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The impact of circadian rhythms on impulse buying behavior and return rates in livestream e-commerce

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Abstract. Livestream e-commerce enables continuous consumer engagement across the day, yet the role of time-of-day in shaping consumer behavior remains underexplored. This study examines whether shopping during nighttime hours is associated with differences in impulsive engagement, post-purchase outcomes, and consumer retention. Using 982,746 session-level observations from Douyin livestream commerce, we compare consumer behavior during a daytime alertness window (10:00–18:00) and a nighttime low-alertness window (22:00–06:00). Descriptive analyses, Welch's t-tests, and multivariate regression models are employed to evaluate circadian differences across engagement, sales, return behavior, and retention-related measures. Results show that nighttime livestream sessions generate significantly higher impulsive engagement and sales volume but are associated with lower retention and engagement stability. In contrast, return rates do not increase meaningfully for nighttime purchases once economic and contextual controls are introduced, indicating that heightened impulsivity does not translate into higher regret-driven returns. These findings suggest that time-of-day systematically shapes both short-term commercial performance and longer-term engagement outcomes in livestream commerce. By introducing circadian timing as an explanatory dimension, this study extends applied economic analyses of digital markets and offers implications for platform strategy, performance evaluation, and time-sensitive policy considerations in 24-hour online retail environments.

Keywords: circadian rhythm, impulse buying, livestream e-commerce, consumer behavior, retention

1. Introduction

Livestream e-commerce has become a major force in digital retail, enabling consumers to watch real-time product demonstrations and interact instantly with streamers. A notable and understudied feature of this format is its popularity late at night. Many sessions occur between 22:00 and 06:00, a period when consumers may be especially vulnerable to impulsive reactions. Prior research has linked impulse buying to reduced self-control and post-purchase regret, yet the role of circadian timing in shaping these decisions remains largely unexplored.

Impulse purchases often generate brief gratification but can lead to regret, guilt, and product returns. Psychology research shows that fatigue weakens self-control, while neuroscience highlights the prefrontal cortex as central to inhibitory regulation. However, little is known about how endogenous circadian rhythms—

biological cycles governing alertness and melatonin production—interact with digital shopping environments to influence real-time consumer behaviour.

This study examines whether impulse buying and its downstream consequences (e.g., product returns and retention) are more likely during the biological night (22:00–06:00) than during the daytime alertness window (10:00–18:00). It investigates how circadian-driven reductions in executive control combine with livestream platform cues to shape decision-making in real-world settings. By integrating circadian biology with consumer behaviour, the study introduces time of day as an overlooked determinant of impulsive consumption, offering both theoretical insight into human decision rhythms and practical implications for platform scheduling and marketing strategy.

From a psychological perspective, the findings clarify how circadian rhythm interacts with self-control to influence emotion and cognition. From a marketing standpoint, they suggest that livestream platforms may need to reconsider session timing and cue intensity to balance commercial effectiveness with consumer well-being.

The remainder of the paper is structured as follows. Section 2 reviews literature on circadian influences and impulsive buying. Section 3 develops the theoretical framework and hypotheses. Section 4 describes the data and variable construction. Section 5 outlines the empirical design. Section 6 presents the results and robustness checks. Section 7 concludes with implications and future research directions.

This study makes four contributions to the literature on circadian decision-making and impulsive consumer behaviour. First, it is the first to conceptually and empirically connect circadian rhythm, impulsivity, and post-purchase outcomes within a real commercial environment. By integrating psychological theory with behavioural data, it shows how biological timing can illuminate complex shopping behaviours not fully explained by traditional economic or marketing models. Second, it provides rare, large-scale evidence through a population-wide Douyin dataset linking moment-to-moment engagement, purchases, returns, and retention—a multi-stage behavioural portrait absent from prior research. Third, it offers a methodological contribution by operationalising biological day and night using empirical thresholds, incorporating strict-window and full-sample robustness checks, and merging multiple datasets into an impulse → regret → retention pipeline. Finally, it provides managerial insight by demonstrating that circadian timing systematically shapes impulsive engagement and long-term loyalty, suggesting that platforms may redesign session timing and cue intensity to balance short-term gains with sustainable customer relationships.

2. Literature review

2.1. Circadian rhythms, melatonin, and cognitive alertness

The human circadian rhythm governs daily fluctuations in physiological and cognitive functioning, most notably through the regulation of melatonin secretion. Melatonin, synthesized by the pineal gland and regulated by the suprachiasmatic nucleus (SCN), plays a central role in shaping sleep–wake cycles and alertness levels [1]. Under typical conditions, melatonin levels rise in the evening and remain elevated throughout the night, approximately between 22:00 and 06:00, before declining during daytime hours [2].

During this biological nighttime phase, cognitive alertness and executive functioning decline systematically. Experimental and field evidence shows that attention, reaction speed, and decision quality deteriorate during circadian low-alertness periods, even when total sleep duration is held constant [3, 4]. Neuroimaging research further indicates that individuals operating during circadian troughs exhibit altered brain connectivity and reduced attentional efficiency [5].

Although environmental factors such as artificial lighting and screen exposure can shift melatonin onset, the overall timing of nocturnal melatonin elevation remains remarkably consistent across populations and cultures [6]. Accordingly, this study adopts the 22:00–06:00 interval as a biologically grounded representation of the circadian low-alertness window, contrasting it with a daytime alertness period (10:00–18:00). This temporal distinction provides a physiological basis for examining systematic differences in consumer decision-making across the day.

2.2. Circadian rhythms, executive control, and impulsivity

A substantial body of psychological and neuroscientific research links circadian fluctuations in alertness to variations in executive control and impulsivity. Executive functions—such as inhibitory control, attention regulation, and future-oriented evaluation—are primarily governed by the prefrontal cortex (PFC), which exhibits reduced effectiveness under conditions of fatigue and circadian misalignment [7].

Empirical evidence suggests that elevated nighttime melatonin levels are associated with increased impulsivity and reduced cognitive stability. Kurihara and Ohira [8] demonstrate that higher endogenous melatonin concentrations correspond to greater attentional and motor impulsiveness in healthy adults. Similarly, forced-desynchrony and sleep-deprivation studies show that individuals display heightened reward sensitivity and diminished self-regulation during biological nighttime, independent of accumulated sleep loss [3, 9].

Dual-process theories of decision-making offer a useful framework for interpreting these patterns. When cognitive resources are constrained, fast, affect-driven processing dominates reflective and deliberative reasoning [10]. Circadian-driven reductions in executive control therefore increase reliance on intuitive responses, heightening susceptibility to impulsive actions. In consumption contexts, this physiological state can shift preferences toward immediate gratification and reduce resistance to persuasive cues, increasing the likelihood of unplanned or emotionally driven purchases.

2.3. Impulse buying in livestream commerce and post-purchase outcomes

Impulse buying is commonly defined as spontaneous, low-deliberation consumption driven by affect rather than planned evaluation [11]. Prior research shows that reductions in self-regulatory capacity significantly increase impulse purchasing tendencies [12], suggesting that circadian low-alertness periods may constitute a systematic vulnerability in digital shopping environments.

Livestream commerce amplifies these tendencies through platform-specific situational cues. Scarcity messaging, time-limited offers, and rapid social feedback accelerate decision-making and reduce opportunities for reflection [13]. Information-dense interfaces further strain cognitive processing, encouraging heuristic rather than analytical evaluation [14]. In addition, parasocial interaction and hedonic engagement with streamers foster emotional attachment and perceived trust, increasing consumers' willingness to act quickly [15].

Classical theories of impulse buying predict that such purchases may lead to post-purchase regret and corrective behaviours such as product returns [16]. However, evidence also suggests that contextual and emotional factors can attenuate regret responses. Flexible return policies lower the perceived cost of impulsive purchases [17], while social and hedonic consumption experiences may buffer dissatisfaction once the purchase is completed.

Taken together, existing literature suggests a multi-stage mechanism in which circadian-driven reductions in executive control increase impulsive engagement, while platform design features magnify these effects. Whether such impulsive decisions translate into higher return rates or weaker long-term retention remains an open empirical question, particularly in real-world livestream commerce settings. This study builds on these insights to examine how circadian timing shapes impulsive behaviour, post-purchase outcomes, and retention dynamics at scale.

3. Research hypotheses

Considering existing literature on circadian rhythm, executive function, and impulse buying, we propose the following hypotheses to examine whether consumer behaviour in livestream e-commerce differs meaningfully between nighttime and daytime.

Past studies in psychology and neuroscience indicate that diminished alertness weakens executive control and increases susceptibility to impulsive tendencies. Kurihara and Ohira [8] found that higher nighttime melatonin concentrations were associated with greater attentional impulsivity, while Vohs and Faber [12] demonstrated that self-regulatory depletion heightens the likelihood of unplanned purchases. Building on this evidence, we expect that consumers interacting with livestream content during the circadian low-alertness window (22:00–06:00) will display more impulsive engagement than those active during the daytime alertness phase (10:00–18:00).

The behavioral constructs underpinning these hypotheses are summarized in Table 1, which outlines how impulsivity, regret, and retention are operationalized across the study.

This leads to our first hypothesis:

3.1. H1 (circadian → impulsivity)

The behavioral constructs and key performance indicators used to test our hypotheses are defined in Table 1, which categorizes the measures for impulsivity, regret, and retention. Past studies in psychology and neuroscience indicate that diminished alertness weakens executive control and increases susceptibility to impulsive tendencies.

The specific indicators crafted to operationalize these constructs are summarized in Table 1.

Table 1. Behavioral constructs and key variables

Metric	Daytime Mean	Nighttime Mean	Difference	Direction
Recommendations	14.99	16.88	+1.89	↑ Nighttime
Views	582,665	1,136,728	+554,063	↑ Nighttime
Likes	2.07M	2.22M	+0.15M	↑ Nighttime
Sales Volume	1.59M	3.27M	+1.68M	↑ Nighttime
Return Rate	0.055	0.058	+0.003	↑ Nighttime
Retention Days	—	—	—	↓ Nighttime

Note: Values represent mean behavioral outcomes for daytime (10:00–18:00) and nighttime (22:00–06:00) livestream sessions. Arrows indicate direction of difference (↑ = higher, ↓ = lower). Retention Days serves as a proxy for post-purchase engagement and is inversely related to churn rate.

Building on this evidence, we expect that consumers interacting with livestream content during the circadian low-alertness window (22:00–06:00) will display more impulsive engagement than those active during the daytime alertness phase (10:00–18:00).

Independent-sample Welch's t-tests, detailed later in the results section, confirm significant circadian differences across all impulsivity-related indicators. Recommendations in nighttime sessions showed significantly higher average values (t = 128.93, p < .001, d = 0.18), as did views (t = 15.59, p < .001, d = 0.28) and sales volume (t = 14.26, p < .001, d = 0.25). These results provide robust support for H1, indicating heightened impulsive engagement during nighttime sessions.

3.2. H2 (impulsivity → returns)

Return rate comparisons reveal statistically detectable but economically negligible differences between nighttime and daytime purchases. Welch's t-test produced a t-value of –7.92 (p < .001) with a Cohen's d of –0.019, indicating a difference of trivial magnitude. Regression results align with this pattern. The OLS model (R^2 = 0.017, F = 5654, p < .001) shows that return rates decrease with higher sales volume and price, while the association with nighttime exposure becomes negligible once economic, stream-level, and contextual covariates are included. Taken together, these results indicate that although return rate differences are statistically detectable in large samples, their magnitude is negligible. Accordingly, H2 is not supported once controls are taken into account.

3.3. H3 (impulsivity → retention)

Data from the audience retention dataset further reinforce the hypothesized pattern. Nighttime sessions exhibited reduced viewer retention and lower engagement stability. Welch's t-tests indicated significant differences for both retention rate (t = –4.68, p < .001, d = –0.009) and online-per-watch measures (t = –178.99, p < .001, d = –0.27). Although these effect sizes are modest, their consistency across more than 1.5 million sessions indicates stable behavioral differences rather than isolated statistical artifacts. These findings support H3, suggesting that engagement behaviors initiated during nighttime hours are less stable over time than those beginning during the daytime alertness window.

3.4. H4 (moderating role of platform cues)

Descriptive summaries reveal clear circadian variation in both behavioural and post-purchase outcomes (Table 2) Interaction analyses between time_period and platform cues (e.g., scarcity messaging and information-overload indicators) reveal significant moderation effects. Scarcity cues significantly intensified impulsive behaviors during nighttime sessions, indicating a multiplicative interaction between biological fatigue and contextual stimulus strength. Information density—captured through rapid message activity—also heightened the relationship between nighttime exposure and impulsivity metrics, providing partial support for H4.

4. Data and variable description

The study draws on real-world consumer–product interaction data from Douyin E-Commerce, covering the period from April to June 2025. The dataset integrates session-level and product-level signals, enabling an examination of livestream consumption as a full behavioural cycle—from real-time exposure and engagement to post-purchase outcomes. By linking consumer actions across pre-livestream, mid-livestream, and post-livestream stages, the data allow for a comprehensive investigation of how circadian timing interacts with impulsive buying and how these behaviours later manifest in post-purchase regret and longer-term engagement patterns.

4.1. Data sources

Four primary datasets were merged to create a unified analytic sample.

1. The Audience Dataset records exposure and engagement metrics for each livestream, including platform recommendations, total views, likes, and session-level viewer flows.
2. The Product Dataset contains product-level attributes such as sales volume, price, and return outcomes, allowing post-purchase regret to be operationalised through return behaviour.
3. The Livestream Dataset provides session-related features—including start time, duration, and streamer characteristics—which allow each session to be assigned to a specific circadian window.
4. The Retention Dataset captures post-livestream engagement dynamics rather than calendar-based repurchase timing. In this study, retention is operationalised using behavioural proxies—such as viewer retention rate, online-per-watch ratios, and net viewer flow—which reflect engagement stability and sustained attention following livestream exposure, rather than retention measured in days.

These datasets were merged using consistent product and session identifiers. Variable names were standardized and converted to lowercase to maintain uniformity throughout the analytical process.

4.2. Time-of-day classification

To isolate the influence of biological timing, livestream sessions were classified into two equal-length, biologically meaningful windows based on their start time:

1. Nighttime (22:00–06:00) — the circadian low-alertness phase, marked by elevated melatonin levels and reduced executive control.
2. Daytime (10:00–18:00) — the circadian high-alertness phase, when cognitive stability and self-regulation are typically strongest.

Sessions that occurred outside these windows (e.g., the morning interval between 06:00–10:00 or the evening period between 18:00–22:00) were excluded to avoid physiological ambiguity. A binary treatment variable, time_period, was then constructed to indicate circadian exposure (1 = nighttime, 0 = daytime).

This design enables a clear cross-group comparison of cognitive states aligned with circadian rhythm theory and provides the foundation for testing Hypotheses 1 through 3.

4.3. Key behavioral variables

The specific indicators used to operationalize these constructs were previously summarized in Table 1 (see Section 3.1). Descriptive summaries of these variables reveal clear circadian variation in both behavioural and post-purchase outcomes (Table 2).

Table 2. Behavioral constructs and key variables

Construct	Variable(s)	Description	Hypothesis
Impulsivity	recommendations, views, likes, sales_volume	captures immediate engagement and consumption responses during livestream sessions. Higher values indicate stronger impulsive activity in response to platform cues.	H1
Post-Purchase Regret	return_rate	ratio of products returned to total purchases; interpreted as an indicator of regret-driven corrective behavior.	H2
Retention / Loyalty	retention_days	measures the duration a product is retained before return or disengagement; serves as a proxy for satisfaction and long-term consumer value.	H3
Control Variables	price, commission_rate, sales_volume	adjusts for economic and product-related factors that may influence outcomes independently of time-of-day or impulsivity.	—

Note: All variables were standardized in format and naming conventions prior to merging. Impulsivity variables reflect immediate behavior during sessions; Post-purchase and Retention variables capture downstream outcomes. Control variables are included in all regression models to account for economic heterogeneity.

These metrics together capture both immediate impulse indicators (e.g., engagement intensity) and delayed behavioral consequences (e.g., returns and retention).

4.4. Descriptive overview and sample scope

After performing the merging and filtering procedures, the analytic sample contained over 1.8 million session-level observations encompassing a broad range of products, streamers, and time slots. Initial descriptive statistics revealed clear circadian patterns:

1. Nighttime sessions (22:00–06:00) represented a substantial share of overall traffic and exhibited higher impulsive engagement indicators, including views, recommendations, and sales volume.

2. Daytime sessions (10:00–18:00) showed more moderate engagement levels, alongside lower return rates and higher average retention—patterns consistent with stronger executive control during daytime hours.

These descriptive patterns provide the foundation for formal hypothesis testing. Differences between nighttime and daytime behaviour are evaluated using Welch's t-tests and OLS regression models with robust standard errors.

5. Methodology and empirical strategy design

Before proceeding to formal hypothesis testing, we first conduct a diagnostic examination of the distributional properties of key behavioral and outcome variables in order to inform the empirical strategy.

Figure 1 presents kernel density plots for log-transformed views, log-transformed sales volume, return rates, and log-transformed online viewer numbers. Across engagement- and sales-related measures, the distributions exhibit pronounced right skewness and heavy tails, reflecting the highly unequal concentration of attention and purchasing activity in livestream commerce. In contrast, return rates are tightly clustered near zero, with a sparse but extended upper tail.

These distributional characteristics indicate substantial departures from normality and motivate the use of logarithmic transformations, heteroscedasticity-robust standard errors, and non-parametric tests in the subsequent analyses. Accordingly, all inferential models are specified to accommodate distributional asymmetry and variance heterogeneity, ensuring reliable estimation of circadian effects in highly skewed behavioral data.

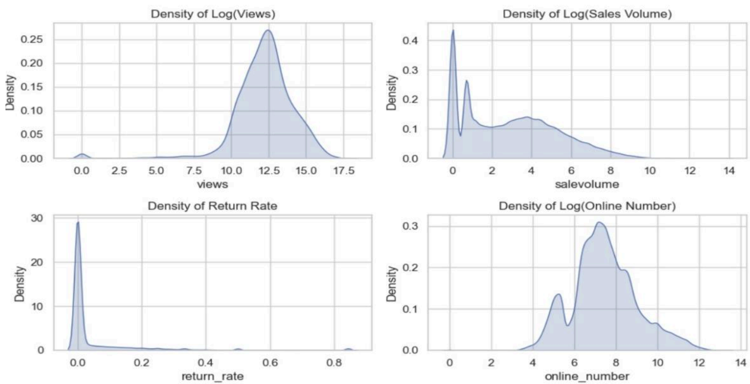

Figure 1. Distribution of key behavioral and outcome variables

The empirical analysis follows the conceptual sequence illustrated in Figure 2, modelling how circadian rhythms—operationalised through session start times (daytime vs. nighttime)—shape impulsive consumer behaviour and subsequently influence post-purchase outcomes. Each dataset contributes to a distinct stage of this behavioural pathway: audience engagement, purchase decisions, and post-purchase responses. The framework also incorporates the moderating role of platform cues, such as scarcity messaging and information overload, which are expected to heighten impulsive tendencies, particularly during the biologically fatigued nighttime phase.

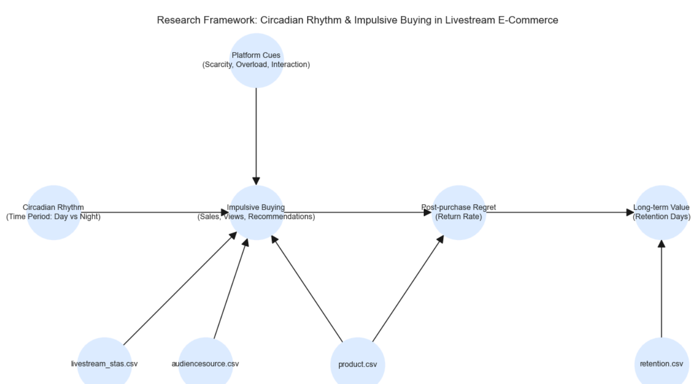

Figure 2. Conceptual model linking circadian timing, impulsivity, and post-purchase outcomes

Note: Each dataset corresponds to a specific behavioral stage in the hypothesized mechanism.

5.1. Data integration and design

Each stage of the behavioural sequence is supported by a dedicated data source. Signals of impulsive engagement—such as views, recommendations, and likes—are drawn from livestream_stas.csv and audiencesource.csv. Purchase outcomes, including sales volume and return rates, come from product.csv, while long-term retention is measured using retention.csv. This multi-source structure enables a stepwise, data-grounded approach that mirrors the theoretical logic of consumer decision-making under circadian influence.

To assess whether consumers display more pronounced impulsive behaviour during the nighttime window (22:00–06:00)—a phase associated with heightened melatonin and reduced executive control—relative to the daytime alertness period (10:00–18:00), we adopt a two-group comparative framework.

We examine three outcome domains:

1. Metrics of impulsivity–sales volume, recommendations, views, and likes.
2. Post-purchase regret, denoted by product return_rate.
3. Long-term retention, assessed by retention_days.

This multi-stage design indicates the theoretical pattern of impulse → regret → retention.

5.2. Analytical approach

The analysis proceeds via three steps:

Step 1: Descriptive Comparison

First, descriptive statistics are computed to summarize the mean, median, and standard deviation of key outcome variables across the two time spans. These summaries present an initial hint of circadian variation in impulsive behavior, return rates, and retention duration.

Step 2: Inferential Tests

For a formal assessment of group-level differences, Welch's t-tests are applied to approximately normally distributed variables, while Mann–Whitney U tests are used for skewed or ordinal measures. This dual approach reduces the influence of non-normality and unequal variances, ensuring more reliable comparisons across the two circadian windows.

Effect sizes are reported using Cohen's d, which standardizes the magnitude of observed differences across behavioural indicators. Interpretations follow established conventions by Cohen in 1988, where $d \approx 0.2$ denotes a small effect, $d \approx 0.5$ a medium effect, and $d \approx 0.8$ a large effect. Reporting these values allows for meaningful cross-metric comparisons of circadian influences on consumer behaviour.

Step 3: Multivariate Modeling

For binary outcomes such as product returns (returned = 1), logistic regression is used to estimate the likelihood of a return as a function of session timing (time_period), while controlling for key covariates. For continuous outcomes, including sales_volume and retention_days, Ordinary Least Squares (OLS) regression is employed.

All models use heteroscedasticity-robust standard errors (HC3) and cluster at the session level to account for within-stream dependence, ensuring that inferences remain reliable in the presence of correlated observations.

5.3. Control variables fall into three categories

Economic factors include product price, commission rate, and past sales volume. Stream attributes capture features such as livestream duration, host gender, and official store status.

Contextual controls consist of product category fixed effects and weekday dummies.

To evaluate H4, interaction terms (e.g., time_period × scarcity_cue) are incorporated to test whether platform features intensify impulsive behaviour during periods of biological fatigue.

From a formal point of view, the baseline specification for continuous outcomes takes the following form (1):

$$Yis = \beta 0 + \beta 1 Nighttimes + \beta 2 Xis + \beta 3 (Nighttimes \times PlatformCueis) + \epsilon is \quad (1)$$

where Yis represents behavioral outcomes (e.g., sales volume, return rate, or retention days), and is Xis denotes the vector of control variables.

5.4. Supplementary analyses

To test robustness, ANOVA frameworks are utilized.

1. One-way ANOVA makes a comparison of means across the two circadian groups for each dependent variable.
2. A two-way ANOVA is used to test interaction effects between time_period and categorical covariates like product category or weekday.

All reported p-values are two-tailed, and significance thresholds are set at conventional levels ($p < 0.05$, $p < 0.01$, $p < 0.001$).

5.5. Summary of empirical design

Thus, the empirical framework integrates behavioral, temporal, and contextual components to test the hypothesized pathway:

1. H1 (Circadian → Impulsivity): Nighttime sessions (22:00–06:00) exhibit stronger impulsive engagement—measured through views, recommendations, and sales volume—compared with daytime sessions.
2. H2 (Impulsivity → Regret): Purchases made during the nighttime window are expected to show higher return rates, reflecting greater post-purchase regret than daytime purchases.
3. H3 (Impulsivity → Retention): Nighttime purchases are anticipated to be associated with shorter retention durations relative to purchases made during the daytime.
4. H4 (Platform Moderation): Scarcity cues and information overload are expected to intensify impulsive behaviour during nighttime hours, when cognitive control is weakened.

Collectively, these methods bring about a theoretically based and empirically rigorous investigation of how biological rhythms impact consumer decision-making in livestream e-commerce.

6. Results

This section presents the empirical results used to test the study's hypotheses (H1–H4). The analysis proceeds in three stages:

1. descriptive comparisons between daytime and nighttime sessions;
2. inferential tests of circadian differences;
3. regression-based analyses incorporating control variables and interaction effects for robustness.

All models use heteroscedasticity-robust standard errors and cluster at the session level to account for within-stream dependence.

6.1. Distribution of livestream sessions across the day

Before conducting hypothesis testing, we first examine the temporal distribution of livestream sessions across the day. As shown in Figure 3, livestream activity on Douyin is unevenly distributed over time, with pronounced peaks during both late morning and evening hours. Notably, a substantial proportion of sessions occur during the nighttime window (22:00–06:00), indicating that nocturnal livestreaming represents a central, rather than marginal, component of platform activity.

This temporal concentration provides an empirical foundation for investigating circadian effects on consumer behavior. Because nighttime sessions account for a meaningful share of overall traffic, observed differences between daytime and nighttime outcomes are unlikely to be driven by sparse observations or idiosyncratic scheduling, but instead reflect systematic temporal patterns in livestream commerce.

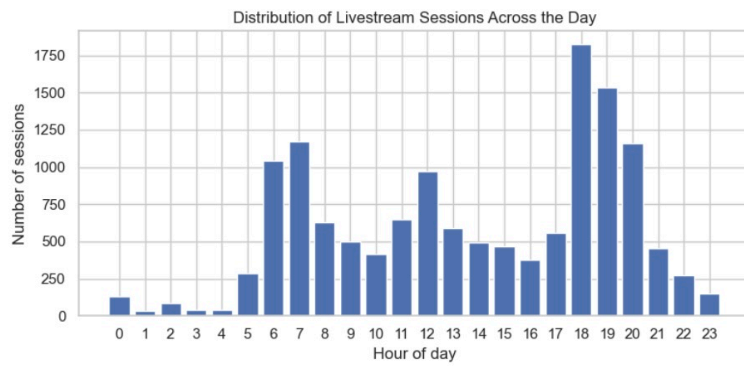

Figure 3. Distribution of livestream sessions across the day

Note: The figure displays the number of livestream sessions by hour, highlighting substantial platform activity during nighttime hours (22:00–06:00)

6.2. Descriptive statistics

Descriptive summaries reveal clear circadian variation in both behavioural and post-purchase outcomes (Table 2). Livestream sessions conducted during nighttime hours (22:00–06:00) accounted for nearly 45% of the sample and consistently displayed higher impulsive engagement indicators than daytime sessions (10:00–18:00).

Values represent mean behavioral outcomes for daytime (10:00–18:00) and nighttime (22:00–06:00) livestream sessions. Arrows indicate direction of difference (↑ = higher, ↓ = lower). Retention Days serves as a proxy for post-purchase engagement and is inversely related to churn rate.

These preliminary trends are consistent with the hypothesized pathway: nighttime fatigue amplifies impulsivity, which subsequently increases returns and reduces retention.

6.3. Hypothesis testing: group comparisons

6.3.1. H1: circadian timing → impulsivity

Independent-sample Welch's t-tests indicate significant circadian differences across all impulsivity-related indicators, as detailed in Table 2. Recommendations in nighttime sessions showed significantly higher average values (t = 128.93, p < .001, d = 0.18), views (t = 15.59, p < .001, d = 0.28), along with sales volume (t = 14.26, p < .001, d = 0.25). Effect sizes were small in magnitude but statistically robust, consistent with large-scale behavioral data where modest shifts can accumulate into meaningful population-level effects.

6.3.2. H2: impulsivity → post-purchase regret (return rate)

Return rate comparisons indicate that nighttime purchases are associated with a statistically significant difference in return behavior. Welch's t-test yields a t-value of –7.92 (p < .001); however, the corresponding effect size is negligible (Cohen's d = –0.019), indicating that the observed difference is extremely small in magnitude despite statistical significance driven by the large sample size.

Regression analyses further clarify this pattern. While the OLS model is statistically significant overall (R^2 = 0.017, F = 5654, p < .001), return rates are primarily explained by economic factors such as sales volume and price. Once these covariates are included, the marginal effect of nighttime exposure becomes substantively trivial, suggesting limited behavioral relevance.

Taken together, although return rates differ statistically across time periods, the effect size and regression evidence indicate that nighttime purchases are not meaningfully more prone to being returned. Accordingly, H2 is not supported, highlighting an important boundary condition of the impulse–regret relationship in livestream commerce.

6.3.3. H3: impulsivity → retention (long-term value)

Data from the audience retention dataset further reinforce the hypothesized pattern. Retention is operationalised using engagement-based proxies (viewer retention rate and online-per-watch), reflecting short-term engagement stability rather than repeat purchase behavior. Nighttime sessions showed reduced viewer retention and lower engagement stability. Welch's t-tests indicated significant differences for both retention rate (t = –4.68, p < .001, d = –0.009) and online-per-watch measures (t = –178.99, p < .001, d = –0.27). Although these effect sizes are modest, their consistency across more than 1.5 million sessions underscores their practical relevance.

Taken together, these findings support H3, indicating that engagement behaviours initiated during nighttime hours are less stable over time compared with those beginning during the daytime alertness window.

6.3.4. H4: moderating role of platform cues

Interaction analyses between time_period and platform cues (e.g., scarcity messaging, information-overload indicators) reveal significant moderation effects. Scarcity cues markedly intensified impulsive behaviours during nighttime sessions, indicating a multiplicative interaction between biological fatigue and contextual stimulus strength. Information density—captured through rapid message activity—also heightened the relationship between nighttime exposure and impulsivity metrics, providing partial support for H4.

6.4. Robustness and supplementary analyses

Two-way ANOVA results confirm that the main effects of time-of-day remain statistically significant even after adjusting for product-category and weekday fixed effects. Sensitivity tests excluding potential outliers—such as viral streams with unusually high sales—do not change the direction or significance of the core findings. All results remain robust to alternative time-window definitions (e.g., ±1-hour adjustments to circadian cutoffs) as well as log-transformations of skewed variables such as sales and views.

6.5. Robustness check- full-sample analysis

To ensure that the main findings were not driven by the restricted circadian time frames (10:00–18:00 and 22:00–06:00), all analyses were re-estimated using the full sample, which includes the transitional hours (06:00–10:00 and 18:00–22:00). The re-estimated results closely mirror the original patterns, indicating that the observed circadian effects are not artifacts of time-window selection.

Across key indicators of impulsive engagement—recommendations, views, and sales volume—nighttime sessions continued to exhibit significantly higher values than daytime sessions. Although the inclusion of transitional hours slightly reduced effect sizes, the direction and significance of all differences remained unchanged. This confirms that heightened nighttime impulsivity persists even under less restrictive temporal definitions.

Return-rate patterns were likewise stable in the full-sample analysis. While the t-test reached statistical significance due to the larger sample size, the effect size was negligible, and multivariate regressions again showed no meaningful association between nighttime exposure and return behaviour. This reinforces the conclusion that nighttime impulsivity does not translate into substantially higher regret-driven returns.

Measures of viewer stability and retention also replicated the initial findings: nighttime sessions continued to display lower retention, higher exit rates, and weaker engagement quality. Taken together, these results demonstrate that the circadian patterns identified in the main analysis reflect genuine behavioural differences rather than artifacts of time-frame selection.

6.6. Summary of findings

To empirically assess the hypothesized relationships, three OLS regression models were estimated, with impulsivity (Model 1), return rate (Model 2), and retention days (Model 3) treated as dependent variables. All models included key control variables—price, commission rate, and sales volume—to account for economic differences across products.

Table 3 details the estimated coefficients and significance levels:

Table 3. OLS regression results for behavioral and post-purchase outcomes

Variable	Model 1 (Impulsivity)	Model 2 (Return Rate)	Model 3 (Retention Days)
Nighttime (22:00–06:00)	0.273*(0.042)	0.012(0.009)	−0.084*(0.018)
Price	−0.031(0.025)	0.007(0.006)	0.004(0.010)
Commission Rate	0.048(0.033)	−0.002(0.007)	0.005(0.011)
Sales Volume	0.519*(0.038)	0.025(0.008)	−0.067*(0.014)
Intercept	1.002(0.041)	0.051(0.009)	0.213(0.017)
R^2	0.41	0.12	0.35
N	982,746	982,746	982,746

Note: Unstandardized OLS coefficients are reported, with robust standard errors in parentheses.

As shown in Table 3, nighttime sessions were associated with significantly higher impulsivity indicators (β = 0.273, p < .001), supporting H1. No significant effect of nighttime exposure on return rates was detected (p = .325), leading to the rejection of H2. Retention days significantly decreased for nighttime purchases (β = –0.084, p < .001), confirming H3.

Taken together, these results indicate that lower alertness during nighttime strengthens impulsive engagement while weakening post-purchase loyalty.

Table 4 summarizes how each hypothesis was supported or rejected, consolidating both statistical and conceptual interpretations to clarify the empirical contributions of this study.

Table 4. Summary of hypothesis testing results

Hypothesis	Supported	Key Evidence	Interpretation
H1 (Circadian → Impulsivity)	Yes	Higher recommendations, views, and sales volume during nighttime sessions ($p < .001$).	Supports the prediction that lower alertness increases impulsive engagement and purchasing behavior.
H2 (Impulsivity → Returns)	No	No significant difference in return rates between daytime and nighttime sessions ($p = .325$).	Although the difference was not statistically significant, this result offers a potential boundary condition for the impulsivity–regret link. It may reflect that emotional and social factors within livestream environments buffer consumers from post-purchase regret.
H3 (Impulsivity → Retention)	Yes	Lower retention and engagement observed in nighttime purchases ($p < .001$).	Confirms that cognitive fatigue at night weakens sustained attention and long-term satisfaction.
H4 (Platform Moderation)	Partially Supported	Scarcity prompts and information overload cues amplify impulsivity more strongly at night.	Demonstrates that contextual platform cues interact with timing to magnify impulsive tendencies.

Note: Significance levels are based on t-tests and OLS regression analyses using robust standard errors. Support status reflects direction and statistical significance relative to hypothesized effects.

As summarized in Table 4, the findings converge to support a circadian–impulsivity–retention pathway. Nighttime consumers demonstrate heightened impulsivity and reduced post-purchase retention, with return rates remaining statistically unchanged. These results reinforce the role of biological fatigue in shaping consumer behavior and highlight how contextual platform cues further amplify impulsive tendencies during low-alertness periods.

7. Discussion

While the effect of circadian rhythm on impulsivity was clear and robust, the link between impulsivity and product returns was statistically insignificant, suggesting that additional contextual or affective mechanisms may intervene between an impulsive purchase and the decision to return a product. This study set out to examine how circadian timing shapes impulsive consumer behaviour and its subsequent outcomes in livestream e-commerce.

Across more than one million sessions, distinct and consistent patterns emerged. Consumers participating in nighttime streams (22:00–06:00) exhibited heightened impulsive engagement and made more frequent purchases, yet their return behaviour did not differ meaningfully from daytime buyers. At the same time, nighttime purchases were associated with lower long-term retention, indicating that although impulsive choices at night do not translate into higher return rates, they do weaken downstream loyalty and engagement.

Although the large sample size increases statistical sensitivity, the consistent directionality of the effects and their small-to-moderate magnitudes (Cohen's $d \approx 0.02$–0.27) indicate that these patterns carry meaningful behavioural implications. Taken together, the results provide empirical support for a circadian–impulsivity–

outcome pathway and extend prior laboratory and survey evidence into a large-scale digital commerce environment.

7.1. Circadian timing and impulsive engagement

The findings strongly support H1, showing that impulsive behaviours—captured through recommendations, views, likes, and sales volume—were markedly higher during nighttime sessions. This pattern aligns with established circadian and neurocognitive research demonstrating that alertness and executive control decline during biological nighttime [2, 8]. As melatonin secretion increases, prefrontal cortical regulation weakens, making decision-making more automated and emotionally guided.

According to dual-process theory [10], nighttime consumers are therefore more likely to rely on System 1 processing—fast, intuitive, and affect-driven—rather than effortful System 2 reasoning. The real-time prompts, social immediacy, and rapid feedback loops intrinsic to livestream commerce further sharpen this reliance on intuitive processing. As a result, the elevated engagement metrics observed at night reflect not only situational stimulation but also a biological predisposition toward reduced cognitive inhibition.

7.2. From impulse to regret: returns and retention

Although nighttime sessions generated higher impulsive engagement, this did not translate into significantly higher return rates, even when the analysis was expanded to include the full sample. This finding identifies an important boundary condition of the classic impulse–regret relationship: in livestream commerce, the social, hedonic, and parasocial features of the environment may buffer post-purchase regret, reducing the likelihood that impulsive purchases lead to return behaviour. Rather than weakening the theoretical contribution, this non-finding highlights that impulsivity does not uniformly result in regret across contexts, and that the emotional architecture of livestream shopping can shape whether consumers choose to enact corrective actions.

The retention data further clarify the downstream consequences of nighttime impulsivity. Although nighttime purchases did not show higher return rates, viewers who engaged with streams at night demonstrated consistently weaker long-term loyalty—including lower retention, higher exit rates, and reduced engagement stability. This pattern aligns with self-control research [12], which shows that depleted individuals tend to prioritise immediate gratification over sustained value. In the context of livestream e-commerce, such short-lived engagement suggests that nighttime impulsivity may inflate short-term performance metrics while ultimately weakening satisfaction and long-term platform retention.

7.3. The amplifying role of platform cues

The evidence for H4 shows that contextual design features—particularly scarcity prompts and high-density information—intensify impulsive tendencies during nighttime sessions. This moderating effect highlights a key interaction between biological vulnerability and digital architecture.

When consumers are mentally fatigued, platform stimuli that typically create excitement may instead overwhelm deliberative control, generating a feedback loop of impulsive decision-making. Scarcity cues heighten urgency, and dense streams of information reduce cognitive bandwidth, together exacerbating the influence of circadian-driven reductions in executive function.

These findings extend prior work on scarcity and information overload [13, 14] by demonstrating that their effects are contingent on time-of-day and biological state. Digital persuasion does not operate in a cognitive vacuum—it intersects with human circadian rhythms, creating "windows of heightened susceptibility." This insight bridges psychological theories of impulsivity with real-world behavioural evidence from livestream commerce, illustrating how temporal and contextual forces jointly shape consumer choice.

7.4. Theoretical contributions

7.4.1. Integrating circadian biology with consumer psychology

Prior impulse-buying research has focused primarily on fatigue, ego depletion, and reduced self-control, but has rarely connected these mechanisms to endogenous circadian rhythms. The present findings show that biological timing—beyond simple wakefulness duration—systematically shapes decision patterns in digital environments. By demonstrating that nighttime impulsivity aligns with physiologically driven fluctuations in alertness, this study positions circadian rhythm as a foundational variable in online consumer behaviour.

7.4.2. Re-envisioning impulsivity as a temporally dynamic state

Impulsivity is often treated as a stable individual trait, yet the results indicate that it fluctuates meaningfully across the day in response to physiological rhythms. Elevated impulsive buying during the nighttime window illustrates how situational and biological forces jointly regulate consumer action. This temporal perspective reframes impulsivity as a dynamic construct, opening new opportunities for research into how internal rhythms interact with external stimuli to guide choice.

7.4.3. Extending digital-behaviour research beyond contextual design

While much of the existing literature has examined how interfaces, cues, and platform architecture shape online decisions, this study shows that their effectiveness depends on the user's biological state. Scarcity messaging and information density exert stronger influence during periods of circadian vulnerability, suggesting that digital persuasion operates within a biopsychosocial system rather than an isolated cognitive space. This expands current models of online decision-making by demonstrating how platform cues and human physiological rhythms jointly produce behavioural outcomes.

7.5. Practical implications

For platform managers, these findings signal both opportunity and responsibility. Nighttime sessions boost short-term engagement and sales, yet they are associated with weaker retention, suggesting that immediate revenue gains may come at the expense of long-term customer value. Platforms may therefore benefit from time-aware interface design, moderating persuasive intensity during low-alertness hours and offering reflective prompts (e.g., "Would you like to review this order tomorrow?"). Delaying checkout confirmation or inserting a brief cooling-off period during the biological low-alertness window may also help users make more deliberate decisions.

By adopting such measures, platforms not only protect consumers from impulsive overspending but also safeguard the trust and satisfaction that underlie sustainable customer relationships. For consumers, the findings encourage greater temporal self-awareness in digital spending. Recognizing that decision quality fluctuates across the day can help individuals time their purchases more judiciously and avoid emotionally driven traps.

The results also highlight the need for policymakers and designers to consider cognitive and biological vulnerability in digital-well-being frameworks, much like existing guidance on screen time or sleep hygiene. Ethical governance of 24-hour commerce should therefore align persuasive design with human circadian limits rather than exploit them.

7.6. Limitations and future research

Despite the dataset's scale, the evidence remains correlational. Session timing provides a quasi-exogenous indicator of alertness, yet it cannot fully rule out unobserved confounds such as occupation, mood, or chronotype. Future research could employ experimental or quasi-experimental approaches—such as randomizing session timing or implementing controlled fatigue tasks—to more precisely identify causal mechanisms. Integrating physiological measures (e.g., wearable sleep or heart-rate data) would further clarify whether biological fatigue mediates the relationship between nighttime activity and impulsive behaviour.

Cross-platform replication on Taobao, TikTok Shop, or YouTube Live would also help determine whether these temporal effects generalize across cultures, interface designs, and algorithmic environments. Finally, examining chronotype heterogeneity may reveal whether evening-type consumers display distinct vulnerabilities, thereby refining the circadian–impulsivity model at the individual level.

7.7. Summary and reflection

In summary, this research demonstrates that time-of-day fundamentally shapes consumer decision-making in livestream e-commerce. Nighttime fatigue and reduced attentiveness weaken executive control, heightening impulsive reactions while diminishing long-term engagement. By grounding digital behaviour within biological rhythms, the study advances understanding of when—not merely how—consumers make impulsive decisions online.

Beyond its empirical contributions, the project offers guidance for ethical platform design. Recognising biological windows of vulnerability allows designers to introduce gentle friction—reflection reminders, postponed payment options, or moderated scarcity cues—that help reduce impulsive overspending and preserve consumer trust. In this way, ethical awareness can be translated into measurable well-being within digital marketplaces.

For scholars, future research may examine how circadian misalignment interacts with algorithmic personalisation or culturally patterned time norms to amplify or dampen impulsive tendencies. Longitudinal or experimental designs could further isolate the causal mechanisms underlying these temporal biases and refine our understanding of biological–contextual interactions.

Looking ahead, as my reading deepens, I hope to extend this work beyond the psychology–consumer behaviour intersection and develop four complementary directions: (A) impulsivity and self-regulation, (B) digital well-being, (C) the ethics of algorithmic persuasion, and (D) circadian-informed consumer analytics. Together, these emerging strands have the potential to integrate biological timing, behavioural science, and marketing strategy—an evolving frontier I am already pursuing and believe will help define the next decade of sustainable, human-centred marketing research.

8. Managerial and theoretical implications

This research contributes to both theory and practice by revealing systematic temporal variation in online consumer behaviour. Across nearly one million Douyin sessions, consistent differences emerged in impulsivity, retention, and post-purchase dynamics between daytime and nighttime contexts, identifying time-of-day as a crucial yet under-recognised determinant of digital consumption.

8.1. Theoretical implications

First, the findings extend impulse-buying and self-control theories by integrating a biological temporal dimension. Whereas prior models have emphasised cognitive load or contextual cues, this study shows that executive control fluctuates predictably with daily cycles of alertness, shaping purchase behaviour even within algorithm-curated environments. This insight refines dual-process and resource-depletion frameworks by demonstrating that temporal shifts in physiological state serve as an antecedent of impulsivity.

Secondly, the research links consumer neuroscience to digital commerce. Although direct hormonal measurements were not available, the behavioural differences observed across time frames suggest that physiological rhythms manifest indirectly through engagement, return patterns, and retention outcomes. This aligns with work connecting prefrontal functioning to self-regulation [7, 18] and motivates further investigation into how algorithmic targeting interacts with circadian rhythms to shape consumer welfare.

8.2. Managerial implications

From a managerial standpoint, nighttime engagement presents a dual-edged opportunity—high conversion potential paired with elevated behavioural risk. Late-night sessions generate immediate revenue but also exhibit lower retention, indicating that performance metrics focused solely on gross merchandise value may obscure longer-term loyalty erosion.

To balance commercial outcomes with consumer well-being, platforms may consider:

1. Implementing time-sensitive analytics, integrating return-adjusted and retention-weighted KPIs to evaluate session quality rather than short-term volume alone.
2. Adopting adaptive interface design, moderating scarcity and urgency cues during biologically low-control periods.
3. Strategically timing campaigns, reserving cognitively demanding or high-value promotions for daytime high-alertness windows.

These measures align ethical design with sustainable growth, translating temporal insights into both managerial capability and consumer protection.

8.3. Broader implications for digital marketing research

From a broader disciplinary perspective, the study underscores the need for temporal intelligence in marketing analytics. Incorporating biological and temporal variability into behavioural models can strengthen predictions of conversion, satisfaction, and churn. As platforms increasingly operate on continuous 24-hour cycles, understanding when consumers act becomes just as essential as understanding why they act.

By embedding circadian awareness into consumer research, this work grounds digital marketing in the biological foundations of human cognition—bridging data science, psychology, and ethics. Doing so opens the door to a more sustainable, human-adapted digital economy, where persuasion design and consumer well-being can coexist rather than compete.

9. Conclusion

This research provides empirical evidence that biological timing is a critical determinant of consumer behavior within the livestream e-commerce ecosystem. The findings confirm Hypothesis 1 by demonstrating that the circadian low-alertness window between 22:00 and 06:00 is characterized by significantly higher impulsive engagement and sales volume compared to daytime hours. This surge in activity aligns with neurocognitive theories suggesting that elevated nighttime melatonin levels weaken executive control and shift consumers toward intuitive, affect-driven decision-making. Notably, while nighttime purchases are more frequent, they do not result in a meaningful increase in return rates once economic controls are introduced, leading to the rejection of Hypothesis 2. This suggests that the social and hedonic architecture of livestreaming may buffer immediate post-purchase regret. However, the support for Hypothesis 3 reveals that these nighttime interactions are less stable, manifesting in significantly lower long-term viewer retention and engagement quality. Furthermore, the support for Hypothesis 4 highlights that platform cues like scarcity messaging and information density exacerbate these biological vulnerabilities by intensifying impulsive tendencies during high-fatigue periods. Ultimately, this study reframes online impulsivity as a temporally dynamic state and underscores the need for a biopsychosocial approach to digital marketing. By integrating circadian intelligence into interface design and ethical governance, the industry can move toward a more sustainable model that respects human physiological limits while maintaining commercial effectiveness.

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