

CHAOTIC MODELING OF ATTENTION UNDER VARYING VIDEO GAMING INFLUENCE: A DYNAMICAL SYSTEMS APPROACH

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Abstract : Video gaming has been linked to both improvements and impairments in attention, depending on intensity and pattern of play. This study proposes a nonlinear dynamical systems framework that reconciles these mixed findings. A student's daily attention is modelled as a bounded state evolving under the logistic map $x_{n+1} = r \cdot x_n \cdot (1 - x_n)$, where r encodes gaming intensity. Four extensions are analysed: variation of r across the parameter sweep, periodic forcing capturing a weekday-weekend schedule, stochastic noise representing irregular play, and a resilience parameter λ that carries part of the previous day's attention forward. Simulations generate bifurcation diagrams, 30-day time-series traces, a multi-week time series, and a variance heatmap across the (r, λ) plane. The model recovers the classical route to chaos: stable focus at low intensity, period-doubling at intermediate intensity, and chaotic day-to-day swings at high intensity. Weekly forcing replaces chaos with structured periodicity; stochastic perturbations widen variability; resilience near 0.6 suppresses chaos even at high intensities. The results suggest that the empirical conflict in the literature on gaming and attention may reflect underlying nonlinear dynamics rather than measurement artefacts.

IndexTerms - logistic map, attention dynamics, video gaming, chaos theory, resilience

I. INTRODUCTION

Video games are a common part of modern students' lives, and their influence on cognitive skills—especially attention—has drawn significant research interest. A growing body of work suggests moderate gaming can bolster certain aspects of attention. Experienced video game players often outperform non-gamers on basic attentional tasks [1], and controlled trials have found that training on fast-paced action games can causally improve visual attention and tracking skills [2]. On the other hand, concerns have been raised about potential negative effects of excessive gaming. Very high levels of play have been associated with shorter attention spans and reduced concentration in school, indicating that heavy gamers may develop attention problems [3]. These contrasting findings pose a puzzle: under what conditions does gaming enhance attention, and when might it impair attentional focus? This duality suggests the impact of gaming on attention is not linear, but depends on factors like intensity and play patterns.

Addressing this question requires new approaches beyond the existing empirical studies. Most prior research has been observational or experimental, measuring cognitive changes after gaming interventions. However, there is a gap in theoretical modeling of how attention could dynamically respond to different gaming habits over time. To bridge this gap, the present study proposes a nonlinear dynamical systems framework for the attention-gaming relationship. Nonlinear (especially chaotic) models are known for producing complex, realistic patterns from simple rules, which makes them compelling tools for modeling cognitive fluctuations [4]. In particular, this study adopts the logistic map—a classic chaotic equation—as a simplified model of a student's daily attention level under the influence of video gaming. Applying a chaos-theoretic framework to the cognitive effects of gaming remains uncommon in this literature.

The goal of this work is to use a logistic map model of attention, with various extensions, to simulate how different gaming scenarios might lead to stable or chaotic attention outcomes. Several realistic modifications are implemented: varying the gaming intensity parameter to represent moderate versus heavy play, introducing a weekly schedule (e.g. lower intensity on weekdays and spikes on weekends), adding random fluctuations to mimic irregular play or external distractions, and incorporating a resilience factor that carries over part of the previous day's attention. By examining the model's behavior under these conditions, the work identifies when attention settles into a stable pattern versus when it shows chaotic swings in response to gaming.

1.1 Problem Statement and Research Questions

Empirical studies on video gaming and attention return conflicting results: moderate play is associated with measurable gains in visual attention, spatial processing, and task switching [1, 2], while heavy play is associated with shorter attention spans, ADHD-related behaviours, and reduced academic focus [3]. These contrasting outcomes cannot be reconciled by a linear dose-response model, and the existing literature is dominated by observational and pre-post experimental designs that do not address how attention evolves over time as a function of play habits.

The specific problem this study addresses is: can the contradictory empirical findings on gaming and attention be explained as different regimes of a single nonlinear dynamical system? Formally, the work asks: (i) whether a logistic-map model of daily attention reproduces the qualitative split between stable, periodic, and chaotic regimes as gaming intensity rises; (ii) whether realistic extensions — weekly scheduling, stochastic noise, and an attentional resilience term — generate regime shifts that match the

empirical patterns reported in the literature; and (iii) where the threshold between stable and chaotic attention lies in the joint intensity–resilience parameter space.

II. LITERATURE REVIEW

Research over two decades links moderate video game play with improvements in attention and related skills. Laboratory and field studies report gains in visual attention, spatial processing, and task switching among regular players [1]. Action games, in particular, have been used as training tools that produce measurable enhancements in selective attention and visual tracking [2]. These effects often appear on controlled tasks that require rapid detection, divided attention, or filtering of distractors [1, 2]. Together, this literature supports the view that gaming can benefit attention under bounded doses and structured training.

Findings are not uniformly positive. Meta-analytic work associates heavier media use with more ADHD-related behaviours and attention problems in children and adolescents [3]. School reports and questionnaire studies frequently note reduced concentration, shorter attention spans, and poorer academic focus among heavy gamers [3]. Dose seems to matter. Benefits reported for moderate exposure can plateau or reverse at high playtime, consistent with concerns from clinicians that overstimulation and insufficient recovery may hinder memory consolidation and sustained attention [3]. These mixed outcomes motivate a closer look at how intensity and patterning of play relate to attention over time, rather than only pre–post averages.

Cognitive states such as attention and memory show complex temporal behaviour. They can stabilise, oscillate, or shift abruptly after small changes in input. Nonlinear dynamical systems offer compact tools to represent such patterns. Simple iterative maps can generate rich trajectories, including steady states, periodic cycles, and chaos from minimal rules [4]. The logistic map is a canonical example, widely used in introductory treatments of chaos, and well suited for exploring qualitative regimes without heavy parameterisation [4]. Using these tools for cognition invites questions about thresholds, tipping points, and variability that linear models may miss.

III. METHODOLOGY

3.1 Baseline Logistic Map

The model treats attention as a bounded state that updates daily under gaming influence. The logistic map defines the update rule:

$$x_{n+1} = r \cdot x_n \cdot (1 - x_n) \quad (1)$$

where $x_n \in [0, 1]$ is the normalised attention level on day n , and $r > 0$ represents gaming intensity or impact on that day [4]. The map's qualitative behaviour depends on r . For low r , trajectories converge to a single stable value. For intermediate r , attention alternates among a small set of values in a periodic cycle. Beyond a critical range, period-doubling leads to chaos, producing aperiodic day-to-day fluctuations in attention [5]. Intuitively, mild gaming allows attention to stabilise near a high level, whereas very intense play can push attention into irregular swings.

Baseline simulations initialise $x_0 = 0.5$ to represent moderate starting focus. The update rule runs for many iterations, each iteration denoting one day. To study long-term patterns, initial transients are discarded. A bifurcation diagram is generated by sweeping r from about 2.5 to 4.0, iterating at each value, and plotting the long-run attention states. This reveals where attention settles to a fixed point, splits into periodic orbits, or becomes chaotic as gaming intensity increases [4, 5]. Representative time-series traces are also produced at selected r values to illustrate stable, periodic, windowed, and chaotic regimes.

3.2 Weekly Schedule Modulation

A weekly schedule modulation captures regular routines. Let r_n be piecewise constant with period 7 to mimic weekdays and weekends. For a given base intensity r_0 , set $r_n = r_0$ on five weekdays and $r_n = r_0 + \Delta$ on two weekend days, where $\Delta > 0$ represents longer or higher-intensity weekend play. Sweeping r_0 under this periodic forcing yields a weekly-forced bifurcation diagram that shows the distinct long-run attention states associated with different days in the cycle. A companion time series over several weeks makes visible the recurring rise during structured weekdays and dips after weekend spikes.

3.3 Stochastic Forcing

Irregular habits and external distractions are modelled by adding random perturbations to intensity. Define $r_n = r + \delta_n$, where δ_n is a zero-mean fluctuation drawn from a specified distribution with small variance. This converts the map into a stochastic system. For each base r , multiple runs are simulated to quantify robustness. Long-run variability is summarised by statistics such as the variance of the tail of x_n , allowing comparison between deterministic and noisy conditions. This tests whether small daily deviations in play produce disproportionately large differences in attention trajectories.

3.4 Attentional Resilience

A resilience parameter $\lambda \in [0, 1]$ introduces memory of prior attention. The update becomes:

$$x_{n+1} = (1 - \lambda) \cdot [r_n \cdot x_n \cdot (1 - x_n)] + \lambda \cdot x_n \quad (2)$$

where λ is the fraction of attention carried forward. When $\lambda = 0$, the model reduces to the standard logistic map. When λ is near 1, attention changes only slightly from day to day, modelling an individual's capacity to retain focus despite perturbations. Simulations examine a representative $\lambda = 0.6$ to show how resilience attenuates period-doubling and chaos in the bifurcation diagram. A grid over (r, λ) is then scanned, and the variance of long-run attention is mapped to identify stable and unstable regions across intensity and resilience.

IV. RESULTS AND DISCUSSION

4.1 Baseline Dynamics

The bifurcation diagram of the attention model versus gaming intensity (Figure 1) shows that for relatively low intensity values ($r \approx 2.5$ – 3.0), all simulation runs converge to a single attention level (a stable fixed point). As r increases beyond ≈ 3.0 , the attention values split into two branches, then four, indicating periodic oscillations via period-doubling. For r above ≈ 3.5 , the diagram fills a broad band of points — a hallmark of chaos where attention fluctuates aperiodically. This classical route to chaos [4, 5] implies that increasing gaming intensity can push attention from a steady state into complex, unpredictable behaviour. In practical terms, the model's baseline suggests that moderate gaming intensity may result in a stable, improved attention level, whereas extremely intense gaming could lead to erratic day-to-day attention fluctuations.

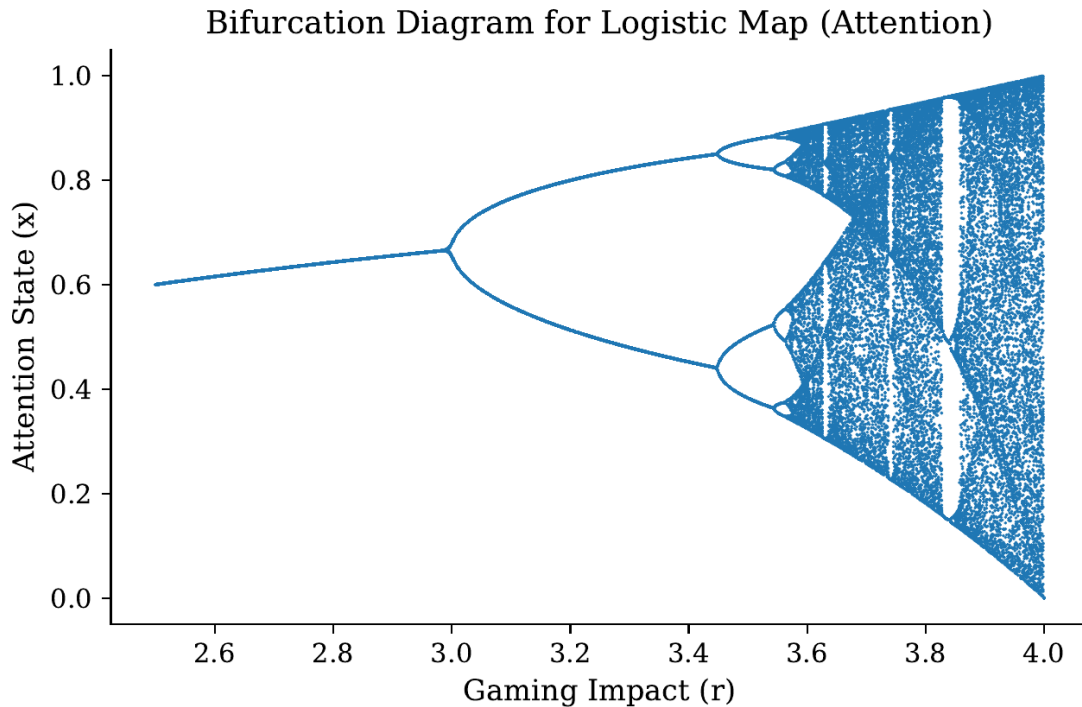


Figure 1: Bifurcation diagram for the baseline logistic map of attention. Long-run x values are plotted against gaming impact $r \in [2.5, 4.0]$. Period-doubling onset near $r \approx 3.0$; chaos beyond $r \approx 3.57$.

4.2 Time-Series Examples of Attention Trajectories

To illustrate the range of possible attention dynamics, time-series simulations were run at representative intensity values corresponding to different regimes (steady, periodic, complex periodic, and chaotic). The resulting 30-day attention trajectories are shown in Figures 2–5. At a low intensity of $r = 2.8$ (Figure 2), attention quickly settles around 0.67 and remains flat, representing a stable high-attention state. At a moderate intensity of $r = 3.4$ (Figure 3), attention oscillates between approximately 0.52 and 0.82 on alternating days, demonstrating a period-2 cycle. For $r \approx 3.83$ (Figure 4), the system exhibits a higher-order periodic pattern: attention cycles through three distinct values in a repeating 3-day sequence — a period-3 orbit appearing as a brief window of order amid an otherwise chaotic parameter range. Finally, at a high intensity of $r = 3.9$ (Figure 5), the attention level varies erratically each day with no repeating pattern.

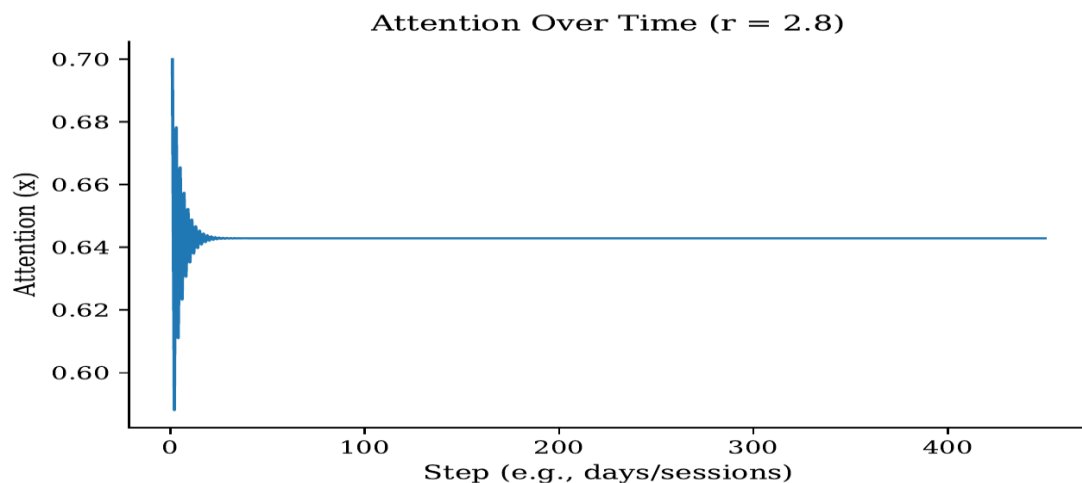


Figure 2: Attention time series at $r = 2.8$ — stable fixed point.

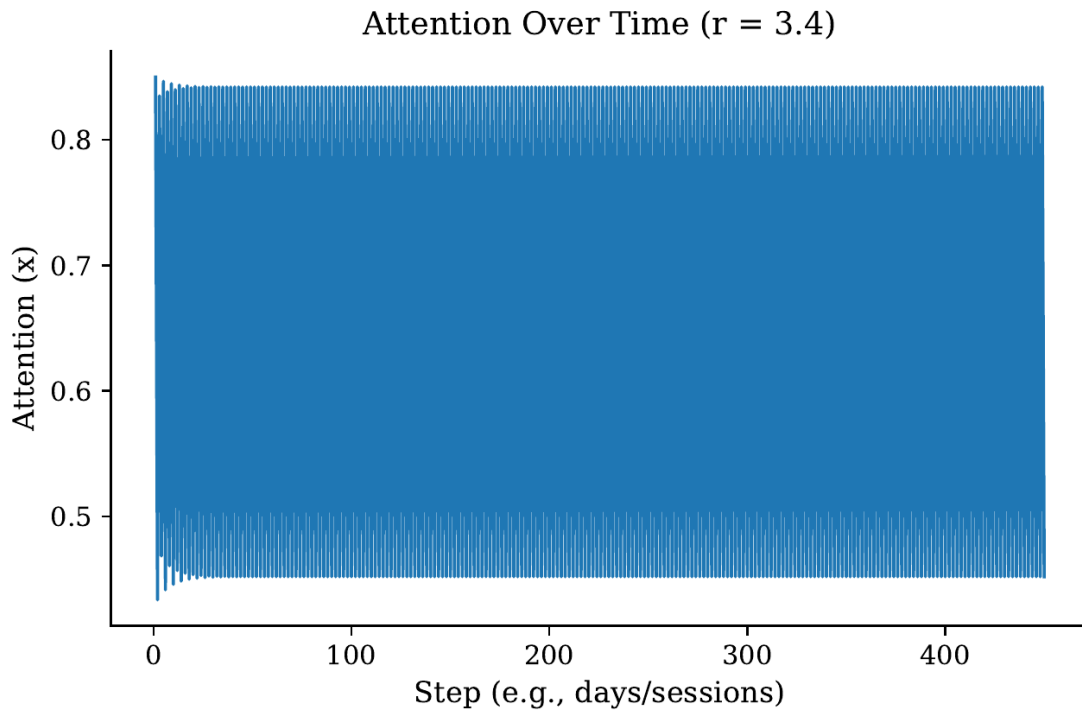


Figure 3: Attention time series at $r = 3.4$ — period-2 oscillation.

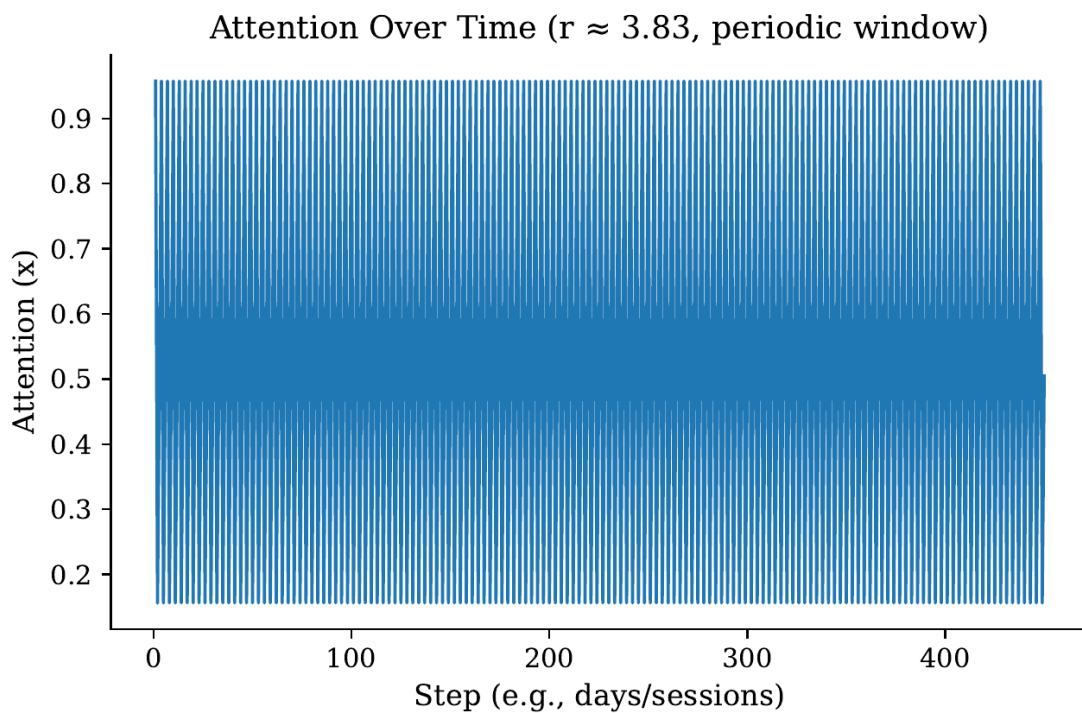


Figure 4: Attention time series at $r \approx 3.83$ — period-3 window within chaotic range.

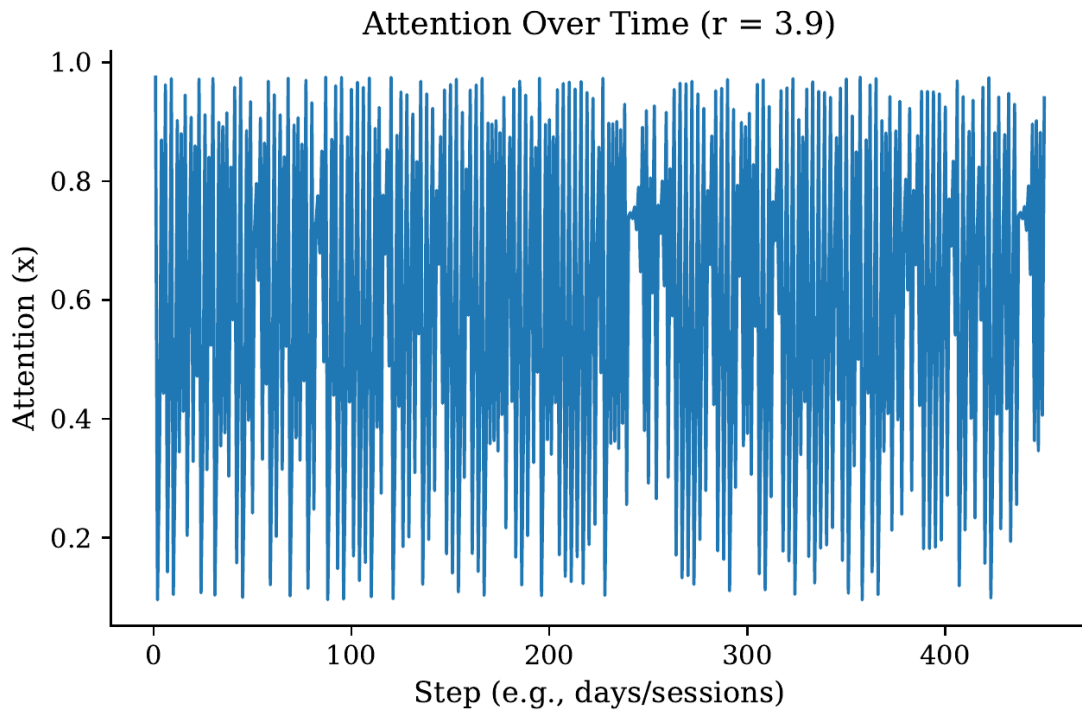


Figure 5: Attention time series at $r = 3.9$ — fully chaotic trajectory.

4.3 Effects of a Weekly Gaming Schedule

Introducing a repeating weekly pattern in gaming intensity markedly alters the attention outcomes. Figure 6 shows the bifurcation diagram with a weekly-modulated gaming intensity (lower r on weekdays and higher r on weekends). The horizontal axis is the base weekday intensity r_0 , and the diagram reveals the attention states achieved over long runs of the weekly cycle. Compared to the single branch in the baseline case, here many points appear for each r_0 , reflecting the multi-day pattern. Notably, the introduction of a weekly rhythm prevents complete chaos in some regions. Instead of a broad continuous spread of points, one sees distinct clusters corresponding to each day in the 7-day cycle. This indicates that a regular schedule can entrain attention into a predictable weekly repeating pattern, even when the base intensity is high.

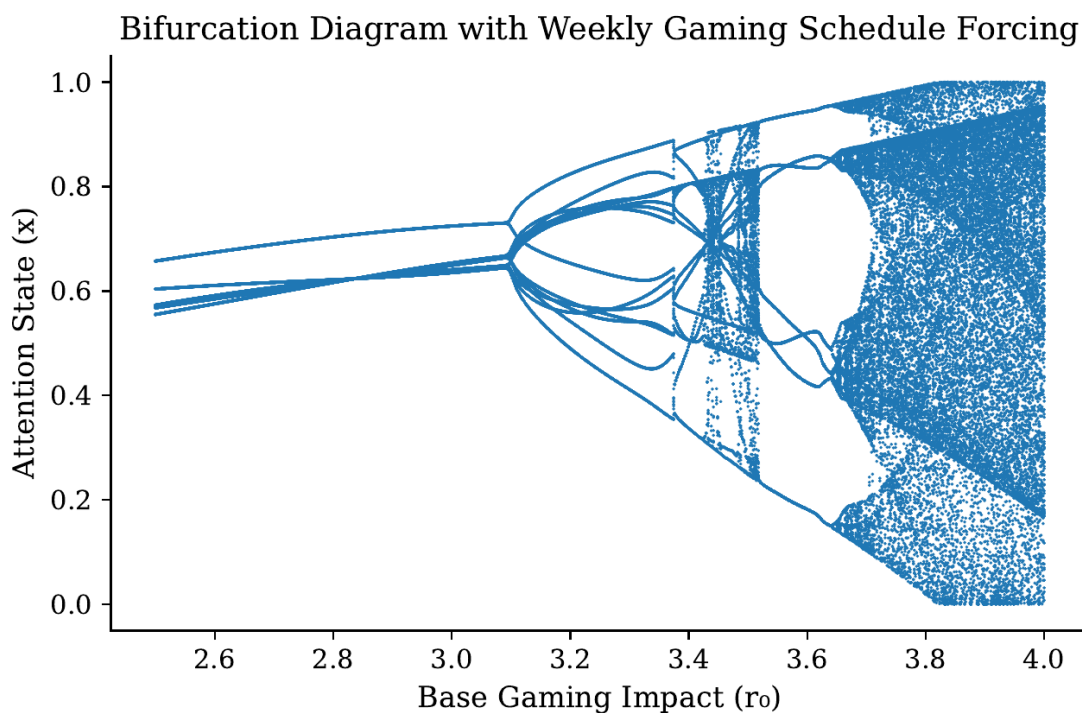


Figure 6: Bifurcation diagram with weekly schedule forcing. Distinct day-of-week clusters delay the onset of full chaos relative to the baseline.

Figure 7 provides a concrete example of attention dynamics under a weekly-varying schedule (moderate gaming on weekdays and intense gaming on weekends). The simulation exhibits a clear 7-day oscillation in attention levels. During weekdays attention gradually improves or remains stable, but after each intense-gaming weekend the attention level dips noticeably then recovers during the following week. This repetitive boom-and-bust cycle demonstrates how regular high-intensity intervals can produce a recurring pattern in attention rather than fully chaotic variability.

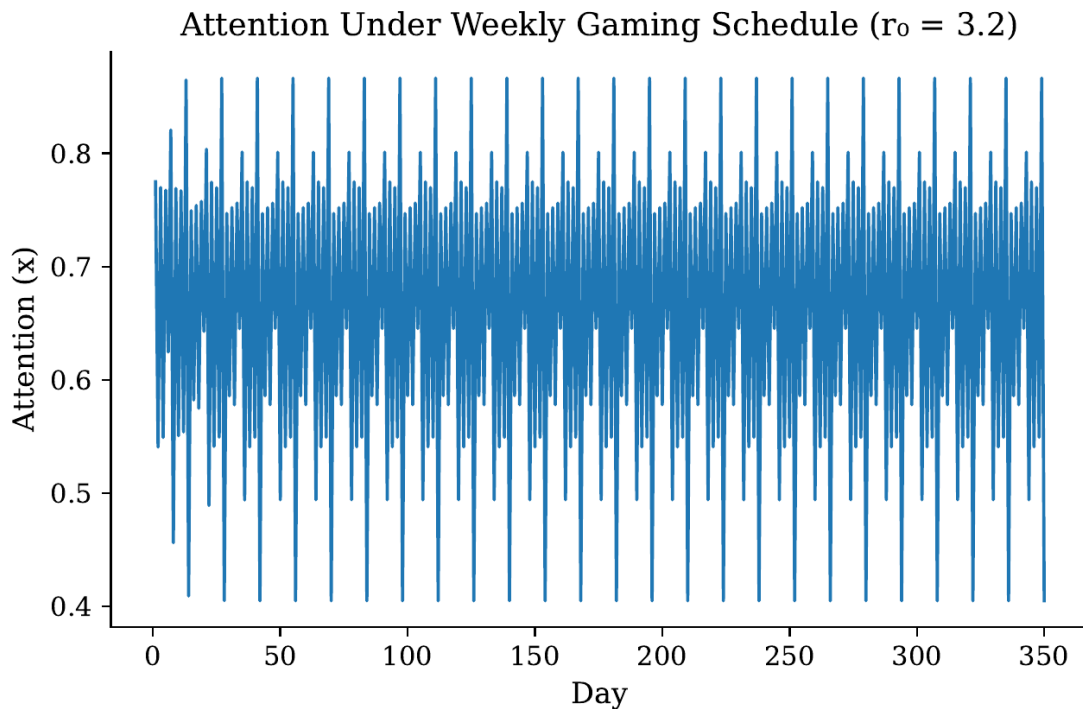


Figure 7: Attention dynamics over multiple weeks under a weekly schedule ($r_0 = 3.2$; weekend spike). Clear 7-day periodicity.

4.4 Influence of Random Intensity (Noise)

Figure 8 shows the bifurcation diagram when stochastic fluctuations are added to the daily gaming intensity. Instead of the crisp period-doubling forks seen in the baseline diagram, the outcomes here appear as fuzzy clouds of points. Even at low base intensities that previously yielded a single stable point, adding noise causes a spread of attention values. Periodic regimes become less distinct as random perturbations knock the system into different phases. In the high- r chaotic range, the points smear into an even wider band, indicating even greater variability. These results suggest that irregular gaming habits or external distractions can further destabilise attention patterns: randomness makes it harder for attention to settle into any strict cycle or fixed point.

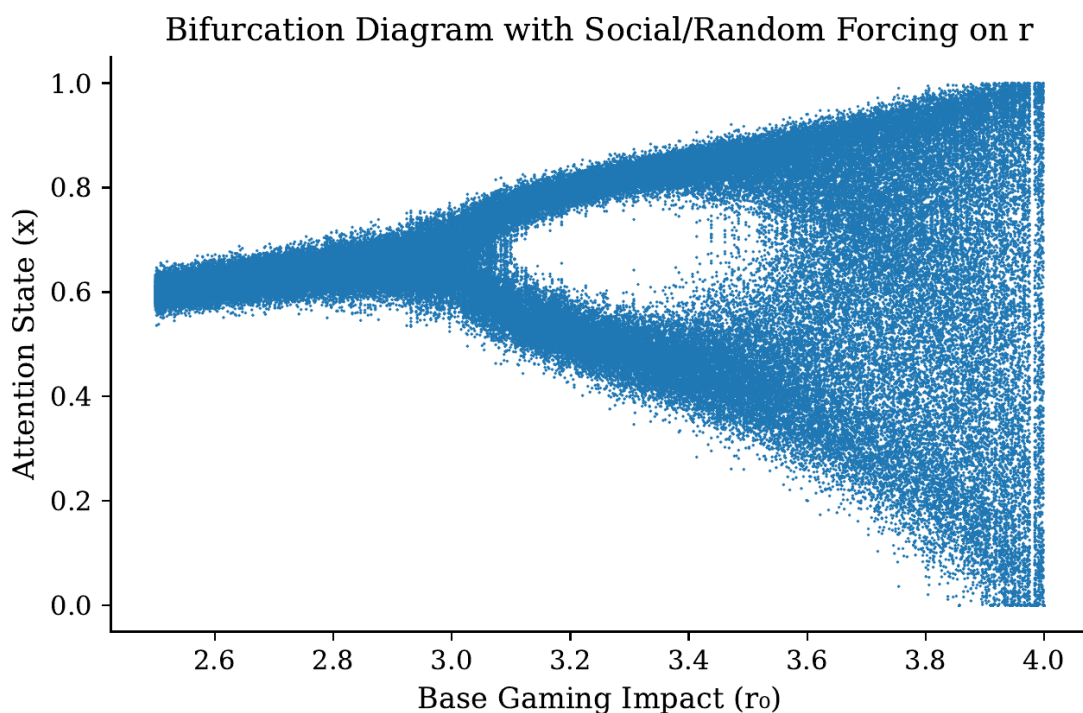


Figure 8: Bifurcation diagram under stochastic (social/random) forcing on r . Period-doubling structure broadened into clouds; variability grows across the chaotic range.

4.5 Influence of Attentional Resilience

Introducing an attentional resilience factor dramatically stabilises the system's behaviour, as shown in Figure 9. With $\lambda = 0.6$, the chaotic bifurcations are almost entirely eliminated — the plot shows essentially a single stable branch (with only tiny oscillations) across all values of r . Even at very high intensity ($r \approx 3.9$), the attention level settles to a steady value around 0.75 instead of exploding into chaos. This stabilisation occurs because the memory term carries over a significant portion of the previous day's attention, damping daily fluctuations. Resilience provides a stabilising inertia: attention becomes reluctant to change drastically from one day to the next, preventing it from bifurcating into wild swings.

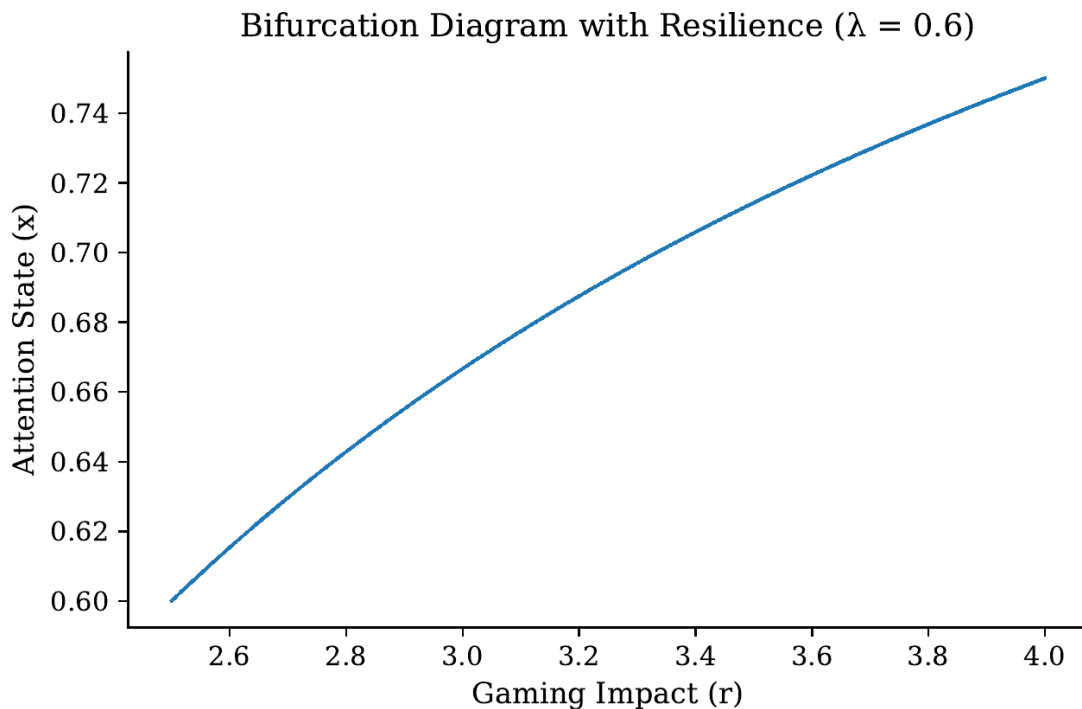


Figure 9: Bifurcation diagram with resilience $\lambda = 0.6$. Period-doubling and chaos are suppressed across the full r range.

4.6 Combined Effects of Intensity and Resilience

Finally, Figure 10 maps the combined influence of gaming intensity and resilience on attention variability. It shows a heatmap of the attention variance as a function of r (horizontal axis) and λ (vertical axis). Dark regions denote low variance (stable attention over time), while bright regions indicate high variance (widely fluctuating, chaotic attention). A clear boundary is visible between stable and chaotic regimes. At high resilience ($\lambda \gtrsim 0.7$), the variance remains near zero regardless of intensity. At low resilience, attention is stable only when intensity is low; beyond an intensity threshold near $r \approx 3.5$, the variance sharply increases. The figure concisely summarises the model's central finding: high gaming intensities tend to induce chaos in attention, but increasing resilience can postpone or even prevent that chaos.

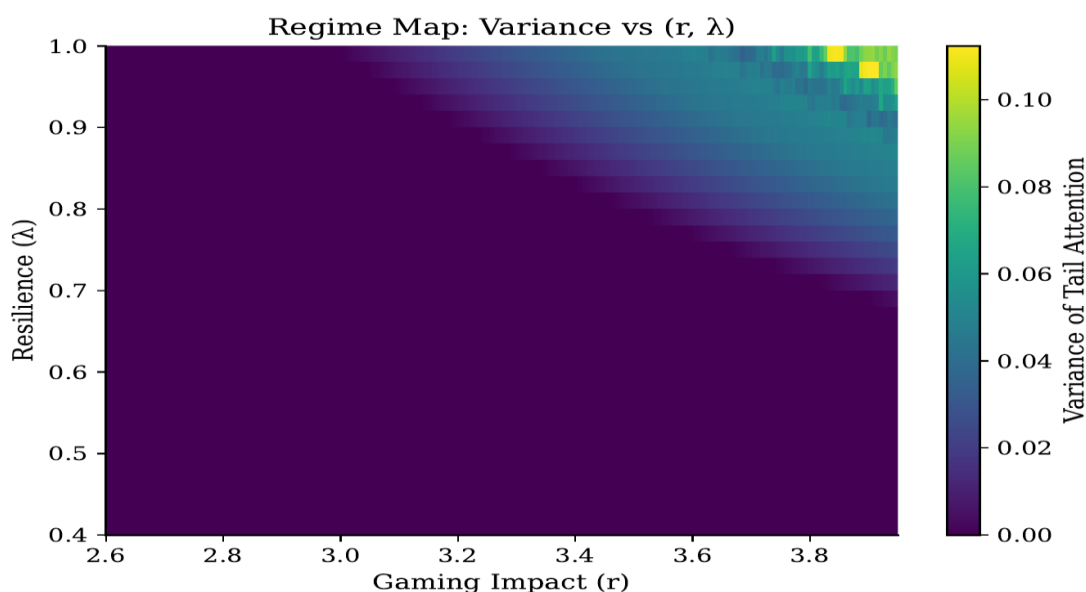


Figure 10: Regime map: variance of tail x_n across (r, λ). Boundary between stable and chaotic regions visible near the upper-right corner.

4.7 Interpretation

The model findings align with patterns reported in cognitive research. Many studies find that video game players outperform non-gamers on basic attention tasks [1, 2], but excessive screen time has been correlated with poorer attention and lower academic performance [3]. The model's chaotic regime at high r mirrors the observation that beyond a certain point, prolonged gaming yields diminishing cognitive benefits. The beneficial effect of a structured schedule in the simulations resonates with the idea that moderation and regular breaks mitigate negative effects. The resilience parameter is analogous to individual differences in psychology: some individuals with strong cognitive skills or support may not suffer attention impairment despite heavy gaming, whereas others are more vulnerable. The model thus provides a theoretical framework congruent with, and helping to explain, the mixed findings in the gaming literature.

The work also underscores the value of applying chaotic dynamics to cognitive questions. Traditional studies of gaming and attention are empirical and often assume linear effects. Here, a simple nonlinear map shows how complex cognitive phenomena could exhibit sudden transitions (from stable to chaotic) as conditions change. This suggests that cognitive effects may not always be gradual: tipping points may exist where a small increase in gaming intensity leads to a qualitative change in attention stability.

V. CONCLUSION

This study used a chaotic dynamical systems model to explore how different video gaming regimes might affect attention over time. The logistic map simulations produced behaviour ranging from stable to chaotic, offering a fresh qualitative explanation for the mixed effects of gaming observed in empirical studies. Moderate and well-structured gaming led to stable or periodic attention patterns, whereas excessive or irregular gaming induced erratic, chaotic attention instability — supporting the idea that the impact of gaming on cognition is highly nonlinear. The inclusion of a resilience factor further showed how personal or contextual factors can modulate these outcomes, damping fluctuations and preventing chaos even at high intensities. From a practical standpoint, the dynamical perspective indicates that maintaining a moderate, regular gaming schedule may keep attention in a beneficial or at least predictable state, whereas all-out intense gaming without breaks could push attentional capacity into an erratic regime.

VI. LIMITATIONS AND FUTURE WORK

Several limitations bound the interpretation of these results. The logistic map is an abstract representation — real-world attention is influenced by many variables, not a single r factor, and may not follow logistic dynamics precisely. The model does not incorporate neural mechanisms or fatigue in a biologically realistic way; it offers a phenomenological simulation rather than a mechanistic account. The chaos-onset thresholds identified are specific to the mathematical setup and would require empirical calibration before they could support quantitative prediction. The parameter values used for the weekend increment Δ , the noise variance, and the resilience level λ are illustrative choices rather than estimates from data, and no empirical dataset was used to validate the model's outputs. Accordingly, the results should be read as a proof of concept for a modelling approach, not as evidence about the magnitude of gaming's effect on attention.

Future work could (i) replace the discrete map with a system of differential equations or a stochastic process more faithful to attentional neuroscience; (ii) extend the model to coupled maps capturing peer influence and multitasking, where multiple individuals' attention states interact; (iii) calibrate model parameters against passively collected screen-time and attention data (e.g. continuous performance task scores) to test whether observed variability indeed increases beyond a threshold of gaming time; and (iv) explore richer resilience structures, including state-dependent or time-varying λ , to model fatigue, recovery, and the formation of healthy habits.

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