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# Reading the Mind at Play: EEG Insights into Player Engagement with Affective AI

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## *Leyendo la mente en el juego: análisis EEG del involucramiento en videojuegos con IA afectiva*

**ABSTRACT**

**Objectives.** This study explores how Affective Artificial Intelligence (AI), systems capable of detecting and responding to human emotional states, impacts player engagement within a video game context. The objective is to assess whether emotional adaptivity significantly influences engagement levels and how individual traits such as gender and gaming experience moderate these effects.
**Methodology.** A controlled experimental design was employed using the psychological horror game Nevermind. Participants (n = 30) were randomly assigned to either an affective AI condition or a non-adaptive control group. EEG data were recorded throughout gameplay to obtain real-time engagement metrics. Participants were stratified by gender and gaming experience (novice, intermediate, advanced) to examine moderating effects. Statistical analyses included non-parametric comparisons and contingency tests
**Findings.** Results showed no significant overall difference in engagement between AI conditions. However, gender and gaming experience strongly influenced engagement. Female participants reported higher engagement regardless of condition. Advanced players demonstrated significantly higher engagement when exposed to Affective AI, suggesting that emotional adaptivity is particularly effective for experienced users. Novice and intermediate players maintained high baseline engagement levels independent of adaptation.
**Value.** This study contributes to affective computing and game design research by offering empirical evidence on how Affective AI influences engagement across user profiles. Using physiological data, it highlights the conditional effectiveness of emotional adaptivity and its potential as a tool for targeted engagement. These findings inform the development of more inclusive and responsive interactive experiences, especially for advanced players seeking novelty and challenge.

*RESUMEN*

***Objetivos***. *Este estudio explora cómo la Inteligencia Artificial Afectiva (IA), sistemas capaces de detectar y responder a estados emocionales humanos, impacta en el involucramiento de los jugadores dentro del contexto de los videojuegos. El objetivo es analizar si la adaptabilidad emocional influye significativamente en los niveles de involucramiento, y cómo características individuales como el género y la experiencia en videojuegos moderan estos efectos.*
***Metodología***. *Se empleó un diseño experimental controlado con el videojuego de terror psicológico Nevermind. Los participantes (n = 30) fueron asignados aleatoriamente a una condición con IA afectiva o a un grupo control con jugabilidad no adaptativa. Durante la partida se registraron datos EEG para obtener métricas de involucramiento en tiempo real. Los participantes se estratificaron por género y nivel de experiencia (novato, intermedio, avanzado), y se aplicaron pruebas estadísticas no paramétricas y análisis de contingencia.*
***Resultados***. *No se hallaron diferencias significativas en el involucramiento general entre las condiciones. Sin embargo, el género y la experiencia demostraron tener un peso importante. Las mujeres mostraron mayores niveles de involucramiento en ambas condiciones. Los jugadores avanzados mostraron un incremento significativo del involucramiento con IA afectiva, indicando que la adaptabilidad emocional resulta especialmente efectiva en usuarios con experiencia. Por el contrario, los jugadores novatos e intermedios mantuvieron niveles elevados de involucramiento sin requerir adaptación.*
***Valor***. *El estudio aporta evidencia empírica sobre cómo la IA afectiva influye en el involucramiento, subrayando su efectividad condicional. Los resultados sugieren oportunidades para el diseño personalizado de experiencias interactivas más inclusivas y emocionalmente resonantes.*

**KEYWORDS**

Affective Artificial Intelligence; Player Engagement; EEG Metrics; Adaptive Game Design; Gaming Experience; Emotional Responsiveness; Human-Computer Interaction; Interactive Entertainment.

*KEYWORDS*

*Inteligencia Artificial Afectiva; Involucramiento del jugador; Métricas EEG; Diseño de videojuegos adaptativo; Experiencia en videojuegos; Respuesta emocional; Interacción humano-computadora; Entretenimiento interactivo.*

# En el joc llegir la ment: anàlisi EEG de la involucració en videojocs amb IA afectiva


**RESUM**

**Objectius**. Aquest estudi explora com la Intel·ligència Artificial Afectiva (IA), sistemes capaços de detectar i respondre a estats emocionals humans, impacta en la involucració dels jugadors dins del context dels videojocs. L'objectiu és analitzar si l'adaptabilitat emocional influeix significativament als nivells d'involucració, i com característiques individuals com el gènere i l'experiència en videojocs moderen aquests efectes.
**Metodologia**. Es va fer servir un disseny experimental controlat amb el videojoc de terror psicològic Nevermind. Els participants (n = 30) van ser assignats aleatòriament a una condició amb IA afectiva o a un grup control amb jugabilitat no adaptativa. Durant la partida es van registrar dades EEG per obtenir mètriques d'involucració en temps real. Els participants es van estratificar per gènere i nivell d'experiència (novell, intermedi, avançat) i es van aplicar proves estadístiques no paramètriques i anàlisis de contingència.
**Resultats**. No es van trobar diferències significatives en la involucració general entre les condicions. Tot i això, el gènere i l'experiència van demostrar tenir un pes important. Les dones mostrar més nivells d'involucració en les dues condicions. Els jugadors avançats van mostrar un increment significatiu de la involucració amb IA afectiva, indicant que l'adaptabilitat emocional és especialment efectiva en usuaris amb experiència. Per contra, els jugadors principiants i intermedis van mantenir nivells elevats d'involucració sense requerir adaptació
**Aportació**. L'estudi aporta evidència empírica sobre com la IA afectiva influeix en la involucració i en subratlla l'efectivitat condicional. Els resultats suggereixen oportunitats per al disseny personalitzat d'experiències interactives més inclusives i emocionalment ressonants.



**PARAULES CLAU**

Intel·ligència Artificial Afectiva; Involucració del jugador; Mètriques EEG; Disseny de videojocs adaptatiu; Experiència en videojocs, Resposta emocional; Interacció humà-ordinador; Entreteniment interactiu.



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## 1. Introduction

In recent years, both player engagement in digital gaming and the advancement of Artificial Intelligence (AI) technologies have become central concerns in academic research and the interactive entertainment industry. As video games continue to evolve in complexity, interactivity, and narrative depth, ensuring sustained user engagement has become increasingly vital not only for commercial success but also for optimizing user experience and emotional resonance.

Engagement in video games is a multidimensional phenomenon encompassing cognitive attention, emotional involvement, and behavioral participation. It is strongly linked to immersion, presence, and the psychological state of "flow," wherein players become fully absorbed in the activity at hand due to an optimal balance of challenge and skill (Chanel et al., 2011; Csíkszentmihályi, 1990).

Games that succeed in maintaining high levels of player engagement are more likely to foster extended playtime, improved enjoyment, and long-term user retention (Ng et al., 2018; Wang et al., 2020) researchers and practitioners in the human-computer interaction (HCI. Traditionally, strategies to sustain engagement have included compelling storytelling, static difficulty tuning, and Dynamic Difficulty Adjustment (DDA), a rule-based system that modifies gameplay parameters in response to performance indicators such as scores, success-failure rates, or task completion time (Picard, 1997).

However, these systems lack sensitivity to the player's emotional state, potentially overlooking important affective cues that signal boredom, frustration, or overstimulation. This shortcoming has prompted interest in technologies capable of incorporating emotional feedback into game mechanics in real time.

Affective Artificial Intelligence (AI) represents a significant development in this direction. Affective AI refers to systems that can detect and respond to users' emotional states using real-time data from various biosignals, including heart rate variability, galvanic skin response, facial expressions, vocal tones, and electroencephalographic (EEG) activity (Muthu T & Bakkialakshmi, 2022; Picard, 1997). Within gaming contexts, Affective AI enables systems to dynamically adjust gameplay elements such as difficulty, pacing, narrative structure, and environmental stressors in direct response to the player's emotional profile (Karpouzis & Yannakakis, 2016; Smith & Carette, 2020) have entranced us with their expansive, complex worlds. However, the Non-Player Characters (NPCs. This approach may help to align player emotions with game adaptation, potentially leading to a more personalized gaming experience.

Commercial implementations illustrate the growing relevance of this paradigm. The game *Nevermind* (Flying Mollusk, 2015) adapts its horror-themed levels in response to real-time stress indicators, encouraging players to self-regulate under pressure. Similarly, Hellblade: Senua's Sacrifice (Ninja Theory, 2017) blends affective storytelling with audio-visual elements to reflect the protagonist's psychological state, enhancing narrative immersion. These examples illustrate how affective feedback loops can influence engagement by reflecting or responding to the player's emotional state, potentially affecting gameplay experience. Nevertheless, robust empirical validation of affective AI's benefits remains limited, particularly in relation to physiological engagement metrics.

Emerging studies offer initial support for the benefits of affective adaptivity. Chanel et al. (2011) found that biofeedback-driven difficulty adjustments improved performance and sustained engagement in a Tetris-like game. Parsons et al. (2022) ubiquitous computing, and wearable sensor technologies real-time monitoring of neurocognitive and affective states can be studied in an objective manner. Whilst establishing the optimal relation among frequency bands, task engagement, and arousal states is a goal of neurogaming, a standardized method has yet to be established. Herein we aimed to test classifiers within the same context, group of participants, feature extraction methods, and protocol. Given the emphasis upon neurogaming, a commercial-grade electroencephalographic (EEG; Emotiv EPOC reported positive effects of EEG-based adaptivity in a shooter game. Yet other studies highlight the risks of maladaptive or overly intrusive feedback, which can disrupt immersion and draw attention away from the game itself (Karpouzis & Yannakakis, 2016). These mixed results point to the complexity of designing emotionally adaptive systems that are responsive without being disruptive.

Moreover, player characteristics such as gender and gaming expertise appear to significantly moderate the impact of Affective AI. Prior literature suggests that female players often demonstrate higher engagement in emotionally immersive or narrative-rich game environments (Hartmann & Klimmt, 2006; Ravichandran & Ilango, 2023), while expert players tend to benefit more from challenge-responsive systems that maintain novelty and engagement over time (Beale & Creed, 2009). Conversely, beginner players may initially exhibit high engagement due to the novelty effect, independent of system adaptivity (Bontchev, 2016).

Despite these insights, most empirical studies on Affective AI rely on small samples and focus narrowly on behavioral or self-report data, often neglecting psychophysiological measures and user segmentation. This limits our understanding of how engagement unfolds across different user types and gameplay contexts. Addressing this gap requires experimental designs that incorporate both objective physiological metrics and user profile variables.

The present study responds to these needs by empirically evaluating the impact of Affective AI on player engagement using EEG-based measurements. Participants played either an adaptive or non-adaptive version of a commercial video game called *Nevermind* (Flying Mollusk, 2015) under controlled lab conditions. Gender and gaming experience were recorded to investigate moderating effects. By combining physiological data with a sample classified by gaming experience and gender, this research contributes to a more nuanced understanding of how affective personalization strategies can be effectively deployed in contemporary game design.

Rather than assuming a universal benefit, we explore the contextual and user-dependent nature of affective adaptivity.

Beyond the empirical scope, affect-aware systems also raise socio-technical questions. By translating bodily signals into actionable variables for adaptation, Affective AI participates in the quantification and regulation of the body within commercially mediated environments. While such translation can enhance usability and accessibility, it may also risk commodifying emotional states and reinscribing demographic stereotypes if not designed with care. We therefore frame our work as an empirical examination of when and for whom affective adaptivity appears beneficial, coupled with a critical stance on its ethical and design implications.

This work also speaks to the narrative dimension of interactive media by examining how affect-adaptive mechanisms behave in a psychologically driven, story-rich context.

In doing so, we aim to contribute to the field of affective computing identifying specific subgroups for whom Affective AI influences player engagement in a video game context.

## 2. Methodology

### *2.1. Research questions and hypotheses*

Grounded in the mixed findings of prior affective-computing studies, the present work formulated two research questions (RQ) and three associated hypotheses (H). Each hypothesis is directly linked to its guiding question to preserve conceptual coherence.

**RQ1.** Does the integration of Affective Artificial Intelligence (AI) into a commercial video game produce higher physiological engagement than an otherwise identical, non-adaptive version?

**H1.** Participants exposed to the affective-adaptive condition will display significantly higher EEG-derived engagement scores than those playing the non-adaptive build.

This hypothesis is informed by studies showing that biofeedback-driven difficulty adjustments can improve performance and sustain engagement in games through physiological alignment with emotional states (Chanel et al., 2011).

**RQ2.** Does gender influence engagement outcomes when playing with or without Affective AI?

**H2.** Gender will be associated with engagement outcomes irrespective of AI condition. Prior studies suggest that women may show higher engagement in narratively rich or emotionally immersive environments (Hartmann & Klimmt, 2006; Ravichandran & Ilango, 2023). However, evidence is mixed, and male engagement patterns may diverge, particularly in a horror-narrative context such as *Nevermind* (Flying Mollusk, 2015).

We therefore frame this hypothesis as a two-sided test, acknowledging both female and male patterns as theoretically relevant and explicitly avoiding essentialist assumptions.

**RQ3.** Does gaming experience influence engagement outcomes when playing with or without Affective AI?

**H3.** Gaming experience will moderate the impact of Affective AI such that advanced players derive greater engagement benefits from the adaptive system than beginner or intermediate players.

Prior research indicates that experienced users are more likely to benefit from adaptive emotional systems, particularly those involving dynamic physiological feedback (Beale & Creed, 2009).

These hypotheses reflect and extend the conceptual assumption that affective personalization is not universally effective, but rather contingent on the gender, emotional disposition, cognitive expectations, and gameplay history of the user. By explicitly integrating user profile variables into our experimental design, the study seeks to contribute empirical clarity to the boundary conditions under which Affective AI enhances engagement in gaming contexts.

## *2.2. Experimental design and sample*

Our study employed a between-subjects experimental design to examine the effects of Affective AI on player engagement, with participants randomly assigned to one of two conditions using a simple computerized allocation procedure.

The experimental group interacted with a version of the video game *Nevermind* (Flying Mollusk, 2015) featuring real-time affective adaptivity, while the control group played a non-adaptive version of the same game.

- **Affective AI condition (Experimental group)**: Participants experienced a dynamically adaptive version of the game Nevermind (Flying Mollusk, 2015), where gameplay elements such as difficulty, pacing, and environmental stressors adjusted in real time based on participants' emotional states, inferred via physiological signals.
- **Non-Affective AI condition (Control group)**: Participants played an identical version of the game, but with a fixed difficulty curve and no emotion-driven adjustments.

A total of 30 participants (17 males, 13 females) were recruited and the sample was stratified based on gaming experience:

- **Beginner (n = 11)**: Participants with minimal or casual gaming experience.
- **Intermediate (n = 11)**: Participants with regular, non-competitive gameplay experience.
- **Advanced (n = 8)**: Participants with extensive gaming histories or involvement in competitive play.

Expert classification was based solely on self-reported experience across genres and play hours, and it was independent of gender: both female and male participants were represented in the expert subgroup. No assumption was made that expertise equates to masculinity.

## *2.3. Procedure and analysis*

All sessions were conducted using a mobile PC station equipped with 17-inch monitor and noise-cancelling headsets to standardize the audiovisual environment and reduce contextual variability across participants.

All participants reported normal or corrected-to-normal vision and no history of neurological or cardiovascular conditions that could interfere with EEG or emotional responses.

Ethical approval was obtained from the University of Deusto Research Ethics Committee and all participants provided written informed consent. The study conformed to the principles outlined in the Declaration of Helsinki.

The game *Nevermind* (Flying Mollusk, 2015) was selected for its psychological horror theme and built-in support for biofeedback mechanisms, which allowed for real-time responsiveness to stress and arousal indicators (Figure 1).

Each participant underwent the following procedure: they were fitted with the EEG headset, received basic gameplay instructions, and completed a brief calibration to ensure signal quality.

Participants then played for 20 minutes, with all receiving identical instructions to "play naturally," regardless of condition.

After the session, the EEG devices were removed, and participants completed a brief post-game questionnaire including five Likert-type items. These assessed subjective impressions of immersion, difficulty, emotional involvement, system responsiveness, and perceived adaptivity. Though not included in the primary statistical analysis, this instrument served as a subjective complement to the physiological measures, and responses were archived for future exploratory research.

Physiological data were captured using the Emotiv Insight (Emotiv Insight, 2015) headset, a five-channel, wireless EEG device sampling at 128 Hz and interfacing with EmotivPRO v4.6 (Emotiv Insight, 2015) software. Although the device computes several high-level emotional metrics such as Excitement, Focus, Stress, and Relaxation this study exclusively focused on the Engagement metric, which is derived from the ratio of beta (13–30 Hz) to alpha (8–12 Hz) wave activity. Beta waves reflect alertness and cognitive effort, while alpha waves are associated with relaxation and disengagement. Higher beta-to-alpha ratios are interpreted as indicators of attentional engagement. Accordingly, the Emotiv "Engagement" metric is best interpreted as attentional activation. It does not directly capture affective valence, motivational states, or narrative absorption. We therefore use engagement here in its attentional sense and discuss this limitation explicitly in the Discussion. "Engagement" metric, scaled from 0 to 100, was recorded at 1 Hz and analyzed as a continuous time-series signal.

Heart rate and webcam-based facial expression data were accessed internally by the game engine for adaptivity purposes but were neither stored nor analyzed externally. This ensured participant privacy and focused the study on EEG-based engagement as the primary outcome variable.

This integrated experimental protocol, combining standardized equipment, stratified sampling, validated physiological instrumentation, and ethical safeguards, was designed to ensure methodological robustness, ecological validity, and reproducibility.

The statistical analysis followed a robust approach suited for small sample sizes and non-normally distributed data. Descriptive statistics were computed to summarize engagement scores across AI condition, gender, and gaming experience levels.

For inferential comparisons, non-parametric tests were employed: the Mann-Whitney U test was used for comparing two independent groups (e.g., Affective vs. Non-Affective AI, male vs. female), and the Kruskal-Wallis H test was applied


Figure 1. *Nevermind* screenshot. Source: Author's own work based on screenshots.

for comparing engagement across three experience levels. Additionally, Chi-square tests were conducted to explore associations between categorical variables, such as high vs. low engagement and participant characteristics.

To investigate potential interaction effects, stratified analyses were performed examining combinations of AI condition with gender and gaming experience.

Outliers identified via interquartile range methods were adjusted using Winsorization to reduce distortion. All statistical procedures were conducted using SPSS Statistics (IBM Corp, 2023), with select analyses cross-verified using Python for consistency.

## 3. Findings

### 3.1. Engagement analysis

Overall, participants demonstrated moderate-to-high levels of engagement throughout the gameplay session. Across the sample, the mean engagement score was 53.78, with a Standard Deviation (SD) of 13.09, and values ranging from 14 to 97, reflecting considerable individual variability. Engagement values were recorded as one-minute averages derived from EEG-based data, providing a robust time-series profile of attentional and emotional involvement during gameplay (Figure 2).

Analysis by gender revealed clear differences in engagement. Female participants recorded a higher average engagement score (M = 56.52, Median = 57) compared to male participants (M = 51.69, Median = 51). While the dispersion was comparable between groups, the maximum scores achieved by female participants were noticeably higher. This difference was statistically significant as indicated by a Mann–Whitney U test ($p < 0.001$). A contingency analysis, based on a median split classification of "high" vs. "low" engagement, also showed a significant association between gender and engagement category ($p < 0.05$), with a higher proportion of females in the "high engagement" group.

Participant engagement was further analyzed across three experience levels: Beginner, intermediate, and advanced. Beginner participants recorded the highest average engagement (M = 56.38), followed by intermediate players (M = 52.97), and advanced players (M = 51.32). The Kruskal–Wallis H test confirmed that these differences were statistically significant ($p < 0.001$). Contingency analysis reinforced this pattern, showing that beginner players were most frequently categorized in the high engagement group.

These findings suggest a negative gradient between experience level and engagement, potentially due to the diminishing novelty effect among more seasoned players (Figure 3).

### 3.2. Impact of affective AI on engagement

The comparison between Affective AI and Non-Affective AI conditions showed no statistically significant difference in overall engagement.

Specifically, the average engagement score for the Non-Affective AI group was slightly higher (M = 54.41, SD = 12.82) compared to the Affective AI group (M = 53.15, SD = 13.34).

However, this difference was not statistically significant (Mann-Whitney U test, $p = 0.24$). Additionally, Chi-square tests revealed no significant associations between AI condition and engagement categorization (high vs. low engagement).

Further subgroup analyses were conducted separately for each experience level group. Advanced players demonstrated a statistically significant difference, with higher average engagement scores in the Affective AI condition compared to their counterparts in the non-affective condition (Mann-Whitney U test, $p = 0.026$). In contrast, no significant

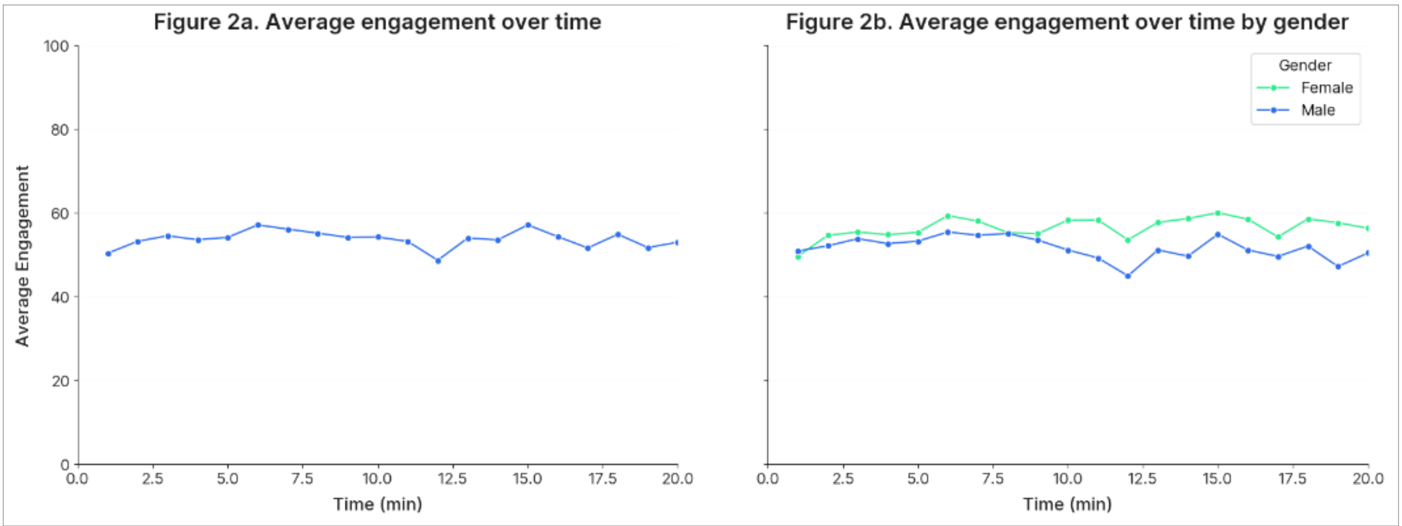


Figure 2. EEG-based engagement over time: (a)overall average and (b)by gender. Source: Authors' own work.

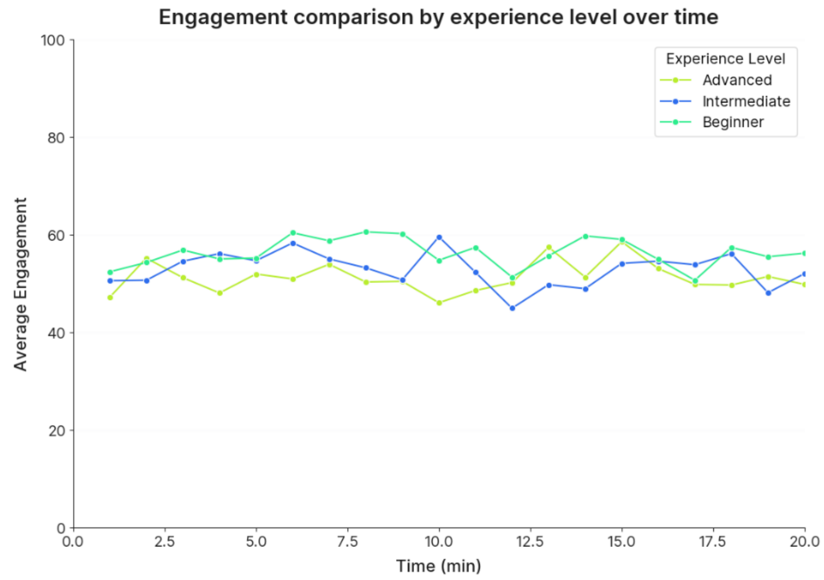


Figure 3. Engagement comparison by experience level over time. Source: Authors' own work.

differences were found for beginner (p = 0.24) or intermediate (p = 0.11) player groups.

Engagement was also analyzed with respect to gender, irrespective of AI condition. Female participants recorded significantly higher average engagement scores compared to male participants (Mann–Whitney U test, $p < 0.001$). Additionally, a significant association was found between gender and engagement classification, with females more frequently categorized in the high engagement group (Chi-square test, $p < 0.05$).

**Summary of hypothesis testing:**

The statistical analyses yield mixed results in relation to the proposed hypotheses.

H1 was not supported, as no statistically significant difference in overall engagement was found between the affective and non-affective AI conditions (p = 0.24).

In contrast, H2 was supported, with female participants exhibiting significantly higher engagement scores than male participants ($p < 0.001$).

H3 was also supported, as advanced players in the Affective AI condition demonstrated significantly higher engagement levels compared to their counterparts in the non-affective group (p = 0.026).

These results indicate differential effects of Affective AI depending on specific participant characteristics.

Given theoretical interest in intersections, we inspected descriptive trends by Gender × Experience. Within the limits of our small cells (and without reliable inferential power), we observed no consistent interaction patterns warranting firm conclusions. We report these trends descriptively to support future, adequately powered replications (Figure 4).

## 4. Discussion

Our study examined the influence of Affective AI on player engagement in a controlled gaming context, emphasizing how individual differences such as gender and gaming experience interact with adaptive systems.

The findings offer an understanding that aligns with and extends the current literature in affective computing and user-centered game design. Rather than revealing a universal effect, the results underscore that the efficacy of Affective AI is highly conditional, shaped by user characteristics and gameplay context.

The lack of a statistically significant difference in overall engagement between the Affective AI and non-adaptive conditions is consistent with prior studies suggesting that subtle affective adjustments, particularly those limited to stress-based adaptations, may be imperceptible at the group level (Karpouzis & Yannakakis, 2016; Melhart et al., 2023).

The substantial overlap in engagement score distributions across conditions highlights the limitations of generic implementation. This reinforces the broader view that personalization is key: emotionally adaptive systems must be attuned to player profiles, not just transient emotional states. Designing adaptive systems that can balance general applicability with specific relevance remains an open research challenge in the field (Yannakakis & Paiva, 2015).

Where this study does contribute significantly is in identifying specific subgroups for whom Affective AI demonstrates measurable benefit. Advanced players in the Affective AI

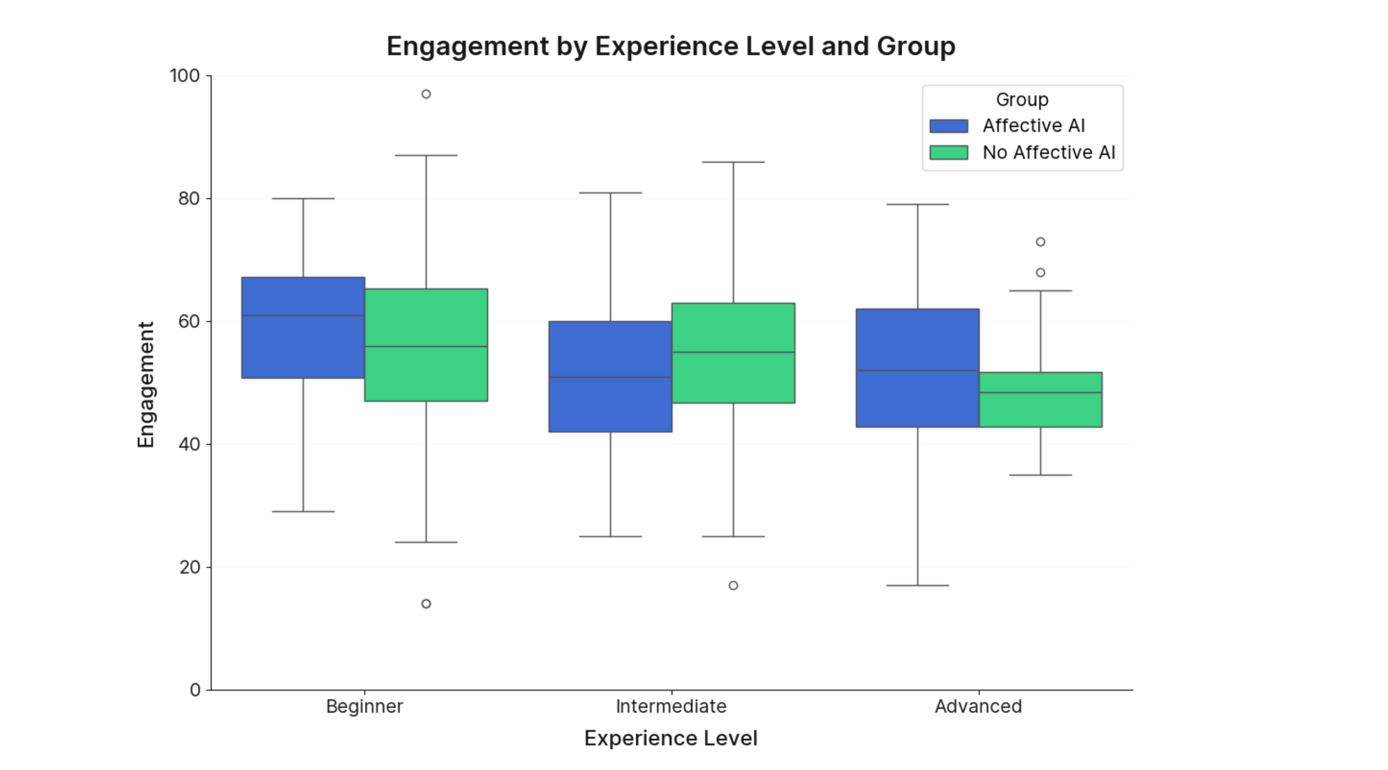


Figure 4. Engagement by experience level and condition group. Source: Authors' own work.

condition displayed significantly higher engagement levels than their counterparts in the control condition. This empirical result supports longstanding theoretical models positing that experienced players, who are more familiar with conventional gameplay mechanics, are more likely to appreciate and benefit from adaptive features (Beale & Creed, 2009; Burak Arslan & Filiz, 2022). The integration of emotional feedback into gameplay could introduce novelty or adjust cognitive demands for this subgroup, possibly maintaining engagement over time.

Some of our findings align with long-standing models, for example, that experienced players may exhaust novelty-driven engagement more quickly and thus require additional challenge. Rather than treating this as a limitation, our contribution is to provide objective, EEG-based evidence that specifies when and for whom affective adaptivity is more likely to matter. In doing so, we delineate boundary conditions that qualify prior assumptions with time-resolved physiological data.

In contrast, beginner and intermediate players showed consistently high engagement regardless of condition, likely due to novelty effects. These effects are well-documented in the literature on learning and entertainment technologies and are understood to stem from initial curiosity and cognitive effort required to navigate a new environment (Bontchev, 2016; Chanel et al., 2011). For these users, the additive value of emotional adaptivity may be minimal or even disruptive. This suggests the importance of temporal calibration in adaptive system logic: affective responsiveness may be more effective once baseline engagement has plateaued, rather than being introduced prematurely.

Gender also emerged as a significant and consistent moderator of engagement. Female participants tended to report higher engagement across both conditions, corroborating previous findings that emphasize women's stronger responses to emotionally rich, narrative-driven content (Hartmann & Klimmt, 2006; Ravichandran & Ilango, 2023). Given that the experimental game ***Nevermind*** (Flying Mollusk, 2015) relies on psychological horror and emotional storytelling, it is plausible that the genre itself aligned with motivational profiles more common among female players. We caution against essentialist interpretations: observed gender patterns are treated as context-contingent rather than intrinsic, shaped by genre affordances, player motivations, and task framing. Male engagement may follow different vectors (e.g., challenge/mastery), underscoring the need for profile-aware but stereotype-averse design. This raises important questions about genre sensitivity and the need to develop adaptive algorithms that account for both demographic variables and thematic context.

These patterns contribute to the emerging consensus that emotionally adaptive systems must be modular and profile-aware. Our findings support calls in affective computing for stratified system evaluation and adaptive personalization, whereby system responses are tailored based not only on real-time affect but also on stable user characteristics like experience level, gender, and genre preference (Rukavina et al., 2016). Future research should explore how adaptive AI can dynamically update and refine user models over time through reinforcement learning or neuro-symbolic approaches.

Methodologically, the use of EEG-based physiological metrics represents a meaningful advance. Unlike self-report scales or behavioral proxies, EEG provides moment-to-moment tracking of attentional states(Zhang et al., 2021). Specifically, the beta-to-alpha power ratio offers a window into cognitive alertness and attentional engagement. Nevertheless, this metric has limitations. It does not fully capture affective valence, intrinsic motivation, or narrative absorption, dimensions crucial for understanding engagement in emotionally rich games. Triangulation with subjective measures and in-game telemetry (e.g., response time, decision patterns, or verbal expressions) would enrich future analyses and yield a more comprehensive view of player experience (Parsons et al., 2022) ubiquitous computing, and wearable sensor technologies real-time monitoring of neurocognitive and affective states can be studied in an objective manner. Whilst establishing the optimal relation among frequency bands, task engagement, and arousal states is a goal of neurogaming, a standardized method has yet to be established. Herein we aimed to test classifiers within the same context, group of participants, feature extraction methods, and protocol. Given the emphasis upon neurogaming, a commercial-grade electroencephalographic (EEG; Emotiv EPOC

Affective adaptivity operates by translating bodily signals into computational variables that drive real-time adjustments. This translation can enhance accessibility and personalization, yet it also raises concerns about the quantification and commercial regulation of the body in interactive environments. First, when physiological indicators become optimization targets, there is a risk of commodifying emotional states—prioritizing time-on-task or monetization metrics over player well-being. Second, if demographic attributes (e.g., gender, experience) are operationalized naïvely, adaptive policies may reproduce stereotypes or amplify subgroup disparities.

In this study we adopt a non-essentialist stance: observed gender patterns are treated as context-contingent, likely shaped by genre affordances, player motivations, and task framing. We therefore caution against design logics that encode demographic shortcuts; instead, we argue for profile-aware but stereotype-averse decision rules and for ongoing auditing of adaptive outcomes across subgroups (including non-binary identities and broader cultural backgrounds).

From a data-governance perspective, affective systems should follow proportionality and data-minimization principles: collect the least intrusive signals compatible with the intended adaptation, prefer on-device processing when feasible, disclose what is sensed, how it is transformed, and how long it is retained, and provide informed opt-in/opt-out and granular controls for users. Given that EEG-based "engagement" primarily reflects attentional activation, we recommend clear labeling of what the metric captures (and what it does not), together with safeguards to prevent coercive or manipulative feedback loops.

The findings suggest that affective adaptivity should be deployed selectively rather than universally: it appears more beneficial for advanced players and in contexts where novelty has stabilized. Moreover, adaptive algorithms need to be genre-sensitive and subject to periodic re-evaluation, since benefits may vary across narrative-driven versus action-oriented games. Finally, the integration of fairness audits and user-side transparency mechanisms emerges as a key avenue for both responsible design and future scholarly inquiry.

Finally, the cross-sectional nature of this study offers only a snapshot of engagement dynamics. Longitudinal designs are needed to determine whether adaptive systems retain their effectiveness over time or if players habituate to the emotional feedback. Such research could also examine whether adaptivity should evolve across gameplay sessions, especially as players become more familiar with game mechanics and narrative structure. Tracking engagement across multiple play sessions could illuminate whether emotional adaptivity contributes to sustained engagement or merely enhances short-term novelty.

In conclusion, our results do not validate a general engagement boost from Affective AI, but they do identify meaningful benefits for advanced players and reveal consistent engagement trends across genders. These findings point toward the need for flexible, adaptive architectures that adjust interventions based on long-term user traits and in-the-moment affective signals. For developers and researchers alike, this suggests a path forward: building adaptive systems that are not only emotionally intelligent but also contextually sensitive, ethically designed, and behaviorally grounded.

## 5. Conclusions and final remarks

The study contributes to the field of affective computing by empirically examining how Affective AI influences player engagement in a video game context.

Using EEG-based physiological measures, we investigated how individual traits, specifically gender and gaming experience, modulate the effects of emotional adaptivity.

Our results suggest that while Affective AI does not universally enhance engagement, it can significantly improve the experience for advanced players. These users, likely accustomed to conventional gameplay dynamics, benefited from the emotional responsiveness of the adaptive system, showing increased attentional engagement. In contrast, beginner players maintained high engagement levels irrespective of

AI condition, likely due to novelty effects. Female participants, regardless of condition, consistently exhibited higher engagement, aligning with literature that links gender to responsiveness to narrative and emotional immersion.

However, these findings should consider several limitations. The sample size (n = 30), although balanced across gender and experience groups, restricts the statistical power of subgroup comparisons. Future work should include larger, more diverse samples, including non-binary identities and broader cultural backgrounds, to support inclusive design. Additionally, the use of a single game limits generalizability across genres.

Moreover, the Affective AI employed focused solely on physiological stress and engagement via heart rate and webcam analysis did not include richer affective or social dimensions such as narrative branching, character responsiveness, or multiplayer emotional adaptation.

Engagement itself was analyzed via EEG-derived metrics, which represent only a narrow slice of the broader engagement experience, excluding motivational, affective valence, and narrative components.

Potential participant bias also warrants consideration. Despite the covert implementation of the adaptive system, several participants indicated awareness of possible adaptation during post-game debriefing. This perception may have influenced their behavior or reported experience, complicating interpretation of results. Although physiological data offers a level of insulation from subjective distortion, the psychological effect of perceived adaptivity, particularly in emotionally charged contexts, remains an important variable to control for in future work.

Building on these findings, future research should aim to broaden the empirical base by conducting studies across different genres, players demographics, and affective modalities.

More diverse samples, including broader cultural backgrounds and non-binary gender identities, are necessary to ensure inclusive design. Studies should also explore longitudinal implementations of adaptive AI, tracking whether emotional personalization sustains or diminishes engagement over time.

Combining EEG with behavioral data, in-game telemetry, and psychometric scales would provide a more holistic understanding of player experience and system effectiveness. Additionally, exploring multi-user environments and cooperative gameplay could reveal how Affective AI might support or complicate engagement dynamics within teams or social interactions.

The practical implications of these findings are clear. Emotionally adaptive AI may influence player retention and immersion, especially among experienced users interested in more personalized gameplay.

Rather than applying emotional adaptivity as a default feature, developers may benefit from embedding it as a modular system that activates in response to behavioral and emotional thresholds. Gender-sensitive design heuristics, and eventually adaptive systems that respond to evolving user profiles, will further enable more inclusive and emotionally resonant games.

In conclusion, the strategic value of Affective AI lies in its capacity to personalize interactive experiences by dynamically adjusting to player traits and emotional trajectories. While its success is not guaranteed across all users or contexts, its targeted deployment, grounded in ethical, transparent, and empirically informed design, represents a powerful tool for shaping the future of emotionally intelligent game design.

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