Examining Mental Fatigue Through League of Legends Ranked and Teamfight Tactics Gameplay Patterns in the Context of Gaming Addiction

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***Abstract*—Competitive digital gaming environments such as League of Legends and Teamfight Tactics impose sustained cognitive demands through continuous attention, rapid decision making, and prolonged engagement. This study adopts a longitudinal single-participant case study design to examine how gameplay structure, including session duration, cumulative daily exposure, timing, and wakefulness, relates to self-reported mental fatigue and focus. A total of 120 session-level observations were analyzed using a custom Cognitive Strain Index to capture the joint behavior of perceived exhaustion and attentional capacity.**

Results indicate that gameplay exposure is systematically associated with cognitive state, with stronger effects observed at the cumulative daily level than at the single-session level. Session duration was positively associated with mental fatigue and negatively associated with focus, and these associations strengthened when gameplay was aggregated daily, indicating that accumulated exposure better reflects cognitive impact than isolated sessions. Temporal context further differentiated outcomes. Late-night sessions exhibited significantly higher cognitive strain than non-late sessions, confirming nocturnal play as a high-risk context for fatigue accumulation. Behavioral clustering revealed distinct engagement profiles characterized by different combinations of duration, wakefulness, fatigue, and focus. High fatigue occurred both in very long sessions and in shorter sessions preceded by extended wakefulness, while some high-frequency patterns maintained low fatigue and high focus. These results indicate that cognitive strain emerges from multi-factor engagement structure rather than duration alone.The findings show that competitive gameplay is not cognitively neutral; extended cumulative exposure, late-night timing, and prior wakefulness jointly align with elevated fatigue, reduced focus, and higher cognitive strain.

***Index Terms*—Competitive digital gaming, mental fatigue, cognitive strain index, League of Legends, Teamfight Tactics, longitudinal case study, session timing, cumulative exposure, self reported focus, late night gaming, temporal trend analysis.**

I. Introduction

Competitive digital gaming has become an increasingly cognitively demanding activity, particularly within ranked multiplayer environments such as *League of Legends* Ranked Solo/Duo and *Teamfight Tactics*. These games require sustained attention, rapid decision-making, strategic planning, and continuous evaluation of performance over extended periods of time. Ranked modes further intensify these demands by introducing performance-based progression systems, social comparison, and persistent incentives to continue playing.

Mental fatigue is a psychophysiological state that emerges after prolonged cognitive effort and is characterized by reduced attentional capacity, diminished focus, slower reaction times, and impaired decision-making. In competitive gaming contexts, mental fatigue may accumulate across repeated sessions within a single day, especially when players engage in long or frequent gameplay without sufficient recovery. Despite this, many players continue gaming even when fatigued, suggesting a disconnect between perceived exhaustion and behavioral regulation.

Existing research has largely focused on population-level analyses or survey-based approaches. While these studies provide valuable insights, they often lack fine-grained temporal resolution and do not capture moment-to-moment gameplay structure. This study addresses this gap by adopting a detailed session-level analytical approach using longitudinal self-collected gameplay data.

This research examines how gameplay session duration, frequency, and timing in *League of Legends* Ranked Solo/Duo and *Teamfight Tactics* relate to self-reported mental fatigue and focus. By integrating statistical analysis, time-based evaluation, and unsupervised clustering, this work contributes the following:

- A session-level characterization of gameplay frequency, duration, and time-of-day patterns across *League of Legends* Ranked Solo/Duo and *Teamfight Tactics*.
- An analysis of how daily gameplay activity and total daily playtime align with self-reported mental fatigue and focus levels.
- A time-based evaluation of gameplay behavior (e.g., late sessions) and its association with elevated cognitive strain.
- An unsupervised clustering of gameplay sessions to identify distinct behavioral profiles that may reflect maladaptive or addiction-related gaming patterns.

Based on cognitive fatigue theory and observed behavioral persistence in competitive gaming, this study evaluates two hypotheses. Hypothesis 1 examines the relationship between gameplay duration or frequency and fatigue and focus ratings. The null hypothesis (H_{0_1}) states that there is no significant relationship between gameplay duration or frequency and fatigue or focus ratings. The alternative hypothesis (H_{1_1}) states that there is a significant relationship between gameplay duration or frequency and fatigue and focus ratings, such that longer and more frequent gameplay is associated with higher fatigue and lower focus.

Hypothesis 2 examines whether late-night gaming sessions are associated with greater cognitive strain than non-late sessions. The null hypothesis (H_{0_2}) states that there is no significant difference in cognitive strain between late gaming sessions and non-late gaming sessions. The alternative hypothesis (H_{1_2}) states that there is a significant difference in cognitive strain between late gaming sessions and non-late gaming sessions, with late gaming sessions showing higher cognitive strain.

II. Related Work

Prior research supports the link between prolonged competitive play and mental fatigue. Bikas et al. monitored League of Legends players over seven weeks and reported that extended play sessions were associated with increased mental fatigue and reduced in-game performance [1]. This work motivates the present study's emphasis on session duration as a primary exposure variable and on fatigue and focus as key outcomes, while the present study extends the approach by examining daily structure and by applying correlation and clustering to a detailed single-player log.

Evidence also suggests that competitive gamers may persist despite fatigue. Luo et al. examined reciprocal effects between esport participation and mental fatigue and found that higher participation was commonly associated with increased post-game mental fatigue, while only a minority reduced participation after fatigue increased [2]. This aligns with the behavioral persistence component of addiction-related models and supports investigating whether fatigue and focus degrade without a corresponding reduction in play frequency or duration.

More recent diary-based work highlights potential reinforcing cycles. Xu et al. reported bidirectional associations between game craving and mental fatigue across a 21-day diary design, where craving predicted subsequent fatigue and fatigue predicted subsequent craving [3]. These findings suggest that fatigue may function both as an outcome and as part of a feedback loop that sustains continued engagement. The present study complements this line of work by focusing on within-day session structure, late-night timing, and clustering-based identification of behavioral profiles that may indicate the onset of reinforcing patterns.

Overall, the literature indicates that competitive gaming can increase mental fatigue, that fatigue does not reliably suppress continued play, and that fatigue may participate in feedback mechanisms that sustain engagement. However, fewer studies integrate session timing, daily aggregation, and composite cognitive strain metrics within a unified empirical pipeline using fine-grained session logs. This study addresses that gap by combining timing-based features, hypothesis testing for late-night effects, and unsupervised clustering on standardized gameplay and cognitive variables.

III. Methodology

A. Study Design and Data Collection

This work uses a longitudinal single-participant case study based on daily self-tracked gameplay sessions. Records were collected continuously using in-client match history, OP.GG logs, and structured manual self-reporting. The analytic dataset contains 128 rows and 9 variables: 120 session-level rows and 8 zero-session rows retained to preserve day-level continuity. The data span 71 calendar days with recorded gameplay activity.

Each session record includes *Date Played*, *Session Start Time*, *Session End Time*, and *Session Duration (min)*. Duration was computed as elapsed time between end and start timestamps. After each session, the participant reported perceived mental fatigue and focus using 10-point ratings (*Mental Fatigue Rating (1 Lowest)* and *Focus Rating (1 Lowest)*), where higher values indicate higher fatigue and higher focus, respectively.

The dataset also includes *Hours Awake Before Session*, defined as the time from wake time to the first session start on the same calendar day. This day-level variable was repeated across session rows for tabular consistency. Day-level aggregates were derived from session records, including *Daily Session Count* and *Total Daily Gaming Duration (min)*. To prevent cross-day leakage, sessions spanning 00:00 (local time) were split into two records, and the post-midnight portion was assigned to the subsequent day.

Table I lists the analytic variables. Table II shows an excerpt of the uploaded CSV used as the dataset reference.

TABLE I.
Data Dictionary of Analytic Variables

Variable	Level	Description
Date Played	Session	Calendar date
Session Start Time	Session	Start timestamp
Session End Time	Session	End timestamp
Session Duration (min)	Session	Elapsed minutes
Mental Fatigue Rating (1 Lowest)	Session	Fatigue rating
Focus Rating (1 Lowest)	Session	Focus rating
Hours Awake Before Session	Day	Awake hours
Daily Session Count	Day	Daily sessions
Total Daily Gaming Duration (min)	Day	Daily minutes

B. Data Preparation and Parsing

All timestamps were parsed into datetime representations to compute durations and extract time-of-day features. Session-level and day-level measures (*Session Duration*, *Daily Session Count*, and *Total Daily Gaming Duration*) were derived deterministically from parsed timestamps. Zero-session placeholder rows were excluded from session-level analyses and retained only to maintain day-level continuity checks.

TABLE II.
Data head

Date Played	Start Time	End Time	Dur (min)	Cnt	Daily (min)	Fat	Foc	Awk (h)
11/21/2025	12:14 AM	7:20 AM	426	2	560	8	2	2.00
11/21/2025	9:41 PM	11:55 PM	134	2	560	2	3	0.50
11/22/2025	3:34 AM	6:48 AM	194	2	331	2	8	0.25
11/22/2025	9:42 PM	11:59 PM	137	2	331	7	4	3.50
11/23/2025	12:00 AM	9:42 AM	582	1	582	9	3	4.00

C. Feature Engineering

1) Late-Night Session Indicator: A binary late-night flag was created from session start time (local time). Sessions starting in the interval 22:00–04:59 were labeled as late-night, and all others were labeled non-late.

2) Day-of-Week Feature: A categorical day-of-week feature was derived from the session date (local time) to summarize weekly timing patterns. The variable was treated as a nominal factor for descriptive comparisons.

3) Cognitive Strain Index: Cognitive strain was operationalized using a bounded index computed from fatigue and focus ratings:

$$\mathrm{CSI}_i = \left(\frac{F_i}{10}\right)\left(1 - \frac{C_i}{10}\right), \tag{1}$$

where F_i and C_i denote the fatigue and focus ratings for session i on a 1–10 scale. This formulation increases with fatigue and decreases with focus, yielding CSI $\in [0, 1]$.

D. Outlier Identification and Missing Data Handling

Outliers in key duration variables were flagged using the interquartile range rule and retained, as extreme play durations may be behaviorally meaningful. Missing values were checked programmatically. Median imputation was applied when required for clustering to ensure complete feature vectors.

E. Descriptive Statistics and Distribution Diagnostics

Descriptive statistics were computed for all numeric variables, including mean, median, standard deviation, minimum, maximum, and quartiles. Normality was assessed using the Shapiro–Wilk test to guide selection between Pearson and Spearman correlation. Prior to hypothesis testing for late-night comparisons, Shapiro–Wilk and Levene's tests were conducted to verify assumptions; Cognitive Strain was non-normally distributed and exhibited heterogeneity of variance (Levene's $p = 0.0235$), and subsequent t-test results were interpreted as a robust approximation.

F. Hypotheses and Statistical Tests

All hypothesis tests used $\alpha = 0.05$ and are reported with corresponding effect estimates, test statistics, and p-values. Given the longitudinal single-participant case study design, inferential results are interpreted as evidence within this dataset and are not generalized beyond the participant.

1) Hypothesis 1: Duration/Frequency vs. Fatigue and Focus: To evaluate whether gameplay duration or frequency is associated with fatigue and focus, correlations were computed at both the session level and the daily level. Given the non-normal distribution of session durations, Spearman rank correlation served as the primary evidence for monotonic associations between duration/frequency and outcomes, with Pearson correlation reported as a complementary measure when assumptions were approximately satisfied.

2) Hypothesis 2: Late-Night Sessions vs. Cognitive Strain: To evaluate timing effects, Cognitive Strain values were compared between late-night and non-late sessions using an independent-samples t-test. Prior to hypothesis testing, Shapiro–Wilk and Levene's tests were conducted to verify assumptions. Because Cognitive Strain was non-normally distributed and exhibited heterogeneity of variance (Levene's $p = 0.0235$), the subsequent t-test results were interpreted as a robust approximation. Despite violations of normality, the Central Limit Theorem suggests that with the study's sample size of $N = 120$, the independent-samples t-test remains a statistically robust indicator of group differences for this dataset. Levene's results were also used to contextualize the reported significance when interpreting late-night group differences.

G. Correlation Matrix and Significance Testing

A correlation matrix was computed across numeric variables, with a corresponding p-value matrix used to annotate statistically significant associations ($p < 0.05$ and $p < 0.01$) in correlation heatmaps.

H. Time-Series Smoothing and Volatility

Temporal trends in *Total Daily Gaming Duration* were summarized using a 7-day moving average. A 7-day rolling standard deviation was also computed for *Total Daily Gaming Duration* to quantify short-window variability in daily playtime.

IV. Results

A. Dataset Overview and Descriptive Statistics

The dataset consisted of 120 gameplay sessions collected from 21 November 2025 to 05 February 2026. Mean session duration was 190.44 minutes and the median was 123 minutes, indicating a right-skewed distribution with a subset of very long sessions. Mean mental fatigue across sessions was 4.45 and mean focus was 5.68. Late-night gameplay accounted for 49 sessions, corresponding to 40.8 percent of all observations, indicating a substantial proportion of nocturnal engagement.

Table III summarizes session-level descriptive statistics. Session duration and total daily gaming duration exhibited large dispersion, with standard deviations of 204.37 minutes and 234.19 minutes, respectively, indicating substantial variability in engagement intensity across days. Daily session count showed moderate variability around a mean of 2.01 sessions per day. Hours awake prior to sessions averaged 6.36

hours with a wide observed range from 0.25 to 23 hours, indicating heterogeneous pre-play wakefulness states. Cognitive strain showed a low mean of 0.27 with values extending to 1.00, indicating that while most sessions occurred under low strain, a subset reached high strain levels. Fatigue and focus ratings spanned the full measurement scale, indicating broad variability in perceived cognitive state across sessions.

TABLE III.
Session-Level Descriptive Statistics

Variable	Mean	Med	SD	Min	Max
Session Dur. min	190.44	123	204.37	9	880
Daily Sess. Count	2.01	2	0.69	1	4
Total Daily Dur. min	330.18	270	234.19	22	1020
Fatigue	4.45	4	2.84	1	10
Focus	5.68	6	2.77	1	10
Hours Awake	6.36	5	4.62	0.25	23
Cog. Strain	0.27	0.19	0.27	0.00	1.00

B. Session-Level Gameplay Patterns

Session-level gameplay exhibited clear structure across session duration, start time, and weekly rhythm.

Fig. 1.
Distributions of session-level variables

Figure 1 shows a right-skewed distribution for session duration, with most sessions concentrated at shorter durations and a smaller number of extended sessions forming a long tail. Total daily duration also demonstrated high dispersion, indicating that a subset of days involved substantially longer cumulative play. Ratings for fatigue and focus spanned the full scale, while hours awake displayed broad variability across sessions. Cognitive strain values were concentrated at lower levels with a smaller proportion of higher-strain sessions.

Session start times in Figure 2 were not uniformly distributed across the day. The histogram indicates concentrated gameplay at early-day and late-day hours, with a noticeable concentration in the late-night window defined as 22:00 to 24:00, confirming the presence of frequent nocturnal play sessions.

Weekly patterns in Figure 3 further differentiate engagement intensity from engagement frequency. Average session

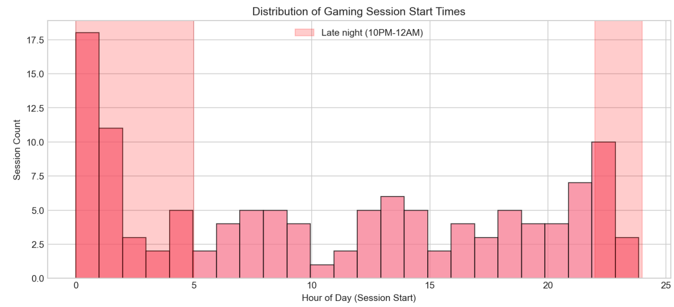

Fig. 2.
Distribution of gaming session start times

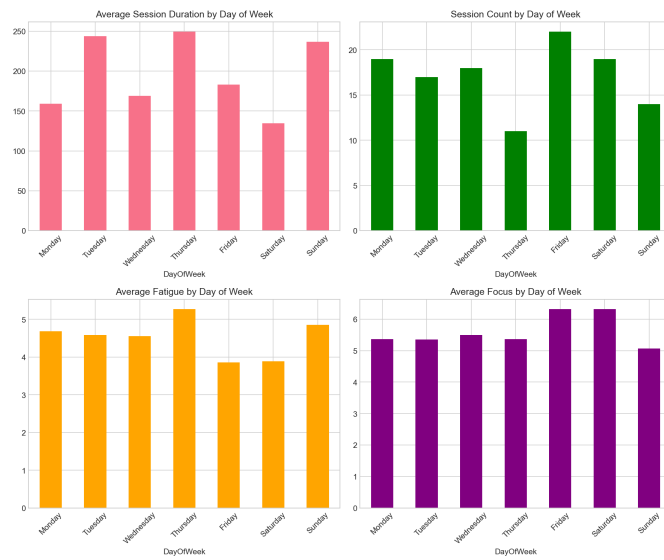

Fig. 3.
Session duration, session count, fatigue, and focus by day of week

duration peaked on Thursday and remained high on Tuesday and Sunday, indicating longer sessions on these days. Saturday showed the shortest average duration, suggesting reduced sustained play. Session counts were highest on Friday, indicating more frequent play sessions near the end of the workweek, while Thursday had the lowest count despite exhibiting the longest average sessions. This combination indicates that Thursday was characterized by fewer but longer sessions, whereas Friday reflected more frequent sessions with shorter durations.

C. Daily Gameplay, Fatigue, and Focus

The association between gameplay duration and cognitive state was examined at the session level and at the daily aggregated level. Figure 4 shows a positive trend between total daily gaming duration and fatigue, and a negative trend between total daily gaming duration and focus, indicating that longer daily exposure to gameplay aligns with higher fatigue and reduced focus.

Pearson correlation analysis provided statistical support for these patterns. Session duration was positively correlated with fatigue, $r = 0.225$, $p = 0.0133$, and negatively correlated with

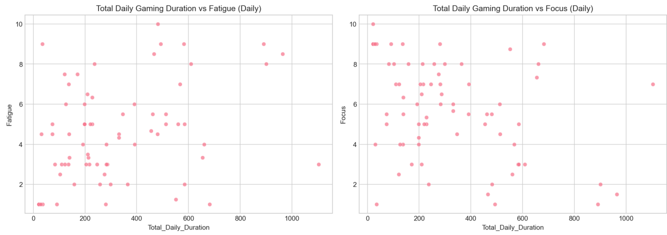

Fig. 4.
Total daily gaming duration versus fatigue and focus

focus, $r = -0.217$, $p = 0.0175$. Stronger associations were observed at the daily level, where total daily duration was positively correlated with fatigue, $r = 0.336$, $p = 0.0041$, and negatively correlated with focus, $r = -0.341$, $p = 0.0036$. These results indicate that accumulated daily gameplay duration is more strongly linked to cognitive state shifts than individual session length.

Nonparametric testing yielded a consistent direction of effect. Spearman correlation between session duration and fatigue was positive and marginally significant, $\rho = 0.179$, $p = 0.0500$, supporting a weak monotonic relationship that is robust to distributional assumptions.

TABLE IV.
Correlation Summary for Hypothesis 1

Comparison	Coefficient	p
Session Duration vs Fatigue	$r = 0.225$	0.0133
Session Duration vs Focus	$r = -0.217$	0.0175
Total Daily Duration vs Fatigue	$r = 0.336$	0.0041
Total Daily Duration vs Focus	$r = -0.341$	0.0036
Session Duration vs Fatigue	$\rho = 0.179$	0.0500

Table IV Correlation structure across variables further contextualized these findings. Session duration showed a strong positive association with total daily duration, $r = 0.692$, $p < 0.001$, indicating that longer sessions substantially contribute to daily exposure. Daily session count showed no significant association with fatigue or focus, $p > 0.44$, suggesting that cognitive outcomes were driven more by duration than by the number of sessions. Fatigue and focus were strongly inversely related, $r = -0.935$, $p < 0.001$, consistent with a shared underlying fatigue focus tradeoff.

These results support Hypothesis 1, indicating that greater gameplay duration is associated with higher fatigue and lower focus, with clearer effects when duration is accumulated across an entire day.

Figure 5 shows the full correlation structure among gameplay duration, cognitive state, wakefulness, and strain variables. Session duration and total daily duration show strong positive association, indicating that longer sessions substantially contribute to cumulative exposure. Fatigue shows strong positive association with cognitive strain and moderate positive association with hours awake, while focus shows strong negative association with both fatigue and strain. Daily session count shows minimal association with cognitive state, indicating that duration rather than frequency drives cognitive outcomes.

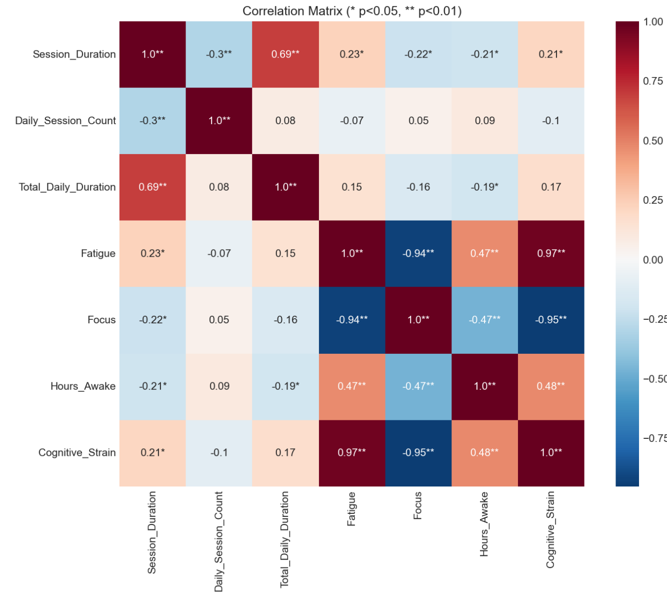

Fig. 5.
Correlation matrix of gameplay duration, cognitive state, and wakefulness variables

D. Late-Night Gaming and Cognitive Strain

Differences in cognitive strain between late-night and non-late sessions were examined to evaluate whether nocturnal gameplay is associated with elevated cognitive load. Figure 6 presents boxplots of mental fatigue and cognitive strain by late-night status. Late-night sessions show higher central tendency and greater dispersion in cognitive strain relative to non-late sessions, indicating more frequent high-strain outcomes. Mental fatigue exhibits a similar upward shift, consistent with elevated cognitive load during nocturnal play.

TABLE V.
t-Test Results for Hypothesis 2

Statistic	Value	p
Levene Test	5.264	0.0235
t-Test Cognitive Strain	3.166	0.0020
Mean Strain Late Night	0.3547	
Mean Strain Non Late	0.2035	

Assumption testing indicated heterogeneity of variance between groups. Levene's test was significant, $F = 5.264$, $p = 0.0235$, indicating unequal variances. An independent-samples t-test reported a significant difference in cognitive strain between late-night and non-late sessions, $t = 3.166$, $p = 0.0020$. Mean cognitive strain was higher for late-night sessions, 0.3547, compared with non-late sessions, 0.2035. These results reject the null hypothesis and support Hypothesis 2, indicating that late-night gameplay is associated with significantly greater cognitive strain.

Table V summarizes variance equality testing and group comparison statistics for cognitive strain by late-night status. The significant Levene result indicates unequal dispersion between groups, while the t-test confirms that late-night sessions exhibit substantially higher cognitive strain than non-late sessions.

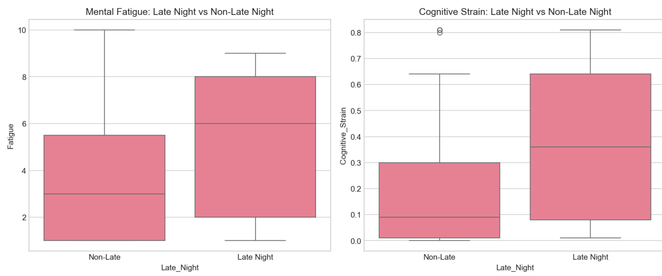

Fig. 6.
Fatigue and cognitive strain by late-night status

The difference in group means reflects a marked increase in strain during nocturnal gameplay, consistent with the visual separation observed in Figure 6.

E. Clustering-Based Behavioral Profiles

Unsupervised clustering was applied to session-level gameplay features to identify distinct behavioral profiles defined by engagement intensity and cognitive state. Figure 7 visualizes cluster separation in the session duration and fatigue space. The plot shows a clear high-duration high-fatigue region that is distinct from lower-duration profiles, indicating that gameplay sessions naturally partition into discrete behavioral regimes.

Cluster-level means in Table VI indicate four profiles. Cluster 0 represents very long sessions with elevated fatigue and reduced focus, indicating a high-engagement high-strain pattern. Cluster 2 shows shorter sessions but similarly high fatigue and low focus, paired with the longest pre-session wake duration, suggesting a fatigue-prone profile potentially driven by extended wakefulness rather than duration alone. Cluster 1 and Cluster 3 exhibit lower fatigue and higher focus, with Cluster 1 reflecting the shortest sessions and lowest fatigue, and Cluster 3 reflecting moderate session duration with relatively high session frequency and low fatigue. These profiles distinguish strain-dominant behavior from more cognitively efficient engagement patterns.

One-way analysis of variance confirmed that fatigue differed significantly across clusters, with $F = 110.305$ and $p < 0.001$, indicating that the clustering captured meaningful variation in cognitive state rather than duration differences alone.

Figure 7 shows four distinct groupings in the session duration and fatigue space. A clearly separated high-duration region appears at durations above 500 minutes with fatigue values concentrated at moderate to high levels, corresponding to Cluster 0. Two additional regions are concentrated at shorter durations below 250 minutes but differ strongly in fatigue, with one band at fatigue levels near 7 to 9 corresponding to Cluster 2 and another band at fatigue levels near 1 to 4 corresponding primarily to Cluster 1 and Cluster 3. The visual separation indicates that fatigue is not a monotonic function of session duration, since high-fatigue sessions occur both at very long durations and at short-to-moderate durations.

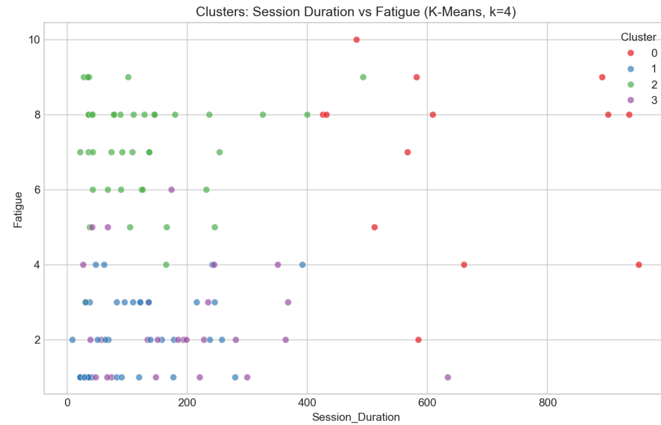

Fig. 7.
Session duration versus fatigue by cluster

TABLE VI.
Cluster Profiles Using Session-Level Means

Cluster	Dur.	Sess.	Daily Dur.	Fatigue	Focus	Awake
C0	656.62	1.38	683.31	6.92	3.38	3.50
C1	113.89	1.56	174.36	2.14	7.92	4.86
C2	122.48	2.17	262.60	7.14	3.07	10.49
C3	174.93	2.62	463.17	2.31	7.69	3.51

Table VI quantifies these patterns using cluster means. Cluster 0 exhibits the longest sessions with mean duration 656.62 minutes and the highest cumulative exposure with mean total daily duration 683.31 minutes, accompanied by elevated fatigue 6.92 and low focus 3.38. Cluster 2 exhibits comparatively short mean session duration 122.48 minutes and moderate total daily duration 262.60 minutes, yet shows the highest fatigue 7.14 and low focus 3.07, together with the greatest mean hours awake 10.49. Cluster 1 and Cluster 3 show low fatigue 2.14 and 2.31 with high focus 7.92 and 7.69, despite differing engagement intensity. Cluster 1 reflects short sessions and low daily exposure, while Cluster 3 reflects higher session frequency and higher daily exposure with maintained low fatigue. These profiles demonstrate that high fatigue can co-occur with long session duration and also with extended wakefulness prior to play, while frequent play can occur without elevated fatigue when focus remains high.

This implies that behavioral risk cannot be inferred from duration alone. Cluster 0 represents a high-engagement high-strain pattern where prolonged sessions coincide with elevated fatigue and reduced focus, which is consistent with sustained cognitive load and potential self-regulation failure. Cluster 2 suggests a fatigue-prone profile driven by extended wakefulness, where high fatigue occurs even when sessions are not long, indicating that timing and prior wake duration may be critical determinants of strain. In contrast, Cluster 3 suggests that higher session frequency and higher daily exposure can occur with relatively low fatigue and high focus, indicating a more cognitively efficient engagement mode. These findings support the use of multi-factor profiling that integrates duration, wakefulness, and cognitive ratings when identifying potentially maladaptive gameplay patterns.

F. Summary of Hypothesis Testing and Alignment with Objectives

This study traced how gameplay structure shapes cognitive state across sessions and across days. A consistent pattern emerged in which greater gameplay exposure aligned with higher mental fatigue and reduced focus. Correlation analysis demonstrated that duration and cumulative daily exposure were positively associated with fatigue and negatively associated with focus, with stronger relationships observed when gameplay was aggregated across an entire day. This progression indicates that cognitive load accumulates across sessions rather than arising from isolated play events. Evidence presented in Section 4.3 together with Figure 4 and Table IV supports Hypothesis 1.

Temporal context further clarified this relationship. Sessions occurring during late-night hours showed substantially higher cognitive strain than sessions played earlier in the day. Group comparison analysis confirmed this elevation in strain, indicating that nocturnal gameplay constitutes a distinct high-risk period for fatigue accumulation. Findings in Section 4.4 together with Figure 6 and Table V support Hypothesis 2.

Behavioral clustering provided a broader perspective on engagement structure. Distinct gameplay profiles emerged that combined duration, wakefulness, fatigue, and focus into coherent regimes. A high-duration high-fatigue profile reflected sustained cognitive load, while another high-fatigue profile occurred at shorter durations under extended wakefulness, indicating that strain can arise through multiple pathways. Significant differences in fatigue across clusters confirmed that gameplay behavior organizes into discrete cognitive-load regimes. Evidence in Section 4.5 together with Figure 7 and Table VI demonstrates this structure.

All study objectives were therefore achieved. Session-level patterns were characterized through weekday duration and frequency analysis. Daily exposure effects were established through correlation modeling. Late-night strain differences were confirmed through group comparison testing. Behavioral clustering identified distinct engagement regimes. Together these results show that gameplay duration, timing, and accumulation jointly shape fatigue and focus dynamics in competitive gaming.

V. Conclusion

This study examined how gameplay duration, timing, and accumulation relate to cognitive fatigue and focus in competitive gaming sessions. Analysis across session-level, daily-level, temporal, and behavioral clustering perspectives revealed consistent relationships between extended gameplay and elevated cognitive strain. Longer cumulative daily duration was associated with higher fatigue and lower focus, with stronger effects at the daily level than at the single-session level. Late-night sessions exhibited significantly greater cognitive strain than non-late sessions, indicating that nocturnal play represents a distinct high-risk context for fatigue accumulation. Clustering analysis further demonstrated that gameplay behavior organizes into discrete profiles characterized by different combinations of duration, wakefulness, fatigue, and focus.

These findings indicate that cognitive outcomes in gaming are not determined by duration alone but emerge from the interaction of exposure length, time of day, and prior wakefulness. High fatigue occurred both in very long sessions and in shorter sessions preceded by extended wake duration, while frequent sessions could occur without elevated fatigue when focus remained high. This multi-factor structure suggests that fatigue risk in gaming environments depends on behavioral patterns rather than isolated metrics such as session length.

The study contributes an empirical characterization of cognitive-state dynamics in naturalistic competitive gameplay. By combining temporal analysis, correlation modeling, group comparison, and unsupervised behavioral profiling, the results provide evidence that fatigue accumulation operates across sessions within a day and intensifies under late-night conditions. The clustering results further suggest that maladaptive engagement may be identifiable through joint patterns of duration, wakefulness, and cognitive ratings.

Practical implications include the potential for fatigue-aware gameplay monitoring systems that consider cumulative daily duration and time of play, rather than relying solely on single-session limits. Detection of high-risk patterns such as prolonged sessions with elevated fatigue or sessions occurring after extended wakefulness may support interventions aimed at maintaining cognitive performance and well-being in competitive gaming contexts.

Several limitations should be acknowledged. The dataset reflects a specific competitive gaming population and may not generalize across genres or player demographics. Cognitive measures were self-reported and may contain subjective bias. Temporal context beyond wake duration, such as circadian phase or prior sleep quality, was not directly measured. Future work should incorporate physiological fatigue indicators, longitudinal behavioral tracking, and cross-population validation to refine predictive models of gaming-related cognitive strain.

In summary, gameplay duration, nocturnal timing, and wakefulness jointly influence fatigue and focus dynamics in competitive gaming. Behavioral profiles derived from clustering indicate that risk emerges from multi-dimensional engagement patterns rather than single exposure measures. These results support the development of integrated fatigue-aware frameworks for monitoring and managing cognitive load in sustained digital gaming environments.

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