Putting the Brakes on Slot Machine Gambling:

Reducing Problematic Gambling Engagement Through Strategic Applications of Friction

by

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A thesis

presented to the University of Waterloo

in fulfilment of the

thesis requirement for the degree of

Master of Arts

in

Psychology

Waterloo, Ontario, Canada, 2026

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Slot machines are designed to promote continuous, automatic engagement, often producing a state of deep absorption known as dark flow. The present research examined whether introducing brief in-game friction, implemented as short mandatory pre-spin delays, would be associated with reductions in gambling perseverance and the experience of dark flow. Across two experiments using a simulated slot machine, participants were assigned to either a Friction condition, in which brief lockout delays preceded spins, or a Non-Friction condition with uninterrupted play. Experiment 1 assessed behavioral perseverance as time spent gambling during a voluntary free-play period following mandatory play, along with post-play measures of flow, positive affect, and negative affect. Experiment 2 examined subjective experience during play using real-time in-task thought probes, in addition to retrospective measures. Results indicated that friction was associated with reduced time spent gambling and greater awareness of time passing, while no reliable differences emerged in self-reported flow, enjoyment, or affect across either experiment. These findings suggest that brief, design-level interruptions may reduce gambling persistence while largely preserving subjective engagement, highlighting friction as a potentially scalable harm-reduction strategy.

Acknowledgements

First and foremost, I dedicate this work to God the Father, Jesus Christ, and the Holy Spirit. Truly, all of this work belongs first to the Lord, who gives strength, wisdom, endurance, and purpose to all of my endeavors. Throughout this degree, there were many moments when I felt uncertain, overwhelmed, or stretched beyond what I thought I could carry. In those moments, my faith gave me grounding and direction. Any perseverance reflected in this thesis is ultimately not my own, but a gift from God, who sustained me through the challenges of this process and reminded me that this work is part of something larger than myself.

I would also like to thank my wife, Juliana, for helping me weather the storm of the Master's. You have been beside me through the long days, late nights, difficult deadlines, moments of doubt, and everything in between. This accomplishment is not mine alone; it is also a reflection of your love and support.

I am also deeply thankful for my family: Delio, Maria, Bethany, Zachry, Greg, Joey, Tina, and Zig. Each of you has supported me in your own way, whether through encouragement, understanding, prayer, humour, or simply being there when I needed you. Graduate school can be isolating at times, but I never felt that I was carrying it entirely alone.

Finally, I would like to thank my supervisor, Dr. Daniel Smilek, for his guidance, patience, and mentorship throughout this project. I am grateful for the freedom you gave me to develop my ideas, as well as the thoughtful feedback that helped shape this thesis into something stronger. I would also like to thank Dr. Michael Dixon and Dr. Jeremy Marty-Dugas for their insight, expertise, and contributions to this work. Your feedback helped sharpen the theoretical framing, improve the clarity of the project, and strengthen the final manuscript. I am grateful to have learned from each of you and to have had your support throughout this process.

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Chapter One: General Introduction

Beginning with the individual and radiating outward, problem gambling produces cascading harms that undermine financial stability, relationships, and community well-being (Hilbrecht et al., 2020; Kourgiantakis et al., 2013; Langham et al., 2015). The rapid spread of highly accessible, technologically sophisticated gambling platforms has transformed what was once a social pastime into a persistent public-health concern (Russell et al., 2023). Within this landscape, electronic gambling machines (i.e., slot machines) have emerged as the economic core of the gambling industry. Across major casino operations, they generate roughly 70 to 95 percent of all gaming revenue (Lucas et al., 2004), a pattern mirrored internationally where electronic gambling machines account for about 70 percent of total gambling income (Kristiansen & Lund, 2022). This concentration of profit makes slot-machine play central not only to industry sustainability but also to the social and psychological burdens of gambling harm.

Modern slot machines generate profit through a finely tuned mathematical system that balances player reward with casino advantage (Balabanov et al., 2015; Farrow & Costa, 2014). Although modern machines may return over ninety percent of the wagers they receive (Farrow & Costa, 2014; Weiss-Cohen et al., 2025), the small statistical edge they retain compounds across hundreds of rapid spins, making even modest house advantages highly lucrative when paired with continuous play (Adams & Wiles, 2017; James et al., 2016). In practice, each wager follows a rapid and repeating temporal sequence: players initiate a spin, animated reels cycle briefly before stopping to reveal an outcome, and winning outcomes are accompanied by celebratory audiovisual feedback, after which the machine immediately permits initiation of the next spin. Contemporary design excels at sustaining this momentum, and the resulting continuous engagement reflects perseverance (Harrigan & Dixon, 2009).

Perseverance in slot-machine play can be sustained in part through a set of design characteristics that promote continued engagement even in the absence of wins. Among these are outcome-based features, which manipulate how results are perceived by players. For example, losses disguised as wins (LDWs) pair net-loss outcomes with the sights and sounds of genuine wins, creating an illusion of success (Dixon et al., 2010), while near-misses heighten arousal through frustration, motivating renewed play despite no monetary gain (Dixon et al., 2013). Slot machines also provide wins along a variable-ratio reinforcement schedule (rewards delivered unpredictably), which is known to sustain responding in a way that is resistant to extinction (Murch et al., 2024; Skinner, 1965). These games allow hundreds of wagers per hour, providing continuous feedback and little opportunity for reflection or consideration of cumulative loss (Harris & Griffiths, 2018; Linnet et al., 2010). Combined with flashing lights, rhythmic animations, and synchronized musical cues that generate a hypnotic sensory rhythm, these mechanisms narrow attention, elevate arousal, and increase the persistence of play (Dixon et al., 2014).

For many players, the convergence of reinforcement, outcome-based features, and sensory immersion culminates in a psychological state closely resembling ‘flow’, a term introduced by Mihaly Csikszentmihalyi (1991) to describe deep absorption in an activity where attention is fully focused and self-awareness recedes. In most contexts, flow is a positive and rewarding experience marked by effortless concentration, enjoyment, and a skill-challenge balance (Marty-Dugas et al., 2021; Peifer et al., 2022; Ullén et al., 2012). Slot-machine players often describe entering a similar state, colloquially known as “the slot-machine zone” (Murch et al., 2017; Schüll, 2012), in which attention narrows and awareness of time fades. Yet when this absorption occurs in a gambling context, where structural features are intentionally designed to

extend time on the device, researchers identify it as *dark* flow, a state subjectively identical to flow but yielding harmful consequences (Dixon et al., 2019). Dark flow is equally pleasurable and immersive, but in gambling contexts it can bind players to prolonged engagement and financial loss. Prior work suggests that, for individuals experiencing depression, the absorption and positive affect characteristic of dark flow can function as a temporary escape from negative mood states and self-focused rumination (Dixon et al., 2019). Slot-machine play provides a highly absorbing environment in which attention is narrowly focused on the task, reducing awareness of external concerns. In this way, dark flow may function as an experiential refuge rather than a source of enjoyment tied to outcomes. However, because this relief is achieved through continued play, it may contribute to longer gambling sessions and greater losses, potentially reinforcing the very difficulties players seek to escape (Dixon et al., 2019).

The persistence created by these reinforcement mechanisms reflects a deeper psychological process: over time, slot-machine play shifts from deliberate action to automatic engagement (Schüll, 2012). In this context, automatic engagement refers to behaviour that becomes fast, effortless, and cue-driven because repeated interactions bind specific environmental cues to well-practiced responses, reducing the need for conscious monitoring (Wood & Neal, 2007). Although especially visible in gambling, this shift is not unique to it; similar patterns emerge across habitual behaviours in which environmental cues begin to guide responding more strongly than reflective intention. Dual-process models describe this transition as a shift in balance toward the rapid, associative, and automatic operations of System 1 over the slower, deliberative operations of System 2 (Barrett et al., 2004; De Neys & Glumicic, 2008; Evans, 2008; Evans & Stanovich, 2013). In many everyday contexts, such automaticity is adaptive because it enables efficient execution of familiar actions while conserving cognitive

resources. However, in reward-dense environments like slot-machine gambling, these same automatic processes can overshadow reflective oversight, allowing behaviour to persist beyond intention (Baumeister, 2002; Wood & Neal, 2007). Through repetition and immediate reinforcement, associations between cues and responses strengthen until monitoring becomes minimal, and eventually cues alone can elicit behaviour even when motivation has faded or outcomes are harmful (Wood & Neal, 2007). Once responding becomes predominantly cue-driven, reflective control must be deliberately reintroduced to interrupt the cycle (Hofmann et al., 2009).

This dynamic is not unique to gambling. Across a range of behaviors, automatic engagement emerges when immediate reinforcement and environmental cueing override reflective control. In overeating, individuals often consume far beyond satiety simply because eating contexts, portion sizes, and sensory cues unconsciously guide consumption rather than hunger (Wansink & Sobal, 2007; Robinson et al., 2013). Smoking shows a similar pattern: habitual motor sequences such as reaching for a cigarette or lighting it can occur automatically in response to cues like stress or social context, even when conscious craving is absent (Payne et al., 2007; Tiffany, 1990). In the digital domain, smartphone and social media use now display comparable mechanisms, where variable reinforcement schedules (likes, notifications, and scrolling novelty) generate compulsive checking and attentional capture (Panek et al., 2015).

Viewed together, these examples reveal a common architecture of maladaptive persistence: environmental cues trigger responses, intermittent rewards, outcome-based features, and hypnotic sensory stimulations maintain them, and opportunities for reflection erode. As fast, habitual processes dominate over deliberative control, disengagement becomes less a matter of willpower than of disrupting the sequence itself. If the absorption and perseverance found in slot-

machine gambling represent one extreme expression of this automaticity, then understanding how to *interrupt* that process becomes essential.

The present research focuses on a mechanism the behavioral literature identifies as an effective disruptor of automatic behavior: *friction*. Friction refers to small obstacles within a behavioral process that momentarily slow action and restore conscious reflection (Cox et al., 2016; Distler et al., 2020; Wood & Neal, 2007). Psychologically, it functions as an interruption of automaticity: friction adds effort, delay, or attention precisely where behavior would otherwise proceed without awareness. The concept was developed in behavioral economics and habit research, where it is treated as a design feature that modifies the process of decision-making (Thaler & Sunstein, 2009; Sunstein, 2018). By increasing the cognitive or physical effort required to act, friction disrupts the rapid cue-response loops that sustain automatic behaviors, creating moments in which reflective control can re-emerge (Cox et al., 2016; Distler et al., 2020; Gould et al., 2021). Frictionless environments encourage automatic engagement by optimizing speed, convenience, and continuity. By contrast, environments that include elements of friction intentionally reintroduce pause and deliberation. Thus, friction is not a barrier to behavior but a tool for recalibrating attention within the flow of action (Cox et al., 2016).

Evidence from other domains demonstrates that friction effectively disrupts automatic behaviors by reintroducing effort and attention into habitual sequences. In smoking contexts, structural changes such as less-accessible packaging and reduced branding have been shown to alter consumption patterns and increase conscious awareness of smoking cues (Martin et al., 2014). A similar principle operates in overeating, where subtle changes in packaging or portion size create small but meaningful interruptions in eating behavior, leading individuals to eat less and monitor consumption more carefully (Wansink, 2010). In digital environments, friction-

based interventions such as countdown timers, confirmation dialogs, and click-through warnings disrupt the immediacy of interaction, introducing short pauses that slow habitual engagement and encourage reflection (Gould et al., 2021). Across these contexts, friction works by restructuring the behavioral sequence itself, transforming what would be an automatic cue-response cycle into a moment of deliberation and choice.

Traditional responsible-gambling interventions have generally targeted players' conscious regulation and decision-making rather than the automatic processes that sustain continuous play. Self-exclusion programs, which allow individuals to voluntarily ban themselves from gambling venues or platforms, can be effective for those who remain committed to abstinence. However, their success depends on the maintenance of long-term self-control within environments explicitly designed to erode it (Kraus et al., 2022). Similarly, pop-up warning messages seem, in theory, as though they should work in the same way as an in-game friction, yet players quickly habituate to them and often react with frustration rather than reflection (Auer & Griffiths, 2015). This is likely because these prompts are clearly identifiable as external to the gambling experience and they stand out as interruptions rather than natural components of play (Auer & Griffiths, 2015). These strategies reveal a fundamental limitation: interventions that depend on conscious self-regulation are poorly suited to behaviors governed by automaticity. When gambling unfolds as a rapid, repetitive sequence where gambling cues come to elicit conditioned responses, intervention strategies that rely on ongoing attention or willpower can be easily bypassed. A more promising approach might involve intervening within the behavior itself by altering the rhythm of play in ways that encourage reflection *within* the gambling experience.

Friction aligns conceptually with the mechanisms that make slot-machine gambling so absorbing. Slot-machine play contains elements of speed, continuity, and immediate

reinforcement, precisely the conditions that transform deliberate play into automatic engagement (Harris & Griffiths, 2018). Each spin occurs within seconds, accompanied by audiovisual feedback that delivers near-instant results and rewards, creating an unbroken behavioral rhythm that minimizes reflection and sustains immersion (Dixon et al., 2014; Murch et al., 2024). Introducing even brief interruptions into the playing sequence may undermine this behavioural rhythm. Such interruptions may serve to delay the initiation of the next spin long enough to interrupt automatic responding and give players a brief moment to reorient before continuing (Cox et al., 2016). If these pauses were to be built directly into the flow of play, they would interrupt the continuity of spinning without adding separate content unrelated to game play, or disrupting the overall gaming experience. In this sense, friction provides a subtle counterbalance to the typically fast and uninterrupted design of modern slot machines by introducing brief, structured pauses that slow automatic responding.

The present research examines whether brief in-game friction, implemented as short mandatory delays following outcome feedback and preceding initiation of the next spin, reduces persistence of gambling behavior and lowers levels of deep concentration with the task (i.e., dark flow). In two studies participants played a simulated slot machine game. During game play, one group (the Friction group) of participants experienced friction introduced by short, mandatory lockout delays that momentarily prevented rapid successive spins. These interruptions were designed to slow action at the very moment that automaticity tends to dominate decision-making. Another group (the Non-Friction group) was not presented with this friction and engaged with regular play. We assessed perseverance in game play (Experiment 1) and the subjective experience of (dark) flow (Experiments 1 and 2). By embedding friction directly inside

gameplay, the present work provides a direct examination of how subtle design changes may shape both behavior and the experiential qualities of play.

Chapter Two: Experiment 1

2.1 Introduction

The primary aims of Experiment 1 were to examine whether introducing friction into slot-machine play would (1) reduce continued gambling behavior during periods of free play (e.g., where players had the option to continue playing or end their session), and (2) influence the experience of dark flow and related affective states. Participants first completed a mandatory-play period, during which they were required to continue initiating spin after spin. Following this fixed phase, they entered a voluntary free-play period, where they could choose to continue playing or end their session at any time; time spent in this phase served as the primary behavioral measure of perseverance. To manipulate friction, participants in the Friction condition experienced brief mandatory time delays that temporarily prevented rapid successive spins, whereas those in the Non-Friction condition encountered no such delays. These short interruptions were intended to disrupt automatic engagement and prompt awareness of time passing. To capture whether friction increased this awareness, Experiment 1 also included a time-check feature that participants could use to view elapsed time, with each voluntary check indicating a momentary shift of attention away from the game. Participants also completed post-play assessments of flow and affect, including the Modified Game Experience Questionnaire (M-GEQ) (see Appendix A) and the Deep Effortless Concentration - External (DEC-E), to determine whether the friction manipulation altered the subjective experience of flow.

2.2 Method

2.2.1 Participants

Two-hundred and ten undergraduate students from the University of Waterloo participated in exchange for partial credit towards their psychology course. Fourteen participants

were excluded for predefined protocol violations. Specifically, four failed to understand the slot-machine controls during the mandatory-play period; two informed the researcher that they were not engaging with the task as instructed (e.g., repeatedly pressing the time-check key for reasons unrelated to the task); and eight reported in advance that they needed to leave immediately after the 35-minute mandatory period and therefore were not available to complete the voluntary free-play phase. An additional four participants were removed because they left the session before completing the minimum required 35 minutes of play, leaving a final sample of 192. Exclusions were evenly distributed across conditions (9 Friction, 9 Non-Friction). The Friction condition comprised 95 participants (65 women, 27 men, 1 other, 2 who did not provide gender; 69 aged 10 to 20 and 24 aged 21 to 30, and 2 who did not provide age), and the Non-Friction condition comprised 97 participants (74 women, 21 men, 1 other, 1 who did not provide gender; 71 aged 10 to 20, 23 aged 21 to 30, 1 aged 31 to 40, 1 over 40, and 1 who did not provide age). Race and ethnicity were not collected. Participants received one percentage point towards their psychology course through the departmental research pool (i.e., SONA) and a $10 CAD honorarium. Written informed consent was obtained prior to participation, and all procedures were approved by the University of Waterloo Research Ethics Board (REB #46922).

2.2.2 Materials and Measures

Slot-Machine Task. The gambling task was a computerized slot-machine simulation developed in Python (Pygame) and run locally in Visual Studio Code. Snapshots of the display without (Panel A) and with (Panel B) the lockout timer is shown in Figure 1. The game displayed five reels and three rows in a multiline format with an ancient-Greek theme. Participants began play with 2000 credits, each valued at $0.005 CAD, and each spin cost 20 credits. The payout system approximated a 94 percent payback percentage, meaning that over the long run, the

machine is programmed to return approximately 94 percent of the money wagered back to players, which is consistent with commercial slot-machine programming. A semi-fixed algorithm produced an average 30 percent rate of celebratory outcomes, including both true wins and losses disguised as wins (LDWs), while preventing participants' credits from exceeding 2000 or falling below 200; LDWs accounted for approximately 10 percent of these celebratory outcomes. The simulation reproduced typical audiovisual features, such as reel animations, symbol-specific sound effects, jackpot fanfares, and continuous background music, to ensure ecological validity. Gameplay outcomes and timing data were automatically logged for analysis.

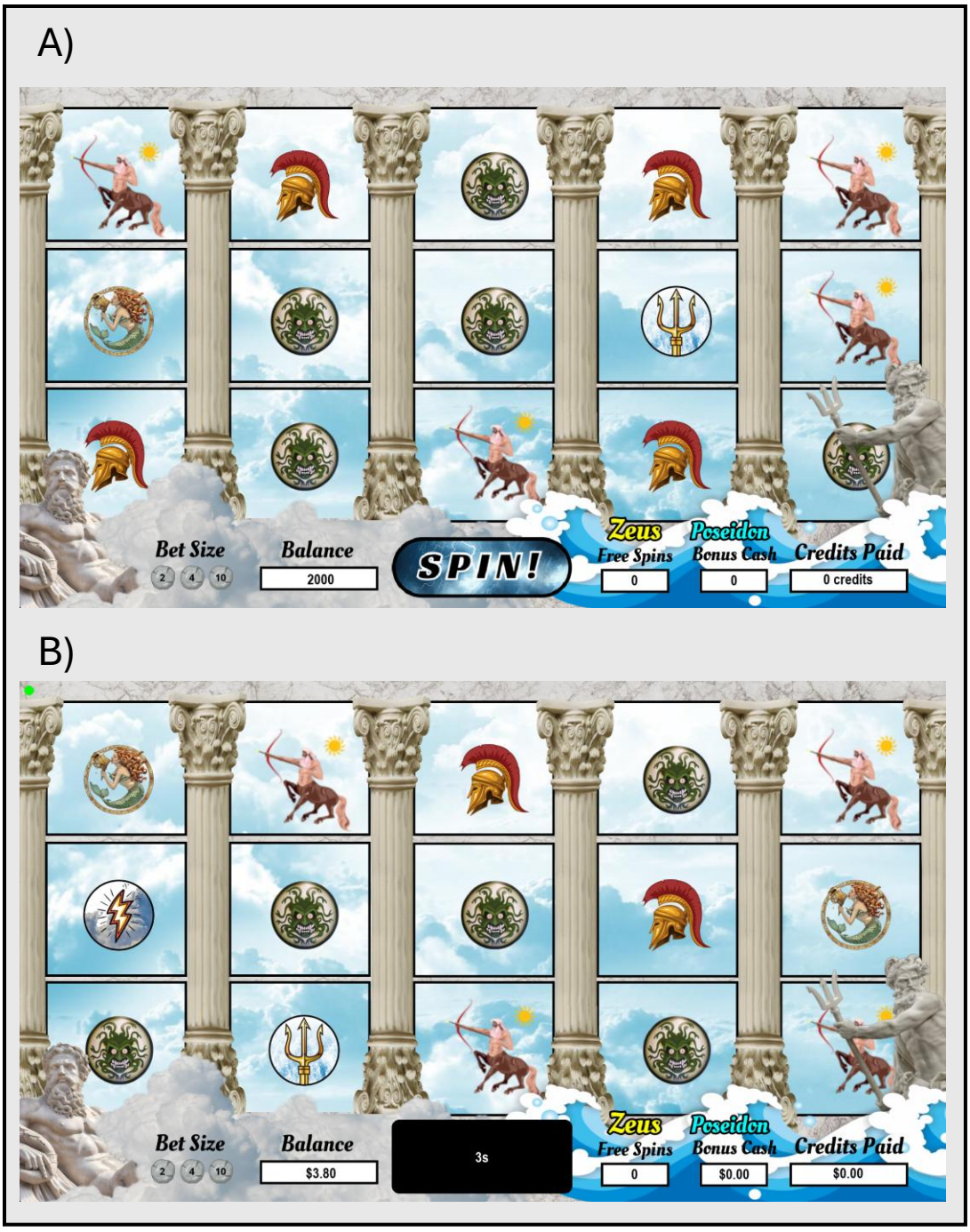


Figure 1 *(A) Screenshot of the slot-machine interface used in the task, showing the five-reel, three-row multiline layout and ancient-Greek theme. (B) Example of a friction lockout screen displaying the 4-second pre-spin countdown imposed during friction blocks.*

Friction Manipulation. In the Friction condition, participants experienced short intervals of delayed play introduced at predetermined points during the session. During each *friction block*, a 4-second pre-spin lockout (see Figure 1B) was enforced before every spin in that window: pressing the spin key triggered a 4-second countdown, after which the spin executed; the lockout reset on each subsequent spin within the lockout window.

Time-Check Function. To measure awareness of elapsed time, a dedicated "time-check" button (space bar) displayed total time elapsed since the start of play as can be seen in Figure 2. The feature had no in-game effect and required a deliberate shift of attention away from the slot-machine interface, providing a behavioral index of attentional disengagement. All button presses were automatically recorded, and external time cues (clocks, phones) were removed from the testing environment.



Figure 2 *Screenshot of the Time Check component of the experiment. A small rectangular black box with time elapsed since the start of the experiment.*

Self-Report Measures. After gameplay, participants completed three questionnaires: the Problem Gambling Severity Index (PGSI; Ferris & Wynne, 2001), assessing gambling risk; a modified version of the Game Experience Questionnaire (M-GEQ; IJsselsteijn et al., 2013), assessing flow, positive affect, and negative affect; and the Deep Effortless Concentration (DEC; Marty-Dugas & Smilek, 2019) indexing the state of flow regarding the task.

PGSI. The PGSI is a nine-item measure assessing gambling-related problems and risk. Items (e.g., "Have you felt guilty about the way you gamble or what happens when you gamble?") are rated on a 0-3 scale (0 = Never, 3 = Almost always). Scores range from 0 to 27, with higher scores indicating greater gambling risk and problem severity.

M-GEQ. The M-GEQ assesses experiential components of gameplay, including flow (e.g., *"I was fully occupied with the game"*), positive affect (e.g., *"I felt good while playing"*), and negative affect (e.g., *"I felt irritated while playing"*). Items are rated from 0 (*Not at all*) to 4 (*Extremely*). Higher scores indicate stronger experiences of the corresponding state (e.g., greater flow, greater positive affect, or greater negative affect).

DEC-E. The DEC-E is a five-item slider measure assessing levels of deep and effortless concentration (i.e., flow) during an activity. Items (e.g., *"I was fully absorbed in what I was doing"*) are rated on a continuous 0-100 slider. Higher scores indicate deeper effortless concentration and greater immersion in the task.

2.2.3 Procedure

All sessions took place in a controlled laboratory equipped with desktop computers and external monitors. Participants were randomly assigned to either the Friction condition (friction blocks present) or the Non-Friction condition (no friction blocks). Upon arrival, participants provided informed consent, completed a brief demographic questionnaire (reporting their age,

sex, and gender), and received standardized task instructions delivered both verbally and on-screen. They then completed several practice spins to familiarize themselves with the controls. A printed instruction sheet summarizing the key mappings remained visible for reference throughout the session. Participants interacted exclusively through the keyboard: the Enter key spun the reels, the space bar activated the time-check display, the Return key submitted questionnaire responses, and the arrow keys adjusted slider ratings. Audio was presented through over-ear headphones to ensure consistent sound quality. Each participant completed the experiment alone to minimize distraction and social influence.

Mandatory Play. Participants were told they were required to play the slot machine for a minimum of 35 minutes but were welcome to continue playing for up to 20 additional minutes if they chose. They were not informed when the mandatory period had ended, nor were there any on-screen signals marking the transition from the mandatory play period to the free play period. Gameplay began when participants were instructed to start. During the mandatory period, those in the Friction condition encountered three friction blocks, while Non-Friction participants played without encountering any friction blocks. In the Friction condition, three friction blocks occurred during the mandatory-play period (345-585s, 930-1170s, and 1515-1755s). Each block enforced the 4-second pre-spin lockout on every attempted spin during that window.

Free Play. After the mandatory 35 minutes elapsed, the program transitioned seamlessly into free play without alerting participants. Gameplay continued in the same format, with no visible indication that the mandatory period had ended. The elapsed time display, when checked, simply showed the total duration of play (e.g., “37 minutes, 28 seconds”). Participants could stop at any point during free play, and sessions were capped at a maximum of one hour. For those in the Friction condition, two additional friction blocks occurred during the voluntary free-play

period (2340-2580 s and 2820-3060 s), applying the same 4-second lockout before each spin. The friction blocks began automatically during gameplay at the beginning of the window, and ended automatically at the end of the window. Participants were not informed about the beginning, end, or duration of the friction window.

Post-task. After completing the slot machine portion of the experiment, participants filled out the self-report measures. The order was consistent across participants and followed this series: PGSI, M-GEQ, and DEC-E. All questionnaires were delivered on-screen within the Python program. At the conclusion of the session, participants received both an on-screen debriefing and a verbal debriefing from the experimenter.

2.3 Results

2.3.1 Gambling-Related Problems

We first sought to characterize our sample with regard to participants' gambling-related problems and risk as indexed by the PGSI. Classification according to established scoring categories indicated that the majority of the sample fell within the non-clinical range. Specifically, 108 participants (56.2%) were classified as non-problem gamblers (score of 0), 71 participants (37.0%) were classified as low-risk gamblers (scores of 1-4), 10 participants (5.2%) were classified as moderate-risk gamblers (scores of 5-7), and 3 participants (1.6%) met the PGSI criteria for problem gambling (scores of 8 or higher). This distribution was comparable across conditions. In the Friction condition, 54 participants (56.8%) were classified as non-problem gamblers, 36 (37.9%) as low-risk, 4 (4.2%) as moderate-risk, and 1 (1.1%) met criteria for problem gambling (M = 1.02, SD = 1.65). In the Non-Friction condition, 54 participants (55.7%) were classified as non-problem gamblers, 35 (36.1%) as low-risk, 6 (6.2%) as moderate-

risk, and 2 (2.1%) met criteria for problem gambling (M = 1.37, SD = 2.23). This distribution confirms that the sample primarily consisted of individuals with minimal gambling-related harm.

2.3.2 Correlations

We next examined the correlations among the experiential measures to ensure that the instruments were functioning as expected. A combined correlation matrix showing the associations across measures for the Non-Friction condition (below the diagonal) and for the Friction condition (above the diagonal) is presented in Table 1. Because the flow and affect scales are designed to assess related but distinct aspects of the gameplay experience, flow measures should show moderate positive correlations with one another and with positive affect, and negatively with negative affect. As expected, the two flow measures (DEC-E Flow and M-GEQ Flow) were strongly and positively associated in both conditions, supporting convergent validity. In both conditions M-GEQ Flow showed positive associations with M-GEQ Positive Affect, and a similar association was found between DEC Flow and positive affect as measured by the M-GEQ. As anticipated, M-GEQ Negative Affect showed significant inverse associations with both flow measures across conditions. Negative affect was also inversely correlated with positive affect in both Friction and Non-Friction conditions. Together, these consistent correlation patterns across experimental conditions confirm that measures of flow and affect behaved as theoretically expected, indicating strong construct validity.

Table 1

Intercorrelations by Condition: Non-Friction (Below Diagonal) and Friction (Above Diagonal)

Variable	PGSI	DEC Flow	M-GEQ Flow	M-GEQ Positive Affect	M-GEQ Negative Affect	Time Checks	Time in Free Play
PGSI		0.13	0.13	0.19	-0.04	0.10	-0.01

DEC Flow	-0.01		0.79**	0.63**	-0.65**	-0.20	0.27**
M-GEQ Flow	0.13	0.76**		0.67**	-0.47**	-0.20	0.32**
M-GEQ Positive Affect	-0.08	0.66**	0.75**		-0.55**	-0.07	0.25*
M-GEQ Negative Affect	0.08	-0.68**	-0.47**	-0.49**		0.09	-0.20*
Time Checks	-0.10	-0.23*	-0.20	-0.18	0.18		-0.43**
Time in Free Play	0.15	0.02	0.16	0.16	-0.04	-0.22*	

Note. Values below the diagonal represent correlations for the Non-Friction condition; values above the diagonal represent correlations for the Friction condition. * $p < .05$, ** $p < .01$.

2.3.3 Group Comparisons

Group differences for all behavioral and experiential outcomes were assessed using independent-samples t-tests. Because several dependent variables exhibited non-normal distributions and unequal variances between conditions, we used bootstrapped t-tests with 1,000 resamples to obtain robust estimates of p-values and confidence intervals. Bootstrapping minimizes bias when parametric assumptions are violated and provides more stable inference for skewed or heteroscedastic data. All reported confidence intervals reflect the percentile bootstrap method. All analyses were conducted in R using the packages dplyr, kableExtra, knitr, psych, purrr, readxl, stringr, tidyr, ggplot2, broom, rstatix, effectsize, and scales.

Group means, standard deviations, and statistical comparisons are reported in Table 2. Participants in the Friction condition played significantly fewer minutes during the voluntary free-play period than participants in the Non-Friction condition, reflecting a reduction in perseverance. Participants in the Friction group also checked the elapsed-time display

significantly more often than those in the Non-Friction group. In contrast to the measures of perseverance, no significant differences emerged between groups on any measures of flow and immersion. Scores on M-GEQ Flow, DEC-E Flow, M-GEQ Positive Affect, and M-GEQ Negative Affect did not differ significantly between Friction and Non-Friction groups. Reported immersion, pleasant engagement, and negative affect did not significantly differ across condition. Taken together, the pattern of results indicates that friction meaningfully reduced behavioral perseverance and increased attentional disengagement (as indexed by time checks), while leaving flow-related and affective experiences unchanged.

Table 2

Group Means, Standard Deviations, and Bootstrap-Based Mean Differences for Behavioral and Experiential Measures in Experiment 1

Variable	Friction M(SD)	Non-Friction M(SD)	Mean Difference (NF - F)	p-value	CI Low	CI High
Time in Free Play	4.02 (4.51)	10.72 (5.96)	6.70	<.001	5.23	8.08
Number of Time Checks	17.37 (9.86)	11.28 (6.74)	-6.09	<.001	-8.50	-3.70
M-GEQ Flow	1.64 (0.88)	1.70 (0.87)	0.06	0.62	-0.19	0.32
M-GEQ Positive Affect	1.87 (0.86)	1.87 (0.93)	-0.01	0.98	-0.25	0.24
M-GEQ Negative Affect	1.61 (0.74)	1.62 (0.87)	0.01	0.96	-0.21	0.24
DEC Flow	51.48 (26.39)	53.10 (23.56)	1.63	0.64	-5.75	8.62

Note. Means and standard deviations are reported separately for the Friction and Non-Friction conditions. Mean differences reflect Non-Friction minus Friction values. *p*-values and 95%

confidence intervals are derived from 1,000-sample bootstrapped t-tests. Time in Free Play values are presented in minutes. PGSI = Problem Gambling Severity Index; M-GEQ = Modified Game Experience Questionnaire; DEC = Deep Effortless Concentration Scale.

2.4 Discussion

Introducing brief friction intervals reduced overall play duration and increased time-checking behavior, indicating that short pauses in the rhythm of play heightened participants' awareness of time passing and curtailed perseverance. However, surprisingly, friction did not significantly influence self-reported flow, positive affect, negative affect, or dark-flow experiences. We expected friction to reduce negative affect by interrupting the intensity of the experience, and to slightly lower positive affect, and we anticipated corresponding decreases in dark flow and flow scores. However, none of these measures showed meaningful change.

Chapter Three: Experiment 2

3.1 Introduction

In the first experiment, friction reduced perseverance but left unchanged experiential measures of flow, dark flow, and affect, revealing a dissociation between behaviour and experience. Because flow measures in Experiment 1 were collected retrospectively, they may have missed transient fluctuations during play. Therefore, to determine whether moment-to-moment experience is similarly resistant to these brief interruptions, in Experiment 2 we introduced in-task thought probes to capture real-time flow experiences immediately following friction events. The experiment again included a Friction group and a Non-Friction group, but there was no free-play period. Thus, participants in both conditions completed a period of continuous play that was equal in length (i.e., 20 minutes), ensuring equivalent exposure to the manipulation. In addition to the probes, we measured flow, dark flow, and affect at the end of the play period using the same measures described in Experiment 1.

3.2 Method

3.2.1 Participants

One-hundred and seventy-five undergraduate students from the University of Waterloo participated in exchange for course credit. No participant data were excluded. The Friction condition comprised 90 participants (68 women, 20 men, 2 other; 50 aged 10 to 20 and 40 aged 21 to 30), and the Non-Friction condition comprised 85 participants (67 women, 17 men, 1 other; 50 aged 10 to 20 and 35 aged 21 to 30). Race and ethnicity were not collected. Participants received .5 percent credit towards their psychology course through the departmental research pool and a $5 CAD honorarium. Written informed consent was obtained prior to participation,

and all procedures were approved by the University of Waterloo Research Ethics Board (REB #47471).

3.2.2 Materials and Measures

Slot-Machine Task. The slot-machine simulation was identical to that used in Experiment 1, with one modification. To make wagering outcomes more salient, the credit display was replaced by a cash format: each participant began with $4.00 CAD, and each spin cost $0.04. All other design parameters remained constant, including the five-reel, three-row multiline layout, the ancient-Greek theme, and audiovisual environment. The payout algorithm maintained a target payback percentage of 94 percent, generated a roughly 30 percent win rate, and restricted cumulative balances between $0.40 and $4.00. Gameplay events and timing data were logged automatically for analysis.

Friction Manipulation. We used the same friction manipulation from Experiment 1 but scaled to match the shorter, fixed-duration gambling task so that there was approximately the same amount of friction-laden gameplay to uninterrupted gameplay. In Experiment 2, the friction windows were two minutes in length (rather than four minutes as in Exp 1), which presented a similar percentage of time spent in friction, given the shorter gambling task. Participants in the Friction condition experienced 4-second pre-spin lockouts displayed as countdowns above the spin button.

Thought Probes. Flow experiences were assessed throughout play using three thought probes administered immediately after each friction block in the Friction condition or at corresponding time points in the Non-Friction condition. Each probe contained five items from the M-GEQ measuring immersion and time distortion: “I was fully occupied by the game,” “I lost track of time,” “I was deeply concentrated in the game,” “I lost connection with the outside

world," and "I forgot everything around me." Participants rated each statement on a 0-4 scale ranging from *Not at all* (0) to *Extremely* (4), reflecting their experience over the previous two minutes of play. Flow ratings collected at three probe points were averaged to form a single composite Probe Flow Score, with higher scores reflecting greater absorption during play.

Self-Report Measures. The same pre- and post-task self-report measures described in Experiment 1 were administered, with participants answering a demographics questionnaire before the gambling task and then completing the PGSI, M-GEQ, and DEC after the gambling task.

3.2.3 Procedure

The experiment used a between-subjects design in which participants were randomly assigned to either the Friction condition (friction blocks present) or the Non-Friction condition (no friction blocks). All testing took place in the same controlled laboratory described in Experiment 1, equipped with desktop computers, external monitors, standard keyboards, and over-ear headphones. Unlike Experiment 1, sessions were run in small groups seated at workstations separated by opaque dividers to prevent visual or social interaction while allowing simultaneous participation. All materials were presented within the Python program. Participants interacted exclusively through the keyboard: the Enter key spun the reels, the arrow keys adjusted slider ratings, and the Return key submitted responses.

Pre-task. Procedures mirrored those of Experiment 1. After providing informed consent and completing the demographic form, participants received standardized verbal and on-screen instructions, completed several practice spins, and were reminded of the key mappings shown on a reference sheet kept visible throughout.

Gameplay. The gambling task lasted 20 minutes. All participants played continuously for the full duration. Those in the Friction condition experienced three friction blocks, each introducing the 4-second pre-spin delay. Friction blocks lasted for two minutes. Non-friction participants played without encountering friction blocks. These lockouts were active only during specific 120-second windows (210-330 s, 540-660 s, and 870-990 s) such that each spin attempted during those periods triggered the 4-second delay before executing the spin. Outside these windows, gameplay proceeded normally without interruption. Non-Friction participants encountered no friction blocks. The purpose and timing of these blocks were not disclosed in advance. Immediately following each friction block (or at matched time points in the Non-Friction condition), a thought probe appeared on screen, requiring the participant to respond to each question within the probe before resuming play.

Post-task. Upon completion of the 20-minute session, participants completed the PGSI, M-GEQ, and DEC questionnaires in the same fixed order as Experiment 1. A written on-screen debrief was followed by a verbal debrief from the experimenter.

3.3 Results

3.3.1 Gambling-Related Problems

We again began by analyzing scores on the PGSI. As in Experiment 1, the majority of the sample fell within the non-clinical range. Specifically, 103 participants (58.9%) were classified as non-problem gamblers (score of 0), 63 participants (36.0%) were classified as low-risk gamblers (scores of 1-4), 7 participants (4.0%) were classified as moderate-risk gamblers (scores of 5-7), and 2 participants (1.1%) met the PGSI criteria for problem gambling (scores of 8 or higher). This distribution was again comparable across conditions. In the Friction condition, 53 participants (58.9%) were classified as non-problem gamblers, 32 (35.6%) as low-risk, 4 (4.4%)

as moderate-risk, and 1 (1.1%) met criteria for problem gambling (M = 1.03, SD = 1.72). In the Non-Friction condition, 50 participants (58.8%) were classified as non-problem gamblers, 31 (36.5%) as low-risk, 3 (3.5%) as moderate-risk, and 1 (1.2%) met criteria for problem gambling (M = 0.97, SD = 1.60). This distribution confirms that the sample primarily consisted of individuals with minimal gambling-related harm.

3.3.2 Correlations

As in Experiment 1, we examined correlations among the experiential measures to confirm that they were operating as expected. Table 3 shows a combined correlation matrix indicating the associations for the Non-Friction group below the diagonal and for the Friction group above the diagonal. Because the DEC, the M-GEQ, and the in-task probe ratings all index the same underlying construct of immersive attention, we expected strong positive associations among them, along with the usual positive relation with positive affect and inverse relation with negative affect. Establishing these patterns provides a brief check of construct validity before turning to group comparisons.

Table 3

Intercorrelations by Condition: Non-Friction (Below Diagonal) and Friction (Above Diagonal)

Variable	PGSI	DEC Flow	M-GEQ Flow	M-GEQ Positive Affect	M-GEQ Negative Affect	Probe Flow Score
PGSI		-0.06	0.05	0.13	0.07	-0.05
DEC Flow	0.20		0.67**	0.57**	-0.63**	0.68**
M-GEQ Flow	0.13	0.82**		0.55**	-0.31**	0.78**
M-GEQ Positive Affect	0.15	0.70**	0.67**		-0.50**	0.42**

M-GEQ Negative Affect	-0.18	-0.66**	-0.49**	-0.70**		-0.36**
Probe Flow Score	0.21	0.78**	0.86**	0.59**	-0.44**	

Note. Values below the diagonal represent correlations for the Non-Friction condition; values above the diagonal represent correlations for the Friction condition. *$p < .05$, ** $p < .01$.

As in Experiment 1, the two flow measures (DEC and M-GEQ Flow) demonstrated strong and positive associations across both conditions, supporting convergent validity. The Probe Flow Score showed the same convergent pattern, correlating positively with both DEC Flow and M-GEQ Flow in both conditions. The M-GEQ Negative Affect demonstrated significant inverse associations with flow in both conditions, including with DEC Flow, M-GEQ Flow, and the Probe Flow Score. Similarly, positive affect again showed significant positive associations with DEC Flow in both the Friction and Non-Friction groups, as well as with M-GEQ Flow. Positive affect was also inversely associated with negative affect in both conditions. These results replicate the convergent and discriminant validity patterns observed in Experiment 1, further confirming that the flow and affect measures functioned as intended in this gambling context.

3.3.3 Group Comparisons

Statistical Approach. To compare experiential outcomes across conditions, we used independent-samples t-tests. As in Experiment 1, all tests were implemented using nonparametric bootstrapping (1,000 resamples) to generate confidence intervals and p-values. Group means, standard deviations, and inferential statistics are presented in Table 4. Analyses revealed no statistically detectable differences between the Friction and Non-Friction conditions on any experiential outcome. Participants in the Friction condition reported similar Flow Probe Scores as those in the Non-Friction condition, and this comparison was not statistically significant.

Table 4

Group Means, Standard Deviations, and Bootstrap-Based Mean Differences for Experiential Measures in Experiment 2

Variable	Friction M(SD)	Non-Friction M(SD)	Mean Difference (NF - F)	p-value	CI Low	CI High
M-GEQ Flow	1.57 (0.81)	1.82 (0.94)	0.25	0.053	-0.00	0.51
M-GEQ Positive Affect	1.54 (0.88)	1.78 (0.94)	0.24	0.075	-0.03	0.51
M-GEQ Negative Affect	1.66 (0.87)	1.65 (0.86)	-0.01	0.948	-0.26	0.25
DEC-E Flow	50.14 (24.19)	55.55 (25.55)	5.40	0.148	-1.90	12.72
Flow Probe Score	1.75 (0.79)	1.97 (0.89)	0.22	0.086	-0.03	0.47

Note. Means and standard deviations are reported separately for the friction and Non-Friction conditions. Mean differences reflect Non-Friction minus Friction values. *p*-values and 95% confidence intervals are derived from 1,000-sample bootstrapped t-tests. M-GEQ = Modified Game Experience Questionnaire; DEC-E = Deep Effortless Concentration Scale - External. Higher scores reflect greater flow or affect in the respective direction.

3.4 Discussion

Experiment 2 focused on the experiential aspects of friction to examine whether subjective flow and affect were altered in real time. Despite indexing flow with repeated thought probes, no significant differences emerged between the Friction and Non-Friction conditions on any measure. Participants reported roughly equivalent levels of immersion, time loss, and enjoyment, both during and after play. These results support the conclusion that friction's influence lies primarily in modulating behavior rather than altering conscious experience. Thus,

friction appears to function as a fine-grained design intervention capable of restoring reflective control without meaningfully reducing the experiential continuity of flow.

Chapter Four: General Discussion

In two experiments, we examined whether inserting brief, externally imposed pauses between spins on a simulated slot machine could reduce perseverance in gambling and disrupt flow-related experiences typically associated with slot-machine play, including the deep absorption and time distortion described in prior work on the "slot-machine zone" and dark flow (Dixon et al., 2019; Murch et al., 2017; Schüll, 2012). In Experiment 1, participants exposed to intermittent 4-second lockouts played significantly less during the voluntary free-play period and checked the elapsed-time display more often than those in the Non-Friction group. These findings suggest that brief friction applications can reduce perseverance and increase temporal awareness even in an otherwise absorbing gambling environment. Yet, contrary to expectation, self-reported flow, positive affect, negative affect, and dark-flow experiences were unaffected by the addition of friction. Similarly, in Experiment 2, there was no evidence that friction altered subjective experience, even when flow was assessed intermittently during gameplay using thought probes. Taken together, the findings show that friction, at least in the present implementation, can modulate overt behavior without substantively diminishing subjective engagement.

These findings help clarify the role of temporal continuity in sustaining slot-machine gambling behavior. Slot-machine play is typically organized around a rapid and repetitive action-feedback sequence in which the outcome of one spin is followed almost immediately by the opportunity to initiate the next. This structure may limit opportunities for reflection and encourage automatic responding, consistent with broader evidence that structural characteristics of electronic gambling machines, including speed of play, can shape gambling behaviour (Harris & Griffiths, 2018; Sharpe et al., 2005). Briefly interrupting this sequence may weaken the

momentum of play by inserting a pause between the intention to continue and the next gambling action. From this perspective, gambling persistence may be influenced not only by how engaging or absorbing play feels, but also by the uninterrupted rhythm with which actions can be repeated. Disruptions to that rhythm may therefore be sufficient to alter behavior, even when players continue to experience the game as immersive.

The dissociation between behavioral and experiential outcomes is especially important. If friction had reduced perseverance simply by making the game less enjoyable, frustrating, or less immersive, its practical value as a responsible-gambling intervention would be limited. Prior work on electronic gambling machines has similarly emphasized the importance of identifying structural modifications that can reduce risky play while minimizing unwanted effects on the broader experience of the game (Loba et al., 2001). Instead, participants in the Friction condition gambled for less time while reporting similar levels of flow, affect, and immersion as those in the Non-Friction condition. This suggests that the behavioral mechanics of gambling persistence and the subjective experience of absorption may be partially separable. Friction may influence the pacing and automaticity of gambling behavior without substantially changing how engaging the game feels.

The increase in time-checking behavior in Experiment 1 provides further insight into how friction may have operated. Participants in the Friction condition checked the elapsed-time display more often than those in the Non-Friction condition. Because checking the time required a deliberate shift of attention away from the slot-machine interface, this behavior may reflect greater awareness of time passing or increased disengagement from the automatic rhythm of play. Prior work has examined whether electronic gambling machine features such as clocks, cash displays, and precommitment tools can help players monitor their gambling activity,

although these tools do not always produce reliable behavioral change on their own (Ladouceur & Sévigny, 2009). Importantly, the increased temporal awareness observed here did not coincide with reduced enjoyment or lower self-reported immersion. Thus, friction may have created brief moments in which attention could move outside the immediate spin-feedback cycle, without causing participants to experience the game as meaningfully less absorbing.

From a responsible-gambling perspective, these findings suggest that friction could represent a subtle alternative to interventions that rely heavily on conscious self-regulation. Many responsible-gambling tools, such as warning messages, pop-up reminders, or self-exclusion programs, depend on players noticing risk, reflecting on their behavior, and choosing to stop. Prior work suggests that pop-up messages can produce short-term changes in gambling behavior and gambling-related cognitions, and experimental work has shown that time-limit pop-ups can reduce time spent on electronic gambling machines (Bjørseth et al., 2021; Kim et al., 2014). However, these tools still require players to notice, interpret, or act on an explicit prompt. These requirements may be poorly matched to gambling environments that encourage automatic, continuous engagement. Friction differs from these approaches because it does not require the player to initiate self-control in the moment. Instead, it changes the temporal structure of the gambling interaction itself. Because the pause is built directly into the sequence of play, it can be applied consistently without requiring players to opt in, monitor themselves, or respond to explicit warnings.

Importantly, friction does not eliminate choice or prevent continued gambling. Participants in the Friction condition could still continue playing, but the pace of play was altered. This makes friction different from more restrictive interventions, such as exclusionary tools or hard spending limits. Rather than functioning as a blunt barrier, friction operates as a

temporal adjustment that changes the conditions under which repeated gambling decisions are made. This distinction is relevant to broader debates about voluntary and mandatory responsible-gambling tools, as voluntary systems often depend on players actively choosing to set limits, whereas mandatory systems may have greater potential because they do not rely as heavily on individual uptake or momentary self-control (Delfabbro & King, 2021). In this sense, friction may be especially useful as a design-level intervention. It is subtle, automatic, and scalable, and it may reduce excessive persistence without making the game feel meaningfully less engaging.

The present research was conducted with non-clinical undergraduate samples reporting low levels of gambling risk, as indicated by PGSI scores. This limits the extent to which the findings can be generalized to individuals with established gambling problems or extensive experience with commercial slot machines. Responses to imposed delays may differ among frequent gamblers, particularly if interruptions conflict with learned expectations about the speed and continuity of real slot-machine play. Prior work suggests that pathological and non-pathological gamblers can respond differently to changes in machine features, and broader models of problem gambling emphasize that gambling problems may arise from multiple psychological pathways rather than a single uniform process (Blaszczynski & Nower, 2002; Loba et al., 2001). Individuals with higher gambling risk may therefore respond differently because motivation, emotional investment, reward sensitivity, and urges to continue may be stronger. Therefore, the current findings should not be taken as evidence that friction would necessarily produce the same effects in clinical or high-risk gambling populations.

At the same time, the use of low-risk undergraduate samples also has some interpretive value. Because most participants reported minimal gambling-related harm, the observed reduction in perseverance is unlikely to be explained by pre-existing gambling severity or

extreme gambling motivation. Instead, the findings suggest that friction can influence persistence even among participants for whom gambling is not a deeply established habit. This may indicate that the temporal structure of gambling behavior matters even before problematic patterns are entrenched. If so, friction may have value not only as an intervention for high-risk gamblers, but also as a preventative design feature that reduces the likelihood of extended, automatic play among casual users.

Future research should extend this work in several directions. First, examining friction-based interventions among individuals with higher levels of gambling risk and greater real-world slot-machine experience would clarify whether the behavioral reductions in perseverance observed here extend to more entrenched patterns of play. Second, future experiments could systematically vary the duration, frequency, and timing of lockout delays to identify the minimum effective pause needed to disrupt automatic play. Recent work on mandatory play breaks in online gambling suggests that the duration of imposed breaks can shape subsequent gambling behavior, making break length an important design parameter for future research (Hopfgartner et al., 2024). The present studies used 4-second delays, but it remains unclear whether shorter pauses would be sufficient or whether longer pauses would produce stronger behavioral effects. Determining the optimal balance between minimal delay and maximal behavioral impact would have direct implications for responsible gambling design.

Future research should also examine whether the placement of friction matters. In the present studies, friction occurred before spins during predetermined windows. Other forms of friction could be introduced after wins, after losses, after near-misses, after a certain number of consecutive spins, or in response to signs of rapid play. These variations would help determine whether friction is most effective when applied continuously, intermittently, or in response to

specific behavioral patterns. It would also be valuable to compare friction with more explicit responsible-gambling tools, such as warning messages or spending reminders, to determine whether structural pauses are more effective than interventions that rely primarily on conscious reflection. Prior work suggests that pop-up messages can influence gambling behavior and cognitions, but these interventions typically operate through explicit feedback or reminders rather than through changes to the temporal structure of play itself (Auer & Griffiths, 2015; Bjørseth et al., 2021).

Overall, these studies suggest that small, well-timed applications of friction can reduce gambling persistence without substantially diminishing players' subjective engagement. Rather than operating as a blunt restriction, friction appears to create brief opportunities for temporal awareness within an activity designed for continuity and automaticity. By showing that gambling perseverance can be reduced independently of flow and affect, the present findings position friction as a promising design-level tool for responsible gambling. Carefully implemented pauses may help shift gambling behavior from automatic continuation toward more intentional action, preserving engagement while leaving the player, rather than the machine, to choose the end.

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Appendix A

Modified Game Experience Questionnaire (M-GEQ)

The M-GEQ is a shortened version of the original *Game Experience Questionnaire* developed by IJsselsteijn and colleagues (2013). In this adaptation, 14 items were extracted from the full instrument to focus specifically on dimensions of *flow, positive affect,* and *negative affect* during gameplay. Participants rated each statement on a five-point Likert scale ranging from *0 = Not at all* to *4 = Extremely*, reflecting their experiences during the slot-machine task.
The modification retained only items most relevant to absorption and affective experience in gambling contexts, ensuring conceptual alignment with measures of flow and dark flow described in the main text.

Please indicate how you felt while playing the game for each of the items, on the following scale:

Not at all	Slightly	Moderately	Fairly	Extremely
0	1	2	3	4
<>	<>	<>	<>	<>

1. I was fully occupied with the game
2. I forgot everything around me
3. I lost track of time
4. I was deeply concentrated in the game
5. I lost connection with the outside world
6. I thought it was fun
7. I felt happy
8. I felt good
9. I enjoyed it
10. I felt aroused/ excited
11. It gave me a bad mood
12. I thought about other things
13. I found it tiresome
14. I felt bored