable = Pre-game FAA (eyes open) / Зависимая переменная = ФАА перед игрой (открытые глаза)					
Self-Monitor / Самомониторинг	-0.01	-0.08 (-0.16 — 0.01)	0.11	0.05 (-0.04 — 0.13)	0.85	36	0.09
Shift / Переключение	-0.02	-0.10 (-0.19 — -0.02)	0.07	-0.02 (-0.10 — 0.06)	0.98	38	0.11
Emotional Control / Эмоциональный контроль	-0.02	-0.10 (-0.19 — -0.02)	0.07	-0.01 (-0.09 — 0.08)	0.98	38	0.11
ERI / ИЭР	-0.02	-0.10 (-0.18 — -0.02)	0.07	-0.01 (-0.09 — 0.08)	0.98	38	0.11
Inhibit / Торможение	-0.03	-0.11 (-0.19 — -0.03)	0.07	0.05 (-0.03 — 0.13)	0.85	37	0.14
BRI / ИПР	-0.03	-0.10 (-0.18 — -0.02)	0.07	0.08 (0.00 — 0.16)	0.3	38	0.2
		Dependent variable = Pre-game FAA (eyes closed) / Зависимая переменная = ФАА перед игрой (закрытые глаза)					
Shift / Переключение	0.09	-0.07 (-0.15 — 0.01)	0.11	-0.00 (-0.08 — 0.08)	0.99	37	0.03
Emotional Control / Эмоциональный контроль	0.09	-0.07 (-0.15 — 0.01)	0.12	-0.01 (-0.09 — 0.07)	0.98	37	0.03
ERI / ИЭР	0.09	-0.07 (-0.15 — 0.01)	0.11	0.00 (-0.07 — 0.08)	0.98	37	0.03
Inhibit / Торможение	0.08	-0.06 (-0.14 — 0.02)	0.12	-0.02 (-0.10 — 0.05)	0.98	36	0.04
BRI / ИПР	0.09	-0.07 (-0.14 — 0.01)	0.11	0.03 (-0.05 — 0.11)	0.98	37	0.05
Self-Monitor / Самомониторинг	0.08	-0.06 (-0.14 — 0.01)	0.12	0.09 (0.02 — 0.17)	0.3	35	0.2
		Dependent variable = Pre-game FAA (average) / Зависимая переменная = ФАА перед игрой (усредненно по условиям)					
Shift / Переключение	0.02	-0.08 (-0.15 — -0.01)	0.07	0.00 (-0.07 — 0.08)	0.98	37	0.07
Emotional Control / Эмоциональный контроль	0.02	-0.08 (-0.15 — -0.01)	0.07	0.01 (-0.07 — 0.08)	0.98	37	0.07
Inhibit / Торможение	0.02	-0.08 (-0.15 — -0.01)	0.07	0.02 (-0.05 — 0.09)	0.98	36	0.08
ERI / ИЭР	0.02	-0.08 (-0.15 — -0.01)	0.07	0.02 (-0.05 — 0.09)	0.98	37	0.08
Self-Monitor / Самомониторинг	0.03	-0.06 (-0.12 — 0.01)	0.12	0.07 (-0.00 — 0.14)	0.3	35	0.14
BRI / ИПР	0.02	-0.08 (-0.15 — -0.01)	0.07	0.07 (-0.00 — 0.13)	0.3	37	0.17

Table 2 / Таблица 2

The relationships between the pre-game FAA and executive functions (models with two predictors)
Взаимосвязь между ФАА перед игрой и исполнительными функциями (модели с двумя предикторами)

X2	X3	Intercept estimate / Свободный член	Age / Возраст		X2		X3		N	$R^2_{Adjusted}$ / $R^2_{Скорр.}$
			Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}		
			Dependent variable = Pre-game FAA (eyes open) / Зависимая переменная = ФАА перед игрой (открытые глаза)							
BRI / ИПР	ERI / ИЭР	-0.03	-0.09 (-0.16 — -0.01)	0.14	0.15 (0.25 — 0.25)	0.06	-0.10 (-0.20 — -0.01)	0.66	38	0.28
BRI / ИПР	Emotional Control / Эмоциональный контроль	-0.03	-0.08 (-0.17 — -0.00)	0.14	0.10 (0.19 — 0.19)	0.06	-0.05 (-0.14 — 0.03)	0.67	38	0.21
BRI / ИПР	Shift / Переключение	-0.03	-0.10 (-0.18 — -0.03)	0.14	0.12 (0.21 — 0.21)	0.06	-0.08 (-0.17 — 0.01)	0.66	38	0.25
Self-Monitor / Самомониторинг	ERI / ИЭР	-0.01	-0.07 (-0.15 — 0.02)	0.17	0.06 (0.16 — 0.16)	0.22	-0.04 (-0.13 — 0.04)	0.67	36	0.09
Self-Monitor / Самомониторинг	Emotional Control / Эмоциональный контроль	-0.01	-0.07 (-0.15 — 0.02)	0.17	0.05 (0.14 — 0.14)	0.29	-0.03 (-0.11 — 0.05)	0.67	36	0.08
Self-Monitor / Самомониторинг	Shift / Переключение	-0.01	-0.07 (-0.16 — 0.01)	0.17	0.07 (0.17 — 0.17)	0.18	-0.06 (-0.15 — 0.03)	0.67	36	0.11
			Dependent variable = Pre-game FAA (eyes closed) / Зависимая переменная = ФАА перед игрой (закрытые глаза)							
BRI / ИПР	ERI / ИЭР	0.09	-0.06 (-0.14 — 0.01)	0.17	0.05 (0.15 — 0.15)	0.38	-0.03 (-0.13 — 0.08)	0.67	37	0.03
BRI / ИПР	Emotional Control / Эмоциональный контроль	0.09	-0.06 (-0.14 — 0.02)	0.17	0.04 (0.13 — 0.13)	0.38	-0.03 (-0.11 — 0.06)	0.67	37	0.03
BRI / ИПР	Shift / Переключение	0.09	-0.07 (-0.15 — 0.01)	0.17	0.04 (0.13 — 0.13)	0.38	-0.02 (-0.11 — 0.07)	0.67	37	0.02
Self-Monitor / Самомониторинг	ERI / ИЭР	0.08	-0.06 (-0.13 — 0.02)	0.17	0.10 (0.19 — 0.19)	0.06	-0.03 (-0.11 — 0.05)	0.67	35	0.19
Self-Monitor / Самомониторинг	Emotional Control / Эмоциональный контроль	0.08	-0.05 (-0.13 — 0.02)	0.18	0.10 (0.17 — 0.17)	0.06	-0.02 (-0.09 — 0.06)	0.67	35	0.19
Self-Monitor / Самомониторинг	Shift / Переключение	0.08	-0.06 (-0.14 — 0.02)	0.17	0.11 (0.20 — 0.20)	0.06	-0.04 (-0.12 — 0.04)	0.67	35	0.2
			Dependent variable = Pre-game FAA (average) / Зависимая переменная = ФАА перед игрой (усредненно по условиям)							
BRI / ИПР	ERI / ИЭР	0.02	-0.07 (-0.14 — -0.00)	0.14	0.10 (0.19 — 0.19)	0.08	-0.05 (-0.14 — 0.04)	0.67	37	0.17
BRI / ИПР	Emotional Control / Эмоциональный контроль	0.02	-0.07 (-0.14 — 0.00)	0.17	0.08 (0.15 — 0.15)	0.08	-0.03 (-0.11 — 0.05)	0.67	37	0.16

BRI / ИПР	Shift / Переключение	0.02	-0.08 (-0.15 — -0.01)	0.14	0.09 (0.17 — 0.17)	0.08	-0.04 (-0.12 — 0.04)	0.67	37	0.17
Self-Monitor / Самомониторинг	ERI / ИЭР	0.03	-0.05 (-0.12 — 0.02)	0.17	0.07 (0.15 — 0.15)	0.1	-0.02 (-0.09 — 0.06)	0.67	35	0.12
Self-Monitor / Самомониторинг	Emotional Control / Эмоциональный контроль	0.03	-0.05 (-0.12 — 0.02)	0.18	0.07 (0.14 — 0.14)	0.1	-0.02 (-0.09 — 0.05)	0.67	35	0.12
Self-Monitor / Самомониторинг	Shift / Переключение	0.03	-0.05 (-0.12 — 0.02)	0.17	0.08 (0.16 — 0.16)	0.09	-0.03 (-0.11 — 0.05)	0.67	35	0.13

Table 3 / Таблица 3

The relationships between the post-game FAA and team game performance (while controlling for the game)
Взаимосвязь между ФАА после игры и командным игровым результатом (при контроле типа игры)

Intercept estimate / Свободный член	Age / Возраст		Pre-game FAA / ФАА перед игрой		Game / Игра		Win / Победа		N	$R^2_{Adjusted}$ / $R^2_{Скорр.}$
	Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}		
	Dependent variable = Post game FAA (eyes open) / Зависимая переменная = ФАА после игры (открытые глаза)									
-0.04	-0.08 (-0.15 — -0.01)	0.07	0.66 (0.90 — 0.90)	<0,01	-0.02 (-0.14 — 0.10)	0.75	0.08 (-0.05 — 0.20)	0.22	34	0.61
	Dependent variable = Post game FAA (eyes closed) / Зависимая переменная = ФАА после игры (закрытые глаза)									
-0.02	-0.01 (-0.08 — 0.06)	0.72	0.54 (0.84 — 0.84)	<0,01	0.05 (-0.06 — 0.16)	0.75	0.09 (-0.04 — 0.23)	0.22	33	0.49
	Dependent variable = Post game FAA (average) / Зависимая переменная = ФАА после игры (усредненно по условиям)									
-0.03	-0.05 (-0.11 — 0.00)	0.1	0.58 (0.83 — 0.83)	<0,01	0.02 (-0.08 — 0.11)	0.75	0.10 (-0.00 — 0.20)	0.16	33	0.61

Table 4 / Таблица 4

The relationships between the post-game FAA and FSS (while controlling for the game)
Взаимосвязь между ФАА после игры и состоянием потока (при контроле типа игры)

FSS-2 scale / Шкала состояния потока-2	Intercept estimate / Свободный член	Age / Возраст		Pre-game FAA / ФАА перед игрой		Game / Игра		FSS-2 scale / Шкала состояния потока-2		N	$R^2_{Adjusted}$ / $R^2_{Скорр.}$
		Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}	*Beta (CI) / Бета-коэффициент (ДИ)*	p_{FDR}	Beta (CI) / Бета-коэффициент (ДИ)	p_{FDR}		
		Dependent variable = Post-game FAA eyes open / Зависимая переменная = ФАА после игры (открытые глаза)									
Total / Общий балл	0.02	-0.07 (-0.14 — 0.00)	0.19	0.65 (0.90 — 0.90)	<0,01	-0.04 (-0.16 — 0.09)	0.98	-0.00 (-0.06 — 0.06)	0.99	34	0.59
Challenge Skill Balance / Баланс между сложностью задачи и уровнем мастерства	0.02	-0.07 (-0.14 — 0.00)	0.19	0.65 (0.89 — 0.89)	<0,01	-0.04 (-0.16 — 0.08)	0.98	-0.01 (-0.08 — 0.05)	0.99	34	0.59
Merging of Action and Awareness / Слияние деятельности и осознания	0.02	-0.07 (-0.14 — -0.00)	0.19	0.64 (0.89 — 0.89)	<0,01	-0.04 (-0.16 — 0.08)	0.98	-0.02 (-0.08 — 0.04)	0.99	34	0.6

Concentration on the Task / Концентрация на задаче	0.02	-0.07 (-0.15 — 0.01)	0.19	0.65 (0.90 — 0.90)	<0,01	-0.04 (-0.16 — 0.09)	0.98	-0.00 (-0.07 — 0.07)	0.99	34	0.59
Sense of Control / Ощущение контроля	0.02	-0.07 (-0.15 — -0.00)	0.19	0.66 (0.90 — 0.90)	<0,01	-0.04 (-0.16 — 0.09)	0.98	0.01 (-0.05 — 0.07)	0.99	34	0.59
Loss of Self Consciousness / Потеря самоосознания	0.02	-0.07 (-0.14 — -0.00)	0.19	0.66 (0.91 — 0.91)	<0,01	-0.03 (-0.16 — 0.09)	0.98	-0.01 (-0.08 — 0.05)	0.99	34	0.59
Transformation of Time / Искажение восприятия времени	0.02	-0.07 (-0.14 — -0.00)	0.19	0.66 (0.91 — 0.91)	<0,01	-0.04 (-0.17 — 0.08)	0.98	-0.02 (-0.08 — 0.04)	0.99	34	0.59
Autotelic Experience / Аутотеличность опыта	-0.02	-0.08 (-0.14 — -0.02)	0.19	0.63 (0.85 — 0.85)	<0,01	0.02 (-0.09 — 0.13)	0.98	0.09 (0.03 — 0.15)	0.16	34	0.68
		Dependent variable = Post-game FAA eyes closed / Зависимая переменная = ФАА после игры (закрытые глаза)									
Total / Общий балл	0.03	0.02 (-0.05 — 0.08)	0.83	0.65 (0.92 — 0.92)	<0,01	0.03 (-0.08 — 0.14)	0.98	-0.01 (-0.07 — 0.04)	0.99	33	0.46
Challenge Skill Balance / Баланс между сложностью задачи и уровнем мастерства	0.05	0.01 (-0.05 — 0.08)	0.83	0.62 (0.89 — 0.89)	<0,01	0.02 (-0.09 — 0.13)	0.98	-0.04 (-0.09 — 0.02)	0.99	33	0.49
Merging of Action and Awareness / Слияние деятельности и осознания	0.03	0.01 (-0.06 — 0.07)	0.85	0.64 (0.91 — 0.91)	<0,01	0.03 (-0.08 — 0.14)	0.98	-0.01 (-0.07 — 0.04)	0.99	33	0.46
Concentration on the Task / Концентрация на задаче	0.03	0.01 (-0.07 — 0.08)	0.89	0.66 (0.92 — 0.92)	<0,01	0.03 (-0.08 — 0.14)	0.98	0.00 (-0.06 — 0.07)	0.99	33	0.46
Sense of Control / Ощущение контроля	0.03	0.01 (-0.05 — 0.08)	0.83	0.66 (0.93 — 0.93)	<0,01	0.03 (-0.08 — 0.14)	0.98	-0.01 (-0.07 — 0.04)	0.99	33	0.46
Loss of Self Consciousness / Потеря самоосознания	0.03	0.01 (-0.05 — 0.07)	0.85	0.65 (0.92 — 0.92)	<0,01	0.03 (-0.08 — 0.14)	0.98	-0.00 (-0.06 — 0.05)	0.99	33	0.46
Transformation of Time / Искажение восприятия времени	0.03	0.01 (-0.05 — 0.07)	0.85	0.66 (0.92 — 0.92)	<0,01	0.03 (-0.08 — 0.14)	0.98	0.00 (-0.05 — 0.06)	0.99	33	0.46
Autotelic Experience / Аутотеличность опыта	0.02	-0.00 (-0.07 — 0.06)	0.98	0.61 (0.88 — 0.88)	<0,01	0.06 (-0.06 — 0.17)	0.98	0.04 (-0.03 — 0.11)	0.99	33	0.48
		Dependent variable = Post-game FAA average / Зависимая переменная = ФАА после игры (усредненно по условиям)									
Total / Общий балл	-0.03	-0.05 (-0.13 — 0.03)	0.36	0.78 (1.10 — 1.10)	<0,01	-0.01 (-0.14 — 0.12)	0.98	-0.00 (-0.07 — 0.07)	0.99	33	0.55
Challenge Skill Balance / Баланс между сложностью задачи и уровнем мастерства	0.05	-0.04 (-0.10 — 0.02)	0.36	0.62 (0.87 — 0.87)	<0,01	-0.01 (-0.11 — 0.09)	0.98	-0.02 (-0.07 — 0.04)	0.99	33	0.56
Merging of Action and Awareness / Слияние деятельности и осознания	0.04	-0.04 (-0.10 — 0.02)	0.36	0.62 (0.88 — 0.88)	<0,01	-0.00 (-0.11 — 0.10)	0.98	-0.01 (-0.06 — 0.04)	0.99	33	0.56
Concentration on the Task / Концентрация на задаче	0.04	-0.05 (-0.11 — 0.02)	0.34	0.64 (0.89 — 0.89)	<0,01	-0.01 (-0.11 — 0.10)	0.98	0.02 (-0.04 — 0.07)	0.99	33	0.56
Sense of Control / Ощущение контроля	0.04	-0.04 (-0.11 — 0.02)	0.34	0.64 (0.89 — 0.89)	<0,01	-0.00 (-0.10 — 0.10)	0.98	0.02 (-0.03 — 0.07)	0.99	33	0.57

Loss of Self Consciousness / Потеря самоосознания	0.04	-0.04 (-0.10 — 0.02)	0.36	0.64 (0.89 — 0.89)	<0,01	-0.00 (-0.10 — 0.10)	0.98	-0.01 (-0.06 — 0.05)	0.99	33	0.55
Transformation of Time / Искажение восприятия времени	0.05	-0.04 (-0.10 — 0.02)	0.36	0.65 (0.90 — 0.90)	<0,01	-0.01 (-0.11 — 0.09)	0.98	-0.02 (-0.07 — 0.03)	0.99	33	0.57
Autotelic Experience / Аутотеличность опыта	0.01	-0.05 (-0.11 — 0.00)	0.19	0.60 (0.83 — 0.83)	<0,01	0.04 (-0.06 — 0.14)	0.98	0.07 (0.01 — 0.12)	0.23	33	0.63

Table 5 / Таблица 5

The relationships between the post-game FAA and flow state
Взаимосвязь между ФАА после игры и состоянием потока

Post-game FAA (eyes-open) / ФАА после игры (открытые глаза)			
Predictors / Предикторы	**Beta coefficients (CI) / Бета-коэффициент (ДИ)**	**p-value $_{uncorrected}$ / p-значение $_{исходное}$**	**p-value $_{FDR}$ / p-значение $_{FDR}$**
(Intercept) / (Свободный член)	–0.02 (–0.11 — 0.06)		
Age / Возраст	–0.08 (–0.14 — –0.02)	0.01	0.19
Pre-game FAA (eyes-open) / ФАА перед игрой (открытые глаза)	0.63 (0.42 — 0.85)	<0.001	<0.001
Game [CS:GO™] / Игра [CS:GO™]	0.02 (–0.09 — 0.13)	0.72	0.98
Autotelic Experience / Аутотеличность опыта	0.09 (0.03 — 0.15)	0.01	0.16
Observations / Число наблюдений	34		
R^2 / $R^2_{adjusted}$ R^2 / $R^2_{скорректированный}$	0.72 / 0.68		