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Zoned in or zoned out? Investigating immersion in slot machine gambling using mobile eye-tracking

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ABSTRACT

Background and Aims Immersion during slot machine gambling has been linked to disordered gambling. Current conceptualizations of immersion (namely dissociation, flow and the machine zone) make contrasting predictions as to whether gamblers are captivated by the game *per se* ('zoned in') or motivated by the escape that immersion provides ('zoned out'). We examined whether selected eye-movement metrics can distinguish between these predictions. **Design and Setting** Pre-registered, correlational analysis in a laboratory setting. Participants gambled on a genuine slot machine for 20 minutes while wearing eye-tracking glasses. **Participants** Fifty-three adult slot machine gamblers who were not high-risk problem gamblers. **Measurements** We examined self-reported immersion during the gambling session and eye movements at different areas of the slot machine screen (the reels, the credit window, etc.). We further explored these variables' relationships with saccade count and amplitude. **Findings** The ratio of dwell time on the game's credit window relative to the game's reels was positively associated with immersion ($t_{(51)}$ = 1.68, P = 0.049 one-tailed, R^2 = 0.05). Follow-up analyses described event-related changes in these patterns following different spin outcomes. **Conclusions** Immersion while gambling on a slot machine appears to be associated with active scanning of the game and a focus on the game's credit window. These results are more consistent with a 'zoned in' account of immersion aligned with flow theory than a 'zoned out' account based on escape.

Keywords Dwelling time, eye tracking, flow, gambling, immersion, saccade, slot machine, zone.

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INTRODUCTION

Immersion is a feeling of intense focus on a particular activity that reduces attention to competing goals and stimuli. Although viewed as desirable in many occupational and recreational contexts [1], immersion in gambling activities is a robust predictor of problem gambling risk [2–10]. Slot machine gambling may be especially immersive: an Australian survey found that 79% of gambling-related immersion experiences involved slot machines [11].

Recently, authors have called for clarity in defining slot machine immersion [12]. Previous work has characterized this state as 'dissociation' [3,9,13–16], the 'machine zone' [17,18] or 'flow' [5,19]. These accounts all highlight a trance-like state that interferes with gamblers' awareness of peripheral events (e.g. people talking nearby) and the passage of time. However, the machine zone and dissociation [15,18] constructs differ from flow by relying on a negative reinforcement mechanism: a sense of relief or escape from aversive realities that is provided by slot machines. Schull ([18], pp. 2, 74) argues that immersion supplants the desire to win money, becoming the sole motivation for gambling. By this account, gamblers could be relatively passive or 'zoned out' while gambling, showing little engagement with the game *per se*. In contrast, the flow account implies that these experiences emerge from skilful performance commensurate to the challenge or difficulty of the task [1]. This implies a 'zoned in' state in which task attention must be maintained to stay in the immersive 'flow channel' [1]. By this account, gambling success necessarily remains a valued goal, the pursuit of which generates immersion.

Table 1 Pre-registered and exploratory hypotheses.

Independent variable	*Dependent variable*	*Hypothesized relationship*	*Indicates*
Immersion	Ratio of dwell time on credit window AOI over dwell time on reels AOI*	+	Zoning in
	Ratio of fixations on credit window AOI over fixations on reels AOI*	+	Zoning in
	Number of saccades	+/–	Zoning in (+) or zoning out (–)
	Number of blinks	+/–	Zoning in (–) or zoning out (+)
	Gambling-related cognitions (GRCS, all subscales)	+/–	Zoning in (+) or zoning out (–)
	Past-week depression, anxiety and stress (DASS, all subscales)	+/–	Individual risk for immersion
Problem gambling (PGSI)	Ratio of dwell time on credit window AOI over dwell time on reels AOI*	+	Potential covariate for immersion
	Ratio of fixations on credit window AOI over fixations on reels AOI*	+	Potential covariate for immersion
Adult ADHD symptoms (ASRS)	Dwell time and fixations on the credit window AOI	+/–	Potential covariate for immersion
	Dwell time and fixations on the reels AOI	+/–	Potential covariate for immersion

Pre-registered hypotheses were based on the results of a convenience-sampled pilot study (see Supporting information, S1). *Primary pre-registered hypothesis. AOI = areas of interest; ADHD = attention deficit hyperactivity disorder; ASRS = adult ADHD Self-Report Scale; PGSI = Problem Gambling Severity Index;

Most research on slot machine immersion has employed self-report measures, but a few behavioural studies have tested whether immersed gamblers were less responsive to stimuli outside the game [3,4,7]. Crucially, this 'dual task' approach cannot assess the allocation of attentional resources to the game itself. Mobile eye-tracking technology offers a means of exploring aspects of overt visual attention during gambling. Rogers and colleagues [20] used mobile eye tracking to examine betting behaviour on fixed-odds betting terminals in British gambling shops, finding that problem gamblers spent more time looking at 'amount-won' messages. This finding complements laboratory studies in which people with gambling problems show visual biases towards gambling-related imagery [21,22].

Our primary aim was to ascertain whether slot machine immersion is akin to being 'zoned in' or 'zoned out'. These characterizations lead to testable and competing predictions regarding eye movements during the immersed state. If gamblers are 'zoned in', they should be relatively more attentive and reactive to the slot machine display—especially to financial information displayed in the credit window—as the main indicator of 'performance' (albeit in a game of chance). If they are 'zoned out', gamblers should be relatively less attentive to their task performance, instead directing their eyes to the most stimulating parts of the display: the spinning reels.

We pre-registered[1] several hypotheses (based on a convenience-sampled pilot study, see Supporting information, S1), to arbitrate between these accounts using eye movement metrics during slot machine gambling (Table 1). We hypothesized that immersed gamblers would look relatively more at the game's credit window and relatively less at the reels in a slot machine gambling session. We interpret this behaviour as consistent with being 'zoned in'.

We examined whether immersed gamblers make more saccades and fewer blinks. We believe such results would be consistent with being 'zoned in', while the opposite pattern would indicate being 'zoned out'. Exploring these data further, we examined event-related fixations during different phases within each bet. We looked for relationships between slot machine outcomes and immersion. Lastly, we examined whether immersion was related to gambling-related cognitions, negative affect [5] or symptoms of adult Attention Deficit Hyperactivity Disorder (ADHD [23–25]; see Supporting information, S3) that have correlated with immersion in past research.

METHODS

Participants

Experienced slot machine gamblers were recruited through craigslist.ca. Respondents (n = 245) completed an on-line eligibility screening. We recruited respondents age 19 years or older, who reported slot machine use (including on-line) in the past 12 months and who reported normal vision, using contact lenses or glasses with a prescription strength between −4 and + 4 diopters. We excluded respondents

[1]Pre-registration: https://aspredicted.org/k4ty9.pdf

who reported recent or severe traumatic brain injury, neuropsychiatric or ophthalmic disease or current use of psychotrophic medications. Because the experiment involved authentic slot machine gambling, we excluded individuals who scored 8 or higher on the Problem Gambling Severity Index [26].

Participants (n = 63) were paid $20 CAD for attending a 1-hour test session, and received $0–20 as an additional bonus from the slot machine. Ten participants were excluded from analysis: seven due to poor quality eye-tracking data, one due to a video capture error that made behavioural data unavailable and two who reported past-year slot machine use on the eligibility screen but none on test day. All experimental protocols were approved by UBC's research ethics board.

Questionnaires

After providing written consent, participants completed four questionnaires (see Supporting information, S2): the Short-Form Adult ADHD Self-Report Scale [27], the Gambling-Related Cognitions Scale (GRCS [28]), the Depression, Anxiety and Stress Scale [29] and the PGSI [26].

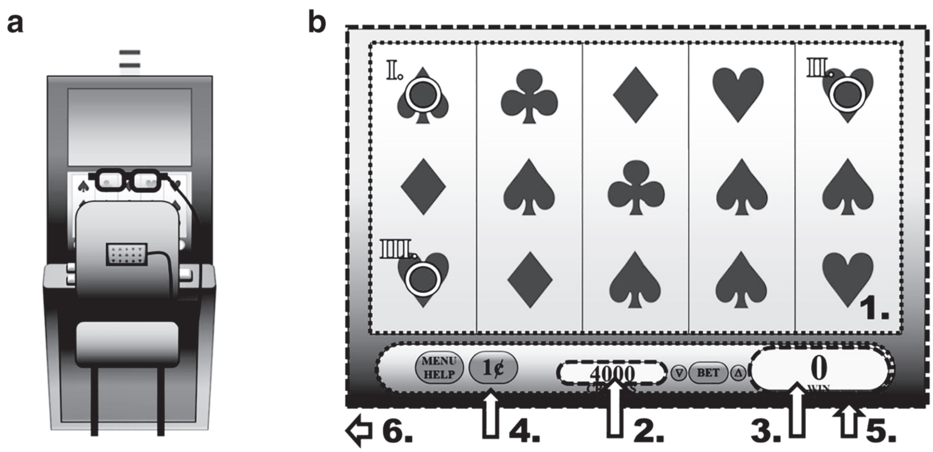
Following the slot machine task, participants completed an immersion questionnaire, which is a concatenation of the Dissociation Questionnaire [3,16] and flow subscale of the Game Experience Questionnaire [30,31]. Seven items (e.g. 'I lost track of time while playing the slot machine', 'I felt completely absorbed') were rated on a five-point Likert scale ranging from 'very slightly or not at all' (0) to 'extremely' (4). Mean scores were calculated and reliability analyses were performed. We have previously employed this measure [25].

Procedure

Participants gambled on a real slot machine for up to 20 minutes using a $40 endowment. We recorded natural gaze behaviour in real time using mobile eye-tracking glasses (SMI, Teltow, Germany). For additional details, see Supporting information, S2.

Data processing

Binocular eye position data were pre-processed using proprietary software (SMI BeGaze 3.7). Data were mapped to a reference image based on the screen layout of the slot machine (Fig. 1). Six mutually exclusive areas-of-interest (AOIs) were defined on the reference image: (1) reels, (2) credit window, (3) win window (a larger window to the right of the credit window that reads zero unless a payout is being delivered), (4) menu bar (which displays information about the game denomination and bet size), (5) game border (the remaining screen area not included in other AOIs) and (6) game periphery (the entire area outside the game screen). Session-wise statistics were exported from BeGaze alongside the raw reference image data. Blinks and saccades were defined automatically in BeGaze. Saccade amplitude was defined as the average distance (pixels) between the start and end position of all saccades. Dwell time was defined as the percentage of task time spent fixating on a given AOI. Fixations were defined as the number of times visual intake was recorded in an AOI following a blink or saccade divided by task time. Gaze data normalized by AOI size are presented in Table 2 for descriptive purposes. Analyses were performed on the non-normalized data. The ratio of dwell time (or



Note: A) slot machine and mobile eye tracking apparatus without participant. B) Game screen with calibration points (I-III) and areas of interest (1-6). 1) reels, 2) credit window, 3) win window, 4) menu bar, 5) game border, 6) game periphery.

Figure 1 Task apparatus.

Table 2 Eye movement metrics by area of interest.

	% Dwell time	*Normalized dwell time*	*Fixations/minute*	*Normalized fixations*
Reels	71.46 (10.06)	1.02 (0.14)	117.10 (21.05)	1.67 (0.30)
Credit window	4.45 (2.98)	4.28 (2.86)	8.67 (4.99)	8.33 (4.80)
Win window	3.07 (1.72)	1.23 (0.69)	5.79 (2.63)	2.32 (1.05)
Menu bar	6.15 (2.77)	0.74 (0.34)	12.48 (5.29)	1.51 (0.64)
Game border	6.59 (3.51)	0.37 (0.20)	7.32 (5.27)	0.41 (0.29)
Game periphery	0.97 (1.97)	∞	2.20 (3.83)	∞

% Dwell time refers to the mean percentage of the session spent fixating on each area of interest (AOI). Fixations/minute refers to the number of fixations at each AOI per minute of the session. Values represent the mean (standard deviation). Normalized data are provided here for descriptive purposes. The data have been divided by the percentage of the screen occupied by the AOI. The game periphery is infinite in normalized columns because it exists off-screen.

fixations) at the credit window to the reels was calculated (see Supporting information, S1). Data were analyzed in R [32–36]. Descriptive data are reported with median, minimum and maximum values where skew was present. Non-event-related hypotheses were tested using bivariate regression. Reported confidence intervals were bootstrapped with 5000 iterations [37].

Event-related analyses

To further explore whether fixation patterns might be affected by specific in-game events and immersion, we derived a time–series of on-screen game events for trial-by-trial analyses. We analyzed data at three phases within each trial: reel spin, audiovisual feedback (where reinforcement is delivered paired with some sound and animation) and spin initiation latency (the delay between the feedback ending and the participant initiating the next spin, Fig. 2). Spin outcomes were categorized into wins, losses, free spin bonuses and losses-disguised-as-wins [38]. Of these, loss trials are unique in entailing a spin initiation latency phase with no preceding feedback phase, as no credits are awarded. The music and spins in a free spin bonus continue without pausing for user input, so we treated them as a single feedback phase. Our use of a genuine slot machine meant that we could not control how many outcomes of each type occurred, or the order in which they appeared. In total, 20 749 events were recorded for each model.

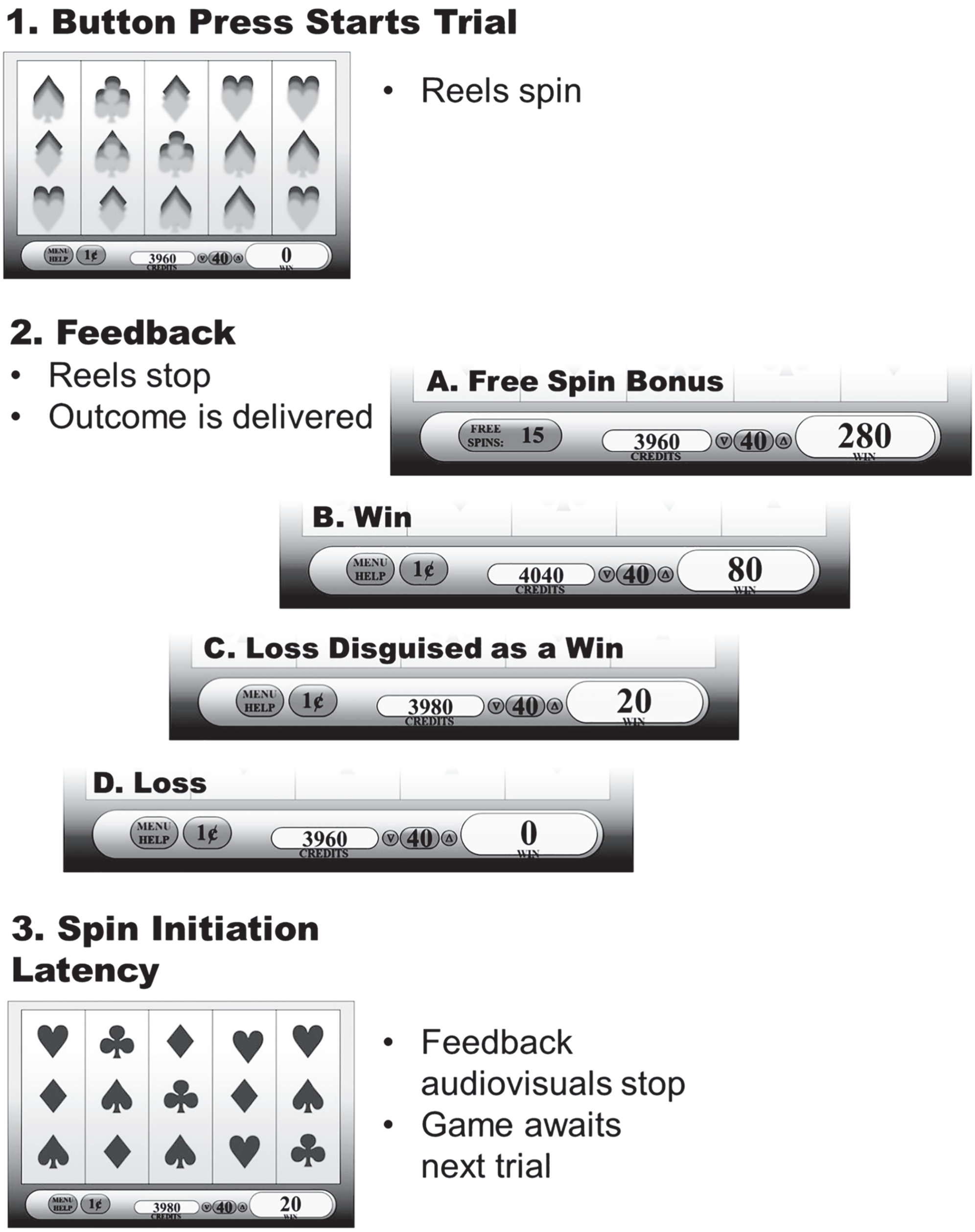
For each trial phase, we recorded a trial number, duration (seconds), outcome type (loss, win, losses-disguised-as-wins or free spin bonus; reel spins were the reference category) and the proportion of that phase spent fixating on the reels, credit window and win window. Data inspection showed that many phases were spent fixating on only one AOI, polarizing the data (i.e. one AOI value equalled 1, and the rest zero). To address this, all non-zero event-related eye movement data were converted to 1 and data were analyzed in three fixed-effects logistic regressions [39–41] that tested the likelihood that the reels, credit window or win window were fixated-on during a given phase (additional details in Supporting information, S2).

Models were composed first of participant (fixed factor), trial number (centred at 1) and phase duration (grand-mean centred). These factors accounted for incidental variance between participants across the span of the task and, as a result of some outcomes (e.g. bonus features), being systematically longer in duration. We then added the dummy-coded outcome phases. Predictions made by these models thus reflect differences in the likelihood of fixating on a given AOI during a particular outcome phase, compared to when the reels are spinning. Lastly, for outcome phases that significantly differed from reel spins, immersion was tested as an interaction term. Non-significant interaction terms were backwards-eliminated, increasing these exploratory models' parsimony and statistical power, but also the risk of Type 1 error. Bootstrapping these data produced instances of complete separation, so not all confidence intervals in Table 3 were bootstrapped.

RESULTS

After data cleaning, the final sample included 53 participants (84.13%, 32 males, 21 females) with a median age of 30 years (range = 19–64). Most participants (n = 34, 64.15%) reported casino gambling one to five times in the past year. Seventeen (32.08%) reported visiting casinos more than five times. Two (3.77%) reported gambling on slot machines on-line, but not in a casino. The modal (n = 23, 43.40%) PGSI score was 0; 17 (32.10%) scored 1–2 (low-risk) and 13 (24.53%) scored 3–7 (moderate-risk).

The median participant made 179 spins (range = 117–233) during the task. Losses were the most common outcome (median = 140, range = 95–190). Losses-disguised-as-wins (median = 18, range = 10–33) occurred approximately as often as wins (median = 17, range = 8–28). The median participant saw one free spin bonus round (range = 0–4), and 14 participants (26.32%) did not experience any of the 58 bonuses that occurred. Sixteen participants (30.19%) finished the session in profit, and the median participant finished the task with $17.20 (range = $0–109.40) of their $40 endowment remaining.



Note: Each trial proceeds from 1 - 3 with only one of 2A - 2D occurring. Feedback phase 2A encompasses 15 or more continuous free spins and any feedback that occurred after they were completed. There is no audiovisual feedback in phase 2D.

Figure 2 Trial phases and outcome types.

Among the 18 participants (33.96%) who ran out of credit before completing a 20-minute session, the median session length was 16.28 minutes (range = 11.00–20.00).

The reels AOI accounted for the most dwell time [mean = 71.46%, standard deviation (SD) = 10.06], but participants also dwelt on the credit window (mean = 4.45%, SD = 2.98) and win window (mean = 3.07%, SD = 1.72). Only 0.97% (SD = 1.97) of dwell time occurred off-screen (see Table 2 and Fig. 3). When these values were normalized to account for the size of each AOI, a clear bias towards the credit window was observed.

Exploratory hypotheses

Cronbach's alpha for the immersion questionnaire was 0.75, an improvement over the Dissociation Questionnaire alone (0.60). The median immersion score was 1.14 of 4

Table 3 Fixed-effects logistic regression models predicting AOI visitation for different outcome phases and states of immersion.

		AOI model											
		(a)				*(b)*				*(c)*			
		Reels			$R_n^2 = 0.89$	*Credit window*			$R_n^2 = 0.50$	*Win window*			$R_n^2 = 0.66$
	Factor	*OR*	*(95% CI)*	*Z*	*P*	*OR*	*(95% CI)*	*Z*	*P*	*OR*	*(95% CI)*	*Z*	*P*
Outcomes:	Trial number	0.99	(0.99, 0.99)	−19.87	< 0.001	1.00	(1.00, 1.00)	−2.98	0.003	1.00	(1.00, 1.00)	−3.33	< 0.001
	Event duration	1.17	(1.03, 1.32)	4.99	< 0.001	1.17	(1.14, 1.19)	18.69	< 0.001	1.16	(1.14, 1.19)	17.96	< 0.001
	Reel spin (reference)												
	Loss SIL	0.30	(0.21, 0.43)	−5.31	< 0.001	0.55	(0.50, 0.60)	−13.42	< 0.001	0.45	(0.40, 0.51)	−13.87	< 0.001
	Win feedback	0.41	(0.28, 0.60)	−4.38	< 0.001	0.58	(0.46, 0.71)	−5.32	< 0.001	1.27	(1.05, 1.56)	2.39	0.017
	Win SIL	0.05	(0.03, 0.08)	−10.18	< 0.001	1.46	(1.26, 1.70)	4.63	< 0.001	6.56	(5.00, 8.62)	11.99	< 0.001
	LDW feedback	0.11	(0.06, 0.19)	−7.19	< 0.001	0.32	(0.25, 0.40)	−9.77	< 0.001	0.30	(0.22, 0.42)	−7.47	< 0.001
	LDW SIL	0.23	(0.12, 0.42)	−3.94	< 0.001	0.78	(0.67, 0.91)	−2.92	0.004	1.99	(1.46, 2.71)	3.87	< 0.001
	Bonus feedback	<0.01	(0.00, 0.00) [A]	−5.61	< 0.001	< 0.01	(0.00, 0.01)[a]	−8.46	< 0.001	0.09	(0.01, 1.47)[a]	−1.69	0.091
	Bonus SIL	0.02	(0.01, 0.03) [A]	−12.32	< 0.001	4.32	(2.43, 7.70)[a]	4.98	< 0.001	7.83	(4.45, 13.78)[a]	7.14	< 0.001
Interactions:	Loss: immersion	1.42	(1.23, 1.63)	2.46	0.014								
	Win SIL: immersion	1.97	(1.43, 2.72)	3.24	0.001					0.66	(0.54, 0.80)	−3.48	< 0.001
	LDW feedback: immersion	1.89	(1.39, 2.56)	3.00	0.003								
	LDW SIL: immersion	1.77	(1.21, 2.58)	2.19	0.029					0.72	(0.58, 0.91)	−2.32	0.020
	Bonus feedback: immersion									0.14	(0.02, 0.91)[a]	−2.06	0.039

Reported confidence intervals have been bootstrapped with 5000 iterations, except where denoted by [a]. OR = odds ratio; CI = confidence interval; LDW = losses disguised as wins; SIL = spin initiation latency; R_n^2 = Nagelkerke's coefficient of determination; AOI = area of interest. Non-significant interaction terms were backwards eliminated from the models in descending order of significance.

Note: A) Heatmap of all participants across the full slot machine task. B) Full-task heatmap for a participant who reported low immersion. C) Full-task heatmap for a participant who reported high immersion. Warmer colours indicate greater time spent fixating on that point.

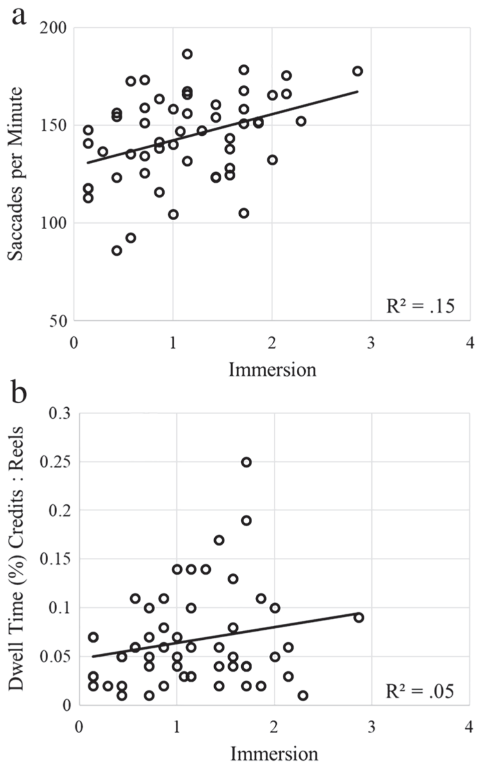
Figure 3 Heat-map of fixations to the slot machine screen.

(range = 0.14–2.86). Immersion was significantly related to PGSI [$B = 1.02$, $t_{(51)} = 2.62$, $P = 0.012$, $R^2 = 0.12$, 95% confidence interval (CI) = 0.16, 1.77], as well as several GRCS subscales. Among these, the subscales for illusion of control ($B = 0.73$, $t_{(50)} = 3.18$, $P = 0.003$, $R^2_{\text{partial}} = 0.17$, 95% CI = 0.30, 1.23, PGSI included as a covariate) and predictive control ($B = 0.65$, $t_{(50)} = 2.47$, $P = 0.017$, $R^2_{\text{partial}} = 0.11$, 95% CI = 0.10, 1.20; additional results in Supporting information, S3).

The median participant blinked 6.92 times per minute (range = 0.35–52.66) and made 147.57 saccades per minute (range = 86.04–186.72). Immersion was associated with a greater total number of saccades during the slot machine task ($B = 13.40$, $t_{(51)} = 2.95$, $P = 0.005$, $R^2 = 0.15$, 95% CI = 5.17, 21.15, Fig. 4a). The number of saccades was not related to saccade amplitude ($B = -0.08$, $t_{(51)} = -0.49$, $P = 0.629$, $R^2 < 0.01$, 95% CI = 0.38, 0.29). Additional results are discussed in Supporting information, S3.

Pre-registered primary hypotheses

The pre-registered hypotheses were partially supported. Consistent with our pilot results (see Supporting information, S1), a higher ratio of dwell time to the credit window AOI relative to the reels AOI was associated with higher levels of self-reported immersion during the slot machine task ($B = 2.98$, $t_{(51)} = 1.68$, $P = 0.049$ one-tailed, $R^2 = 0.05$, 95% $\text{CI}_{\text{lower}} = 0.59$, Fig. 4b). The overall number of fixations on the different AOIs (credit window/reels) was not related to higher immersion ($B = 2.39$, $t_{(50)} = 1.23$, $P = 0.112$ one-tailed, $R^2 = 0.03$, 95%



Note: Immersion score correlated with (A) the number of saccades per minute, and (B) dwell time at the credit window AOI divided by dwell time at the reels AOI. X-axis represents average score on 7-item immersion questionnaire. Each data point represents the mean of one participant. Line represents best-fit linear trend.

Figure 4 Relationships between eye movements and immersion. AOI = area of interest.

$CI_{lower} = -0.59$). Neither dwell time ratio ($B = 0.30$, $t_{(50)} = 0.06$, $P = 0.478$ one-tailed, $R^2 < 0.01$, 95% $CI_{lower} = -7.69$) nor fixation ratio ($B = -0.35$, $t_{(50)} = -0.06$, $P = 0.476$ one-tailed, $R^2 < 0.01$, 95% $CI_{lower} = -8.43$) were significantly related to PGSI.

Event-related analyses

Reels model

Fixations on the different regions of the screen varied by trial phase and outcome. The likelihood of fixating on the reels was lower during every outcome phase than it was during the reel spin (Table 3a, Fig. 5).

Credit window model

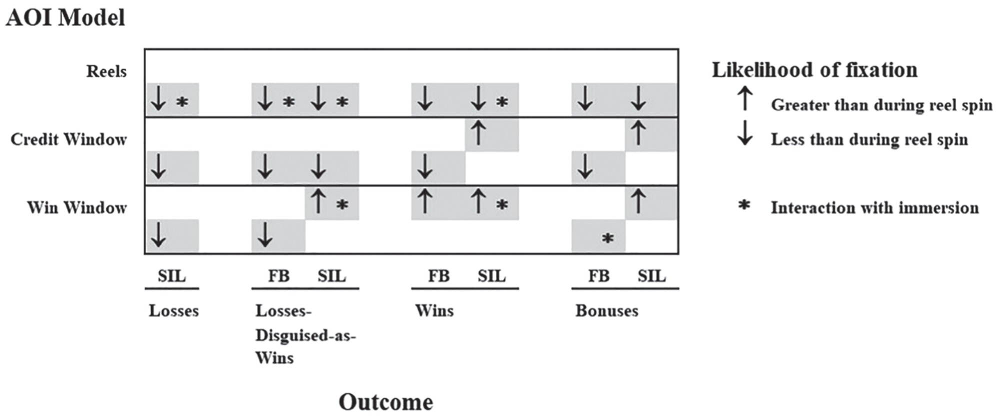
Comparing winning outcome phases to reel spins, participants were less likely to fixate on the credit window during win feedback (OR = 0.58, Table 3b, Fig. 5), but more likely during the ensuing spin initiation latency (OR = 1.46). During bonus feedback, fixations on the (then inactive) credit window were much less likely (OR < 0.01) but were then more likely during spin initiation latencies (OR = 4.32). On losses-disguised-as-wins, participants were less likely to fixate on the credit window during both feedback (OR = 0.32) and spin initiation latency (OR = 0.78).

Win window model

Comparing winning outcomes to reel spins, participants were more likely to look at the win window during both feedback (OR = 1.27, Table 3c, Fig. 5) and spin initiation latency (OR = 6.56). For losses-disguised-as-wins, fixations were less likely during feedback (OR = 0.30) but more likely during spin initiation latency (OR = 1.99). During spin initiation latencies for bonuses, fixations on the win window were more likely (OR = 7.83).

Immersion interactions

Self-reported immersion interacted significantly with some outcomes in the win window and reels models. Higher-immersion participants were less likely to fixate on the reels during losses (OR = 1.42, Table 3a, Fig. 5), and feedback for losses-disguised-as-wins (OR = 1.89), as well as spin initiation latencies for wins (OR = 1.97) and losses-disguised-



Note: Results are relative to the reference category, reel spins. Losses do not have audiovisual feedback. FB = Feedback phase, SIL = Spin Initiation Latency phase.

Figure 5 Direction of relationships in event-related models. AOI = area of interest.

as-wins (OR = 1.77). Higher-immersion participants were less likely to fixate on the win window during bonus feedback (OR = 0.14, Table 3c), as well as spin initiation latencies for wins (OR = 0.66) and losses-disguised-as-wins (OR = 0.72).

DISCUSSION

We described 'zoning in' and 'zoning out' as competing characterizations of slot machine immersion. We examined experienced gamblers' natural gaze behaviour while using a genuine slot machine. The ratio of dwell time on the game's credit window over dwell time on the reels was positively related to immersion. This finding corroborated, and was predicated upon, the same relationship observed in a convenience-sampled pilot study (see Supporting information, S1). Notably, the replicated effect was somewhat smaller, although still statistically significant. Thus, immersed participants were relatively more concerned with financial 'performance'-related information and less concerned with the game's appealing animations. We tested relationships between immersion and the ratio of fixations per minute on the credit window over the reels and with problem gambling severity, but we did not find support for these additional hypotheses.

In exploratory analyses, the total number of saccades explained 15% of the variation in immersion scores, but was not associated with saccade amplitude. Thus, immersed gamblers differed in the amount they looked back and forth, but this did not depend on the exact pattern in which saccades occurred. As less than 1% of dwell time was spent off-screen, we argue that immersed participants were more thorough in their inspection of the game screen. GRCS subscales indicated higher levels of illusory and predictive control in more-immersed participants. Thus, belief in one's control over gambling outcomes may be elevated in gamblers who experience immersion.

These results strongly support a 'zoned in' interpretation of slot machine immersion that entails persistent interest in task performance. In the 'zoned in' model, immersion is a potential motivator—but not the sole motivator—of continued slot machine use among immersed individuals. We associated immersion with a focus on monetary outcomes, increased inspection of the game screen and a stronger sense of control over gambling outcomes, all of which are hard to reconcile with a 'zoned out' or negative reinforcement-only model of slot machine immersion.

At the same time, not every result supported the 'zoned in' model. Event-related analyses revealed significant interactions between immersion and fixating on the game's reels and win window. Although immersed gamblers were less likely to fixate on the reels during some outcomes, this was not coupled with a significant increase in fixations at the credit or win windows. Arguably, these interactions could be more consistent with a general disengagement from the game predicted by the 'zoned out' model. However, these exploratory analyses were not consistent throughout outcome types, and further study is needed to establish reliability.

Several limitations are of note. Our laboratory environment was quiet, minimally distracting and our protocol required gamblers to use a specific bet strategy (Supporting information, S2). Although we selected a popular strategy (maximum paylines, minimum credits [42,43]), it is probably not the preferred betting style for all gamblers. Both factors reduce ecological validity compared to gambling in real venues. We declined to test high-risk problem gamblers, as participant payment ensured that the gambling session would have a positive expected value, producing an unrealistically favourable gambling experience. As we sampled exclusively from craigslist [44] and excluded high-risk problem gamblers, our results may not generalize to eye movements or immersion for clinical populations [45].

Our instruments were also subject to important limitations. The psychometric properties of our immersion questionnaire are not well understood. The scale has not been rigorously validated for internal or external validity. Additionally, we selected a small number of eye movement metrics we believed would be informative. Measures such as pupillometry may alter our interpretation of slot machine immersion.

Irrespective of immersion, our event-related analyses found interesting eye movement patterns among different phases of slot machine spins. The likelihood of fixating on the win window before starting the next spin (i.e. during the spin initiation latency) increased after wins, bonuses and losses-disguised-as-wins, but not losses (Fig. 5). Fixations on the credit window, however, were more likely after wins and bonuses, but less likely after losses and losses-disguised-as-wins. Attention to the win window could contribute to the often-reported confusion between losses-disguised-as-wins and true wins [46]. Notably, the relative infrequency of bonus feature outcomes prevented us from bootstrapping their confidence intervals, and may have also impacted the reliability of their odds ratios. Replication is especially important for these analyses.

These trends raise useful implications for responsible gambling messaging. On-screen pop-ups appear to be somewhat effective in reducing time on device [47–50]. Stewart & Wohl [51] found that pop-up reminder messages improved spend-limit adherence. In real-world settings, however, the effect may be smaller [52], and may diminish with repeated exposure [53,54]. Careful tailoring of message presentation could enhance these tools' effectiveness: eye-tracking results could be used to optimize on-screen message delivery both spatially (by AOI) and temporally (by phase or outcome) to coincide with gamblers' attention. We found that fixations often increased at the credit and win windows in the spin initiation latency following wins, losses-disguised-as-wins and bonuses. Messages presented there and then have the potential to garner greater engagement and resist habituation.

More broadly, these results speak to the conceptualization of immersion as a robust correlate of problem gambling. For problem gamblers, their families, clinicians and venue staff, approaching gambling immersion as just one harmful example on a spectrum of immersive activities (including hobbies, playing sports, etc.) may be more productive for research and less stigmatizing than an approach that treats immersion as uniquely mollifying and solely achievable through gambling. To that end, we recommend adopting the terms 'immersion' or 'flow' [5] to describe the experience.

Declaration of interests

The Centre for Gambling Research at UBC receives funding from the Province of British Columbia and the British Columbia Lottery Corporation (BCLC). The slot machine used in the present study was provided by the BCLC. The British Columbia Government and BCLC had no further involvement in the research design, methodology, conduct, analysis or write-up of the study, and impose no constraints on publishing. L.C. is the Director of the Centre for Gambling Research at UBC. L.C. has received speaker/travel honoraria from Svenska Spel (Sweden), the National Association of Gambling Studies (Australia), and the National Center for Responsible Gaming (USA). He has received consulting fees from Gambling Research Exchange Ontario (Canada) and the National Center for Responsible Gaming (USA). He has not received any further direct or indirect payments from the gambling industry or groups substantially funded by gambling. He has received royalties from Cambridge Cognition Ltd. relating to neurocognitive testing. M.V.C. has received a speaker honorarium from the Responsible Gaming Association of New Mexico (USA). E.H.L. O. works as a postdoctoral fellow at the Centre for Gambling Research. She has received a speaker honorarium from the Massachusetts Council on Compulsive Gambling (USA). She has accepted travel or accommodation for speaking engagements from the National Council for Responsible Gambling (USA), the International Multidisciplinary Symposium on Gambling Addiction (Switzerland), and the Responsible Gambling Council (Canada). She has not received any further direct or indirect payments from the gambling industry or groups substantially funded by gambling. W.S.M., M.A.F., K.I.M. and J.F. report no additional conflicts of interest.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.