Why do slot machine gamblers use stopping devices? Findings from a 'Casino Lab' experiment

[1]Stephanie Chu, [1]Eve H. Limbrick-Oldfield, [1]W. Spencer Murch, [1]Luke Clark

[1]Centre for Gambling Research at UBC, Department of Psychology

University of British Columbia, Vancouver British Columbia, Canada

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Corresponding Author

Luke Clark, Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, British Columbia, Canada V6T 1Z4. Email: luke.clark@psych.ubc.ca

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Biographies

Stephanie Chu conducted this study as part of her Masters thesis in the Department of Psychology at the University of British Columbia. She completed her undergraduate degree in Psychology at the University of Waterloo, and is currently training in Occupational Therapy at the University of Toronto.

Eve Limbrick-Oldfield is a post-doctoral research fellow in the Department of Psychology at the University of British Columbia. She completed her PhD in Cognitive Neuroscience at Imperial College London. Her research focusses on the neural basis of gambling-related cognitive distortions in healthy participants and individuals with gambling problems.

Spencer Murch is a PhD student in the Department of Psychology at the University of British Columbia. He completed his undergraduate degree and Masters in Psychology at the University of British Columbia. His research examines attentional factors in slot machine gambling, and their role in the development of gambling problems.

Luke Clark is an Associate Professor in the Department of Psychology at the University of British Columbia, and Director of the Centre for Gambling Research at UBC. He is an experimental psychologist by training. His research focusses on the psychological and neural basis of decision-making in gambling and its relevance to the development of gambling problems.

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Abstract

Stopping devices are a structural characteristic of modern slot machines that enable the player to brake the spinning reels manually, but with no influence on the predetermined outcome. This study tested two mechanisms for why players might use a stopping device: (1) enhanced 'illusory control', and (2) faster game speed. Thirty student participants and 31 past-year slot machine gamblers played a multi-line slot machine equipped with a stop button, situated in a laboratory environment. During 20 minutes of play, participants could use the stop button as often as they wished. Contrary to predictions, the Gamblers' Beliefs Questionnaire (GBQ), a trait measure of illusion of control, did not predict stop button usage. Participants who did and did not endorse the stop button as effective did not differ in their actual use of the device. Stop button use was associated with faster spin initiation latencies, and specifically increased following spins on which the use of the stop button coincided with a win. We interpret our data as more consistent with a low-level operant conditioning account of slot machine gambling than a higher-level account based on cognitive distortions. By increasing speed of play, stopping devices may increase gambling losses, and exaggerate gambling-related harms.

Keywords: Electronic Gaming Machines, illusions, skill, behaviour, cognition.

Introduction

Slot machines and the broader class of Electronic Gaming Machines (EGMs) are increasingly recognised as one of the more harmful forms of gambling (Dowling, Smith, & Thomas, 2005; MacLaren, 2016; Markham, Young, & Doran, 2016). These harms may be understood in relation to a number of psychological properties that vary across different modes of gambling and across individual games, termed "structural characteristics" (Griffiths, 1993). These variables include the speed of the game, various pay-out characteristics (e.g. win frequency, jackpot size), and the presence and intensity of sensory feedback. This study focusses on the "stopping device" (or "stop button") as a specific structural feature of modern EGMs. On a traditional slot machine, the player initiates each spin by pressing a spin button, and the reels then stop successively over a few seconds to reveal the outcome. On a machine equipped with a stopping device, the player may apply the device during the reel spin to act as a brake, causing the reels to stop more suddenly (and thus more quickly). On different games, this may be achieved via a touch-sensitive monitor or by repeat pressing the spin button itself. Critically, the use of the stopping device does not affect the outcome of the spin, which was randomly determined at the initiation of the spin. Nevertheless, regular slot machine players find stopping devices an attractive feature of modern EGMs, that increases their desire to continue playing the game (Loba, Stewart, Klein, & Blackburn, 2001).

The tendency for slot machine players to use the stop button may be explained by two distinct psychological mechanisms. The dominant account is that stopping devices facilitate the 'illusion of control' (Ladouceur & Sevigny, 2005; Turner & Horbay, 2004). The illusion of control is a common cognitive distortion in gambling, in which game features typically associated with games of skill create a false perception that the player can influence (i.e. increase) their likelihood of winning in a game of chance (Langer, 1975; Stefan & David, 2013; Tobias-Webb et al., 2017). Questionnaire measures and behavioural tests of illusory control indicate elevated levels in people with gambling problems (Goodie & Fortune, 2013; Orgaz, Estevez, & Matute, 2013), and predict preferences for skill-based forms of gambling over chance-based forms (Myrseth, Brunborg, & Eidem, 2010). Within this framework, the stop button could be considered a prototypical illusion of control device: being able to brake the reels may reasonably be expected to allow precise control over the outcome configuration. Conversely, the reality that the outcome configuration is already determined may be counter-intuitive to many players (see Delfabbro, 2004).

This illusion of control interpretation was supported by an early study (Ladouceur & Sevigny, 2005), in which regular gamblers played a real EGM on two occasions, once without the stop button, and a second time with the device enabled. After phase 1, ratings on an illusion of control questionnaire were negligible, but following phase 2, 87% of participants believed that there was a way of influencing the symbols, and 41% endorsed a skill component to the game. In a second experiment measuring persistence, a group who were able to use the stopping device played for twice as long (M = 41.4 trials) as a group for whom the device was unavailable (M = 21.5 trials). Thus, access to the stop button increased cognitive distortions pertaining to illusory control, and increased gambling persistence – although it was not clear whether persistence was directly driven by the cognitive beliefs. The Ladouceur & Sevigny study also did not report how often participants actually used the stop button; presumably because these data could not be readily extracted from the EGM. Another study by Nastally, Dixon, & Jackson (2009) assessed concurrent choice between two simulated slot machines, one of which was equipped with a stop button. In the key condition where the payouts were matched between the two games, there was no overall preference (50.3%) for the game with the stop button. In a third, recent experiment (Dixon, Larche, Stange, Graydon, & Fugelsang, 2017), participants played two sessions on a slot machine simulator, once with and once without a stopping device. On the session with the stopping device, participants showed greater physiological arousal and applied greater force on the spin button.

An alternative explanation for the appeal of the stopping device is that it affects the speed of the game. Slot machines are a continuous and rapid form of gambling in which the interval between the bet and the outcome – which is dictated by the length of the reel spin – is typically less than 5 seconds (Dowling et al., 2005). Groups with gambling problems played a faster slot machine for more trials (e.g. a 2 s vs 10 s spin duration, Chóliz, 2010) and reported less enjoyment and excitement when playing a slot machine that had been slowed down (Loba et al., 2001). Pathological gamblers also played a slot machine at a faster speed (Linnet, Thomsen, Møller, & Callesen, 2013). Crucially, deploying the stopping device affects game speed via two separable components. First, the length of the reel spin is directly, inherently shortened when the device is applied. Second, the player may voluntarily initiate the next spin more rapidly. The "post-reinforcement pause" (PRP) phenomenon refers to a longer initiation latency following slot machine wins (Delfabbro & Winefield, 1999; Dixon, MacLaren, Jarick, Fugelsang, & Harrigan, 2013), an effect that is also observed in rodents in conditioning experiments (Peters, Hunt, & Harper, 2010). Relative to a neutral baseline, losses can also shorten initiation latencies (Verbruggen, Chambers, Lawrence, & McLaren, 2016). From timing four popular slot machines in field research in Ontario, Harrigan and Dixon (2009) report that the speed of play can increase from a spin every 3 seconds (~1,200 spins per hour) to a spin every 1.5 seconds (2,400 spins per hour) when using a stopping device.

The illusion of control and speed of play accounts are not mutually exclusive, but distinguishing between these two candidate mechanisms is worthwhile for several reasons. From a policy perspective, risk assessment tools seek to formally quantify the risk potential of different gambling activities, in relation to a discrete number of structural characteristics. The main tools are consistent in containing at least one dimension reflecting speed of play, but two contemporary tools, Gam-GARD (see www.gamgard.com) and AsTERiG (Meyer, Fiebig, Häfeli, & Mörsen, 2011) diverge in whether they consider illusion of control features as a discrete dimension. In addition, the two mechanisms appeal to different theoretical frameworks for gambling behaviour. The illusion of control account is firmly grounded in the cognitive model of gambling, which emphasises the role of explicit (i.e. conscious, declarative) erroneous beliefs in shaping decisions to gamble (Ladouceur & Walker, 1996), whereas the speed of play account is rooted in a behavioural approach that emphasizes learned associations between behavioural actions and reward (Delfabbro & Winefield, 1999; Dickerson et al., 1992). Irrational behaviours, such as the use of a stopping device that does not objectively alter one's chances of winning, are explained in the behavioural account as superstitious conditioning, based on a coincidental pairing of the response with an unpredictable win (Shaner, 1999; Skinner, 1992).

The present study sought to investigate how players deploy the stopping device in naturalistic slot machine play, and to identify conditions under which the device was used most. Our study uses an authentic multi-line slot machine housed in a laboratory environment (our ‘Casino Lab’). Rather than instructing players to use the stopping device on every spin (Dixon, Larche, et al., 2017), we explained to participants that the game was equipped with a stopping device, and we allowed players to use the device as little or as often as they wished. After piloting our procedure in student participants (who were mostly novice slot machine gamblers), we conduct a more fine-grained behavioural analysis in experienced slot machine gamblers recruited through the community. Based on the illusion of control mechanism and cognitive approach, we formulated from two hypotheses. First, we used the Gamblers’ Beliefs Questionnaire (GBQ) (Steenbergh, Meyers, May, & Whelan, 2002) to probe the trait susceptibility to the illusion of control, predicting a relationship with the use of the stopping device in a laboratory session. Second, we divided participants based on their state ratings of illusory control in relation to their slot machine session (Ladouceur & Sevigny, 2005), predicting a difference in use of the stopping device between those who did and did not endorse the effectiveness of the device. Based on the speed of play mechanism and behavioural approach, we examined how the use of the stopping device affected spin initiation latencies as a measure of gambling intensity / motivation, in a model that also considered the previous outcome (see Verbruggen et al., 2016). The behavioural approach also predicts that when a player wins following use of the stopping device, this would constitute a potent case of reinforcement learning, increasing the operant response on subsequent trials. Thus, we tested whether use of stopping device increased following win pairings, compared to following wins where the stopping device was not deployed.

Method

Participants

The study was approved by the Behavioural Research Ethics Board at University of British Columbia (H14-02509) and all participants provided written informed consent. The student participants for the pilot study (N = 30, age M = 22.6, 15 males) were undergraduates aged 19 years or older, in accordance with jurisdictional gambling laws. The Problem Gambling Severity Index (PGSI) (Ferris & Wynne, 2001) was used to assess symptoms of problem gambling, using the original thresholds of 0 (non-problem gambling), 1 - 2 (low-risk), 3 - 7 (moderate-risk), and > 7 (high-risk). Students scoring in the high-risk range for problem gambling were not eligible to participate. The community sample were recruited from a local website for classified advertisements (Craigslist) (N = 31, age M = 44.3, 16 males) by advertising for 'regular slot machine gamblers'. The inclusion criterion was any slot machine gambling in the past year. (In the jurisdiction where the study was conducted, slot machines can only be accessed in casino premises). We ensured that community participants were not currently seeking treatment or other means of quitting gambling.

Procedures

Participants attended a one hour session following a telephone screening interview to ensure eligibility. On arrival at the lab, participants gave informed consent and completed the PGSI. The participant then entered the Casino Lab; this room houses 4 slot machines, with comfortable casino stools and dim lighting. The participants played a modern multi-line slot machine called "Dragon's Fire" (Williams Interactive, WMS) that was available in local casinos at the time of the study. The experimenter explained the basic rules of the slot machine, which included a description of the stop button. Participants were informed that they could use this feature however often they wished. The participant was given $40 to play the slot machine, and instructed to feed the money into the machine. The participant then played the machine at their own pace, for 20 minutes. They were instructed to play the game for a set period of time (we did not reveal the exact duration in advance, to avoid strategic play) and that remaining credits upon completion would be converted to a bonus payment between $2 and $12. All participants received a further reimbursement ($10 per hour) for their attendance.

Dragon's Fire employs a dragon and knights theme, with a 5 reel x 3 line digital display. The game was set to a $0.05 denomination and the payback percentage was 90.1%. The "Repeat Bet" button on the right side of the facia was used to initiate all spins, and also served as the stopping button. Dragon's Fire is a multi-line game allowing bets on up to 50 paylines simultaneously. Participants were instructed to use the Repeat Bet button set on a 9-payline setting (hence $0.45 per spin); constraining the bet strategy in this way reduced the volatility in relation to the $40 endowment sustaining 20 minutes of play.

Following the slot machine session, the participants completed the following questionnaire measures:

The ***Gamblers' Beliefs Questionnaire (GBQ)*** (Steenbergh et al., 2002) assesses gambling-related cognitive distortions on two related subscales: 'Luck/Perseverance' (13 items, e.g. "There are certain things I do when I am betting [for example, tapping a certain number of times, holding a lucky coin in my hand, crossing my fingers, etc.] which increase the chances that I will win") and 'Illusion of Control' (8 items e.g. "My gambling wins are evidence that I have skill and knowledge related to gambling"). Although our *a priori* focus is on the illusion of control, we noted that the several items on the Luck/Perseverance subscale were also relevant to stopping devices, and so we employed the GBQ Full score as our primary measure, consistent with other studies (Mackay & Hodgins, 2012; Steenbergh et al., 2002),.

The ***Game Experience Questionnaire (GEQ)*** (Ijsselsteijn, de Kort, & Poels, 2008) is a 14-item scale designed to measure subjective experiences in response to video game play, along 7 dimensions: Immersion, Tension/Annoyance, Competence, Flow, Negative Affect, Positive Affect, and Challenge. We note that the original Immersion subscale refers to engagement with the theme of the game (e.g. "I found the game impressive"), as distinct from immersion in relation to Flow, or 'absorption' in the game (Murch, Chu, & Clark, 2017). This scale has been validated in relation to slot machine play experiences (Dixon et al., 2014; Murch, Chu, & Clark, 2017).

Illusion of Control Debrief Items. Four questions were adapted from Ladouceur and Sévigny (2005) and presented on completion of the slot machine session, to investigate participants' beliefs about the stopping device during the game play session (see Table 2). Participants in the community sample were asked two further questions about their use of the stopping device in their real-world slot machine play: (5) Do you play slot machines with the stop button function at gambling venues? (6) If so, how often do you make use of the stop button function (0 – Rarely, 1 – Sometimes, 2 - Most of the time, 3 - All the time).

Analysis

By using an authentic slot machine in this study, we could not control the sequence or frequency of gambling outcomes. For example, some participants did not experience any instances of relatively rare outcomes such as the ‘free spins’ bonus feature. The slot machine also does not generate an ‘output file’ in the sense of a conventional psychological task. Thus, for behavioural analysis, it was necessary to code the spin presses and gambling outcomes. Spin presses were coded by affixing a wire to the Repeat Bet button, which triggered an event marker on an adjacent recording laptop, via a Makey Makey (Joylabz, Cambridge, MA) USB input. The wire was taped over the spin button and contacted the metal facia of the EGM when depressed, to close the circuit. The outcomes were coded by videoing the slot machine display with a tripod-mounted webcam (Logitech HD C165). The webcam footage and USB inputs were synchronized using a Biopac MP150 and Acqknowledge 4.4 software.

We classified each outcome as one of five events (the frequencies of each event per participant is shown in Supplemental Online Material Table 1): (1) a loss was defined as a 0 credit return. On losses, there was no visual or auditory accompaniment as the reels stopped spinning; (2) a win was defined as occurring when the credits won exceeded the 9-credit bet; (3) a loss-disguised-as-win (LDW) was defined as a payout between 0 and the 9-credit bet (Dixon et al., 2014); (4) the free-spins bonus feature on Dragon’s Fire occurred when 3 or more of a special symbol (a purple dragon) were presented; the player received 10 to 40 free spins depending on the number of dragon symbols. Bonus spins were initiated automatically by the machine, so that we coded a sequence of free spins as a single outcome. As rare events, many participants did not experience any of these outcomes, and this outcome type was ultimately excluded from analysis, but their presence in the game enables a more common event: (5) the near-miss, when only two dragon symbols were presented. These symbols were larger than, and visually dissimilar to, the regular line symbols, and their appearance was accompanied by a dramatic auditory flourish that increased in pitch with successive dragons. Thus, when 2 dragons were revealed, the player was aware of having been close to getting a significant event.

To measure spin initiation latencies, it was important to control for the length of the feedback itself. On losses and near misses, there was no audio-visual feedback, and so the outcomes were marked as the moment that the final reel stopped. On wins and LDWs, an auditory jingle played while the credit display counted upwards to reveal how many credits were won, and thus the feedback duration was proportionate to the size of the win. We placed the event markers at the offset of the audio-visual feedback, which also signalled that another bet could now be placed. The spin initiation latency was calculated as the interval between the outcome marker and the initiation of the next spin. (As noted by an anonymous reviewer, the stop button can also be applied during the win feedback to interrupt and terminate the feedback. On some machines this may also initiate the next spin, but on the Dragon's Fire EGM it is still necessary to press again to initiate the next spin, and so the spin initiation latencies are always > 0. This may be a technical difference across EGMs and/or jurisdictions.) The latency data were cleaned using an outlier removal procedure (van Selst & Jolicoeur, 1994) (resulting in 2.7% of datapoints being excluded) and log transformed to reduce skew.

Statistical Analysis

Our semi-naturalistic design created some challenges for the behavioural analysis. First, 3 participants did not use the stopping device at all during their session; these participants were necessarily excluded from the behavioural analysis. Second, 12 participants exhausted their $40 endowment within the 20 minute play period, we included the available data for these participants until they exhausted their funds.

Statistical analysis was run in SPSS (Version 22, IBM Corp, Armonk, NY) and the fixed effects regression models in Statistical Analysis Software (SAS) University Edition (SAS Institute Inc., Cary, NC). The reinforcement learning analysis looked at use of the stopping device in the 5 trials before, and 5 trials after, winning outcomes on which the stopping button was or was not deployed. This was tested using a repeated-measures ANOVA model in SPSS with Time (before, after) and Stopping Device (used, not used) as factors. Nine participants did not experience any wins in either the stopping or no-stopping conditions, and were excluded from this analysis.

For the analysis of the latency data, we set up a statistical model that could distinguish use of the stopping device and the four levels of outcome. Here, the unbalanced nature of the data meant that not all participants experienced all eight trial types, therefore we used a trial-by-trial regression approach with the participant identifier entered as a fixed effect, run using the GENMOD procedure in SAS. Using this type of model, participants act as their own control and so the results are not biased by data 'missing not at random' (i.e. when there is a relationship between the propensity of a value to be missing and its values) (Allison, 2005). For the models we present, the propensity for a participant to be missing a data point was dependent upon the number of times they used the stopping device. Log-transformed spin initiation latencies were entered as the dependent variable, and the four levels of Outcome (loss, LDW, win, near-miss) and Stopping Device use (a binary variable where one equalled use of the stopping device) were entered as categorical predictors. Outcome was entered using dummy variables with losses as the reference category. The Outcome x Stopping Device interaction term was entered as the third predictor. A follow-up model included the Participant x Trial Number interaction term as a fourth predictor to control for generalized changes in speed of play due to familiarity or fatigue. As the order of outcomes was not balanced or pre-determined, such effects could potentially bias the results.

Results

Pilot Study

The student sample comprised 21 non-problem gamblers, 6 low-risk gamblers and 3 moderate-risk gamblers. Only 6 of the student participants had played a slot machine in the past year, and only 1 participant played regularly (6 to 11 times in past year). In the student sample, the distribution of stopping presses was positively skewed: the modal bin was 0-25 presses, and 13 participants used the stopping device more than 50 times (for histograms, see Supplementary Figure 1). This variable was log transformed for subsequent analyses. Descriptive statistics are presented in Table 1. The GBQ was significantly correlated with the PGSI score ($r(28) = .38$, $p = .041$), but was not significantly correlated with the number of stop button presses, $r(28) = .25$, $p = .19$. For the game experience ratings on the GEQ, stop button use was correlated significantly with the GEQ Challenge scale, $r(28) = .37$, $p = .046$, but no other GEQ subscales (Competence, $r(28) = .20$, $p = .29$; Immersion, $r(28) = .06$, $p = .75$; Flow, $r(28) = .20$, $p = .30$; Tension, $r(28) = .02$, $p = .94$; Negative Affect, $r(28) = -.04$, $p = .82$; and Positive Affect, $r(28) = .22$, $p = .24$) (for full correlation matrix, see Supplemental Table 2).

Descriptive statistics for the illusion of control debrief questionnaire are shown in Table 2. Six participants (20%) endorsed at least one of the three items regarding their ability to influence the symbols, control the outcomes, and strategies to increase their chances of winning, and specifically mentioned the use of stop button in their written response. This subgroup (M = 115.0, SD = 109.4) did not differ in the number of stop button presses from the participants who did not endorse any control beliefs (M = 76.7, SD = 85.1), t(28) = 1.25, p = .22.

--- Insert Table 1 about here ---

--- Insert Table 2 about here ---

Community Sample

On the PGSI, the community sample comprised 2 non-problem gamblers, 7 low-risk gamblers, 13 moderate-risk gamblers, and 9 high-risk gamblers. Fifteen participants reported weekly slot machine play, and 8 reported playing on a monthly basis. In the 20-minute slot machine session, participants played an average of 206 spins (SD = 59.1). The distribution for the number of stop button presses was similar to the distribution in the student sample: it was positively skewed, with a modal bin of 0-25 presses, but with 14 participants using the stop button more than 50 times. There was a significant positive correlation between the number of stop button presses (log) during the test session and participants' self-reported use of stopping devices in their real-world slot machine play, $r(29) = .48$, $p = .007$.

Descriptive statistics for the questionnaire measures are presented in Table 1. The correlation between the GBQ and PGSI was r(29) = .24, p = .19. There was no significant relationship between the GBQ score and the number of stop button presses, $r(29) = -.09$, $p = .64$. On the GEQ, the only significant association was between stop button use and lower levels of Positive Affect in response to the slot machine session, $r(29) = -.46$, $p = .009$ (Competence, $r(29) = -.19$, $p = .31$; Immersion, $r(29) = .07$, $p = .72$; Flow, $r(29) = -.07$, $p = .72$; Tension/Annoyance, $r(29) = .33$, $p = .07$; Challenge, $r(29) = -.13$, $p = .48$; and Negative Affect, $r(29) = .15$, $p = .43$) (for full correlation matrix, see Supplemental Table 3). The descriptive results for the illusion of control debrief questionnaire are shown in Table 2. Fifteen participants (48%) endorsed one of more of the illusory control items and referred to the stopping device in their written response. However, this subgroup of the community sample (M = 101.0, SD = 112.9) did not differ significantly in the number of stop button presses from participants who did not endorse the device as effective, $t(29) = 1.06$, $p = .30$, with the latter subgroup continuing to use the device at moderate levels (M = 49.6, SD = 53.5).

Reinforcement Learning. For the community participants, we coded each winning outcome depending on whether the stop button was or was not used on that spin, and we calculated the number of stop presses on the five spins before and after those wins. In a 2x2 repeated measures ANOVA, there was a significant Stopping Device x Time interaction, $F(1,21) = 6.05$, $p = .02$ (see Figure 1). This was qualified by a significant main effect of the Stopping Device, $F(1,21) = 19.61$, $p < .001$; unsurprisingly, stop button use was higher either side of stopping device wins relative to regular wins. The main effect for the Time factor was non-significant, $F(1, 21) = 0.11$, $p = .75$. Analysis of simple main effects showed that stop button use increased significantly following stopping device wins compared to the pre-win baseline, $t(21) = 2.23$, $p = .04$, but that there was no reliable change in stop button use following regular wins, $t(21) = 1.27$, $p = .22$.

--- Insert Figure 1 about here ---

Spin Initiation Latencies. We examined the spin initiation latencies as a function of the outcome and the use of the stopping device on the prior trial. Losses comprised of 81.4% of the outcomes, while LDWs, wins, bonuses and near-misses comprised 5.5%, 8.7%, 0.4% and 4.1% of outcomes respectively (see Supplemental Table 1). In the fixed effects regression, when the stop button was not used, the latencies were significantly longer following wins, LDWs, and near-misses, compared to losses. The Outcome by Stopping Device interaction terms were significant for losses, LDWs, and wins, such that the latencies on each of these three outcomes were shorter following spins when the stopping device was used than when it was not used (See Table 3 and Figure 2). These results remained significant in a follow-up analysis adding the participant x trial number interaction term, indicating that the spin initiation latency effects are stable across the slot machine session.

--- Insert Table 3 about here ---

--- Insert Figure 2 about here ---

Discussion

The current study examined gamblers' use of the stopping device as a specific structural characteristic of modern EGMs. We sought to test two candidate mechanisms for why players deploy this feature; one based on an enhanced sense of control over game outcomes, and the other based upon the speed of play. These mechanisms appeal to distinct theoretical frameworks, the cognitive and behavioural models of gambling, respectively. In both a student pilot study and a sample of community-recruited regular slot machine gamblers, we observed a distribution in use of the stopping device, which was skewed towards low use (modal category 0-25 presses in both groups), but with a sizable subset using the feature more than 50 times within a 20 minute session (students: 13/30; community: 14/31) (see Supplementary Figure 1). In the community sample, the number of stop button presses in the lab session was correlated with their self-reported use of stopping devices in their real-world gambling, supporting the ecological validity of our laboratory environment.

Two analyses tested tenets of the cognitive model of gambling, which posits that the use of the stopping device should relate to erroneous gambling beliefs, specifically pertaining to skill and control. First, there was no reliable association between use of the stopping device and individual differences on the GBQ trait measure. Second, although a subset of players expressed erroneous beliefs about the effectiveness of the stopping device on a debrief questionnaire (students: 20%; community: 48%), these players did not differ significantly in their use of the feature from the players who perceived the game more accurately.

The speed of play hypothesis was only tested in the regular slot machine gamblers, where a panel-based regression analysis showed that spin initiation times were significantly shorter (i.e. faster) following losses, LDWs and wins that involved the use of the stopping device. This generalized effect, which was at trend for the fourth outcome type, the near-misses, indicates a more invigorated, intense style of play when the stop button is being deployed, consistent with the results of Dixon, Larche et al., (2017) measuring arousal and the force of button presses. This effect will combine with the inherent action of the stopping device to shorten the reel spin duration, so that in our data, players who were regularly deploying the stopping device completed up to 57% more spins per minute than players who did not use the stopping device[1]. We note that the stop button can also be used to terminate the (sometimes lengthy) winning feedback, thus constituting a third means by which the speed of play can be increased. The regression model of the latency data also showed a difference in spin latencies as a function of the prior outcome: latencies were shortest following losses and longer following wins and LDWs, corroborating the classic post-reinforcement pause effect (Delfabbro & Winefield, 1999, Dixon et al., 2013; see also Verbruggen et al., 2016 for an alternative interpretation). The significant post-reinforcement pause following LDWs replicates an earlier finding by Dixon et al. (2014) and strengthens the argument that LDWs are processed appetitively, as ‘mini-wins’.

The behavioural model of gambling inspired a further reinforcement learning analysis, looking at how the use of the stop button changed following spins where application of the device resulted in a winning outcome (Skinner, 1992). The significant interaction was driven by an increase in stop presses on the five trials after such wins. This expression of operant conditioning is evidently superstitious, in so far as the stopping device has no direct contingency with winning. Such superstitions can even arise following single pairings, when a salient outcome follows a novel or unconventional behaviour, such as when a sports fan identifies his “lucky shirt” after his team wins an important fixture (Risen, 2016). In these studies, superstitious behaviours can also be detached from cognitive beliefs about the ritual: people may repeatedly perform behaviours that they ‘know’ are pointless (Risen, 2016). In slot machine play, the infrequent nature of wins makes them salient outcomes, and regular players may perceive the stopping device to be a novel

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[1] As there were 3 participants who did not use the stopping device at all, we compared the pace of play in those individuals (mean 10.5 spins per minute, or a spin every 5.7 s) against the pace of play in the 3 participants who recorded the highest number of stop presses (mean 16.6 spins per minute, or a spin every 3.6 s)

or unconventional way to play the slot machine, setting up prime conditions for such superstitious conditioning.

The disparity between the findings for the cognitive and behavioural predictions in our data merits some comment. The speed of play analysis relied on panel data of thousands of individual trials, whereas our cognitive measures relied on small numbers of items, and thus may be less reliable and have lower power. However, the reinforcement learning model also relied on relatively few instances (M = 5.7, see Supplemental Table 1) of the key event. Certainly, our sample sizes were also reasonably modest for correlational tests with the GBQ, which are sensitive to the ranges and distributions of both variables. The GBQ did capture individual differences within both samples; the regular slot machine gamblers scored over 1 standard deviation higher on the GBQ than the student sample (see Table 1) and the GBQ correlated significantly with problem gambling severity scores in the student sample. This relationship was positive, albeit non-significant, in the community sample. As a relationship between problem gambling severity and cognitive distortions is widely observed in past work (Flack & Morris, 2017; Mackay & Hodgins, 2012; Steenbergh et al., 2002), we assume this reflects a Type 2 error. The pattern of correlations on the GBQ did not change qualitatively for the Illusion of Control subscale. Critically, we are not aware of any past work in which GBQ trait scores predicted direct, *in situ* measures of gambling behaviour, such as bet size or persistence.

Perhaps the more striking result in our data is that although many participants expressed cognitive distortions regarding the stopping device on the debrief questionnaire, these beliefs did not align with how frequently they used the feature during the session. This is reminiscent of the argument that faulty beliefs during gambling (e.g. on the think-aloud procedure) could reflect "post-hoc rationalizations" of a lower-level process (Nisbett & Wilson, 1977). By this account, the gambler confabulates an elaborate explanation for their use of the stopping device, but these expressed cognitions are mere 'epiphenomena' that have no causal value in predicting behaviour that has been conditioned via mechanisms operating below conscious awareness. Within the influential dual systems approach to decision-making, the deliberative System 2 may attempt to rationalize processing handled by the fast, automatic System 1 (Evans & Coventry, 2006). A previous study evaluating the effects of a stopping device reported findings that were ostensibly more in line with the cognitive model (Ladouceur & Sevigny, 2005), although that study did not demonstrate a direct link between the expressed illusion of control beliefs and the effect on slot machine persistence, and thus the faulty beliefs could still reflect post-hoc rationalizations of a conditioning process. Ladouceur and Sevigny did not report the actual frequency of stop button usage. In the more recent study by Dixon, Larche et al. (2017), it is notable that the stop button condition was associated with more intense play, despite the low overall level (13.6%) of erroneous cognitions about the stop button. This chimes with our own data in suggesting a dissociation between beliefs and behaviour. Both our study (48%) and Ladouceur & Sevigny (41-87%) observed markedly higher rates of erroneous beliefs; the low rate reported by Dixon, Larche et al. (2017) may be a consequence of specific signage regarding stop buttons on EGMs in Ontario, Canada.

A distinct interpretation of our findings is predicated on the fact that both the debrief questionnaire and GBQ were taken *outside* of the period of slot machine play, whereas the behavioural measures were (inherently) obtained during play. The concept of "double switching"

(Sevigny & Ladouceur, 2003) highlights how cognitive distortions may be activated during gambling, such that a player may express more rational perceptions about the game in ratings taken either before or after the session. If true, this would compromise most research that interrogates gambling-related distortions as stable, trait-like phenomena, and testing this interpretation would require the development of in-game, state-related measures (Schimmenti, Infanti, Badoud, Laloyaux, & Billieux, 2017).

There were few associations seen with the subjective experience of slot machine play, using the GEQ as a state scale that was originally designed for assessing video games, but has been widely applied to EGM experience (Dixon et al., 2014). Notably, the use of the stopping device was not associated with the GEQ Competency scale that captures perceptions of skill, the facet with clearest relevance to illusory control. Stop button usage was not associated with GEQ Flow scores as an index of slot machine immersion (absorption) (Dixon, Stange, et al., 2017; Murch et al., 2017). In the student sample, a positive relationship was observed between stopping use and the GEQ Challenge scale. Challenge is a common motive for gambling in college students (Neighbors, Lostutter, Cronce, & Larimer, 2002), and as a game of pure chance, a subjective perception of a slot machine as "challenging" could indicate that these participants experienced the game as benefitting from practice, in line with some degree of illusory control. The correlation with GEQ Challenge was not confirmed in the regular slot machine players, in whom higher stop button usage was associated with lower levels of Positive Affect on the GEQ. This latter effect is noteworthy but could reflect a third variable issue with the PGSI, which was also negatively correlated with Positive Affect in the community sample. The inconsistencies in these

GEQ correlations across samples (and lack of correction for multiple comparisons) indicates that these exploratory effects should be treated with caution.

Our study has a number of strengths. We used an authentic slot machine that is currently available in local casinos. We tested regular slot machine players, who were incentivized with a cash bonus proportionate to their remaining credits upon completion. Unlike prior studies that directed participants to use or not use the stopping device across different conditions (Dixon, Larche, et al., 2017; Ladouceur & Sevigny, 2005; Loba et al., 2001), we informed players that the game included a stopping device, and let them choose whether and how often to use the feature. We overcame a significant technical hurdle in extracting button press and outcome timing data from real EGM play, and our measure of stop button presses was correlated with self-reported real-world stopping device usage. However, the semi-naturalistic nature of our design highlights a number of challenges that arise in "hybrid" designs using authentic EGMs in laboratory environments. First, although our procedure for marking the timing of spin presses was automatic (via a USB input device), the coding of spin outcomes was performed manually based on webcam footage, and this was time consuming to the extent that we restricted these analyses to the community sample of regular slot machine players. Over a 20 minute session, there was substantial variation in profit and the frequency of the various outcome types, including some participants with missing data in particular cells. Only some participants experienced the free-spins bonus features, which could not be analyzed. By allowing players to deploy the stopping device naturalistically, some participants elected to not use the device and others used the device on almost every spin. The unbalanced nature of the data was accommodated with the use of a fixed effects regression on the spin latency data, which allows each participant to contribute a different mix of outcomes. However, the use of any statistical technique cannot overcome heterogeneity in the session characteristics; for example that some participants experience multiple wins while others face sustained losses. The use of realistic slot machine simulators is the most obvious way to constrain this variability.

The results of our experiments have a number of implications for gambling policy. As a standard feature of modern EGMs, regulators should be aware that the availability of a stopping device has a dual action on the speed of play, shortening both the spin duration and the latency to the next spin. As a consequence, the speed of play can increase substantially in a player making maximal use of the stop button. Gambling harms may be increased by the availability of stopping devices on EGMs, given the negative expectancy of EGMs, the close associations reported between EGM losses and problem gambling (Markham et al., 2016), and evidence that problem gamblers are attracted to faster games (Loba et al., 2001). Stopping devices have been prohibited in some jurisdictions (e.g. Australia) and are subject to specific messaging in other jurisdictions (e.g. Ontario, Canada), but remain a widespread structural characteristic of modern EGMs. Our evidence of superstitious conditioning and invigorated play in relation to the stopping device supports its inclusion as a relevant dimension in risk assessment tools (e.g. Meyer et al., 2011). At the same time, our data caution against a straightforward assumption that this feature operates via a (cognitively-mediated) illusion of control. Our results indicate that stopping devices may be more appropriately categorized as an event speed feature. As many jurisdictions contemplate the introduction of “skill-based” EGMs, there is a pressing need to understand the psychological consequences of these features. We also endorse efforts to use big data from player tracking of online gambling or loyalty card programs, to infer the core dimensions for risk assessment in a data-driven way (Leino et al., 2014).

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Table 1: Descriptive statistics for the student and community samples, mean (SD)

	Student sample	**Community sample**
PGSI	0.7 (1.4)	6.4 (6.6)
Stop Presses	84.4 (89.7)	74.5 (89.8)
GBQ	53.0 (17.3)	72.6 (17.5)
GEQ Competence	0.73 (0.83)	1.31 (1.13)
GEQ Immersion	1.10 (0.79)	1.69 (1.06)
GEQ Flow	0.98 (0.78)	1.65 (1.08)
GEQ Tension/Annoyance	0.80 (0.79)	1.00 (1.10)
GEQ Challenge	0.50 (0.81)	1.00 (1.06)
GEQ Positive Affect	1.45 (0.93)	1.13 (1.14)
GEQ Negative Affect	1.17 (0.96)	1.82 (1.11)

*Exploratory analysis compared the two samples. An independent sample t-test was done to compare the stop button presses in Study 1 and 2, and no significant difference was found. An independent sample t-test showed that the regular slot machine players scored higher on the GBQ ($t(59)=-4.28$, $p<.001$), and on GEQ Competence, $t(59)=-2.25$, $p=.03$, Immersion, $t(59)=-2.47$, $p=.02$, Flow, $t(59)=-2.73$, $p=.008$, Challenge, $t(59)=-2.06$, $p=.04$, and Negative Affect, $t(59)=-2.47$, $p=.02$.

Table 2.

Results from the Illusion of Control debrief questionnaire

Item	Frequency, n (%) Study 1 (N=30)	Frequency, n (%) Study 2 (N=31)
Do you believe that a player can influence the symbols on the screen after having activated the play button? ("Yes")	3 (10.0)	12 (38.7)
Is there a method for controlling the outcome of the game after the play button has been activated? ("Yes")	5 (16.7)	14 (45.2)
If you were to obtain a winning combination, would it be due to chance, skill or a combination of the two? ("Skill" or "Combination of the two")	3 (10.0)	10 (32.3)
Are there any strategies that could enable you to increase your chance of winning after the play button has been activated? ("Yes")	2 (6.7)	10 (32.3)

Table 3.

Fixed effect analysis for the spin initiation latencies

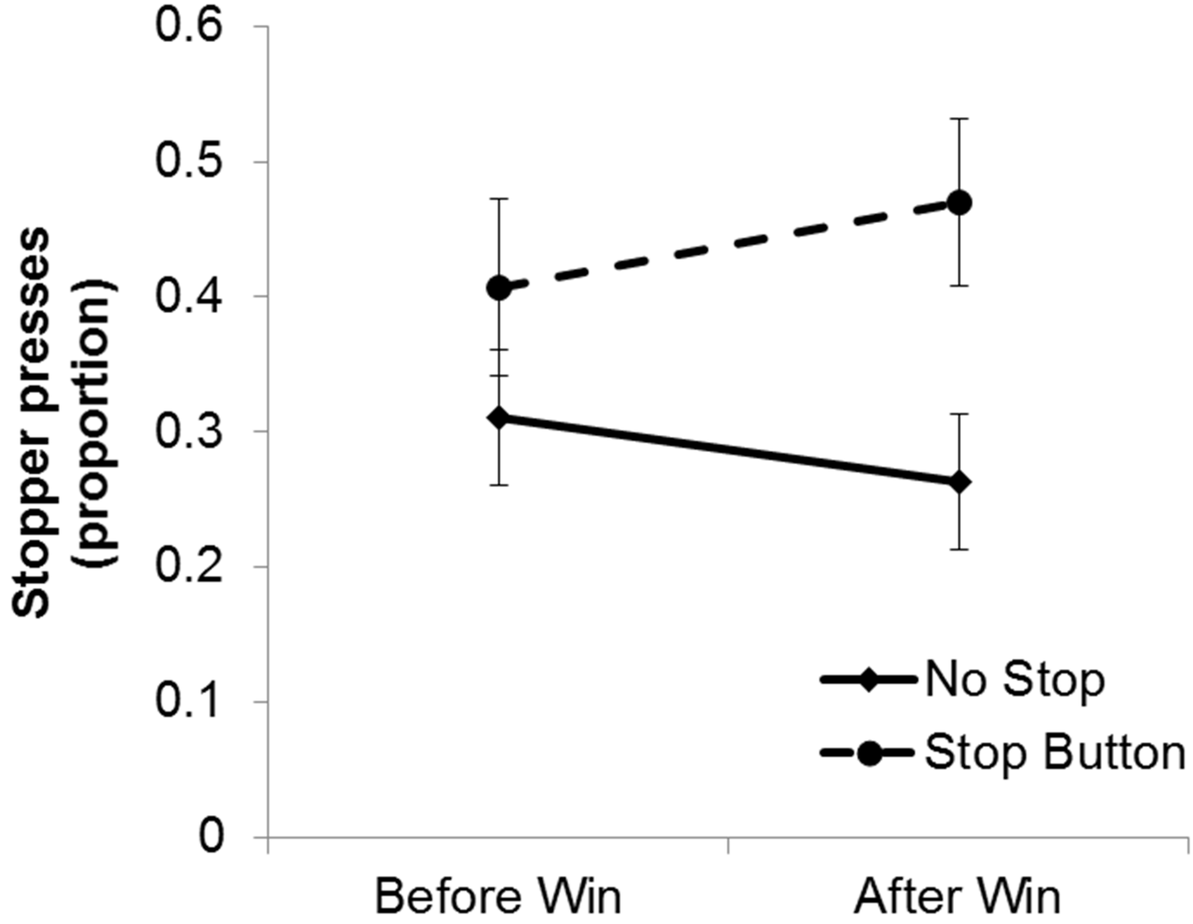
	Types of outcomes							
	Loss		LDW		Win		Near-miss	
Variables	*β (SE)*	*p*	*β (SE)*	*p*	*β (SE)*	*p*	*β (SE)*	*p*
Outcome	-	-	.45 (.03)	<.001	.33 (.03)	<.001	.19 (.04)	<.001
Outcome x Stop Button	-.30 (.02)	<.001	-.21 (.05)	<.001	-.25 (.06)	<.001	-.10 (.06)	.10

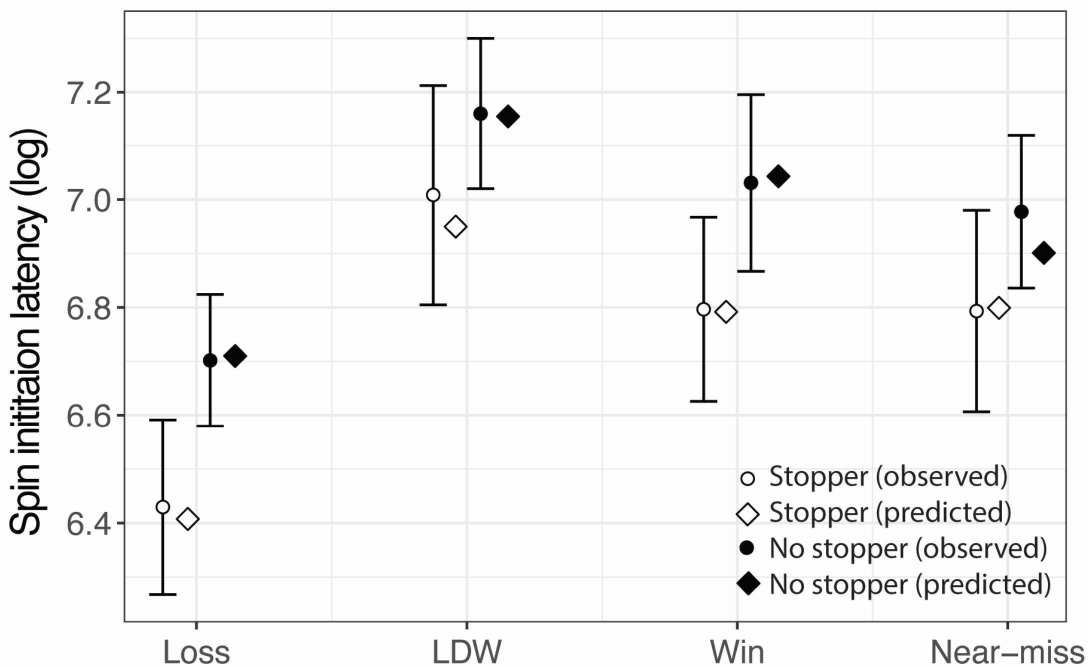
Note. The main effects of Outcome indicates difference (relative to losses as the reference category) when the stopping device was not used (i.e. equals zero). The Outcome x Stopping Device interaction terms indicate the differences between stop button and no stop button trials at each level of Outcome. *SE* = standard error. Subject was also entered as a categorical predictor; individual beta values are not reported due to their arbitrary nature, derived from comparison against the first subject.

Figure Legends

Figure 1. Proportion of stop button presses in the 5 trials either side of winning outcomes where participants either did, or did not, use the stopping device. Error bars represent standard error of the mean.

Figure 2. Spin initiation latencies following the four slot machine outcome types, with and without preceding stopper use. Circles represent the observed data (including only participants who experienced the trial type), with error bars representing the standard error of the mean. Diamonds represent predictions of the regression model. Data shown are log transformed (for reference, 7 = 1097 msec).


0.6
0.5
0.4
0.3
0.2
0.1
0
Stopper presses (proportion)
No Stop
Stop Button
Before Win
After Win



Spin inititaion latency (log)
7.2
7.0
6.8
6.6
6.4
Loss
LDW
Win
Near–miss
Stopper (observed)
Stopper (predicted)
No stopper (observed)
No stopper (predicted)

Supplementary Material

Supplementary Table 1: The number of each outcome type for each participant in the community sample

		Loss				LDW			
	Total spins	No Stop	Stop	Loss total	Loss (%)	No stop	Stop	LDW total	LDW (%)
1	231	58	136	194	83.98	6	5	11	4.76
2	102	86	2	88	86.27	5	0	5	4.90
3	175	129	7	136	77.71	11	1	12	6.86
4	201	144	10	154	76.62	13	1	14	6.97
5	209	140	33	173	82.78	12	3	15	7.18
6	245	81	128	209	85.31	2	5	7	2.86
7	196	149	0	149	76.02	10	0	10	5.10
8	237	90	109	199	83.97	9	6	15	6.33
9	206	157	9	166	80.58	8	3	11	5.34
10	173	120	23	143	82.66	8	0	8	4.62
11	225	193	5	198	88.00	14	1	15	6.67
12	132	69	43	112	84.85	2	1	3	2.27
13	211	104	54	158	74.88	12	0	12	5.69
14	230	74	107	181	78.70	11	2	13	5.65
15	180	138	0	138	76.67	12	0	12	6.67
16	223	181	3	184	82.51	17	0	17	7.62
17	185	138	6	144	77.84	9	0	9	4.86
18	178	102	45	147	82.58	11	0	11	6.18
19	293	49	176	225	76.79	4	13	17	5.80
20	121	96	0	96	79.34	11	0	11	9.09
21	180	59	86	145	80.56	4	6	10	5.56
22	372	73	235	308	82.80	5	13	18	4.84
23	265	91	127	218	82.26	7	8	15	5.66
24	186	107	44	151	81.18	6	0	6	3.23
25	346	7	280	287	82.95	0	15	15	4.34
26	186	121	21	142	76.34	11	3	14	7.53
27	178	58	93	151	84.83	5	4	9	5.06
28	237	174	16	190	80.17	15	1	16	6.75
29	145	112	15	127	87.59	4	0	4	2.76
30	212	176	1	177	83.49	8	0	8	3.77
31	119	97	1	98	82.35	5	0	5	4.20
Mean	205.8	108.8	58.6	167.4	81.4	8.3	2.9	11.2	5.5
Max.	372	193	280	308	88	17	15	18	9.1
Min.	102	7	0	88	74.9	0	0	3	2.3

	Total spins	Win				Bonus			
		No stop	Stop	Win total	Win (%)	No stop	Stop	Bonus total	Bonus (%)
1	231	9	11	20	8.66	0	1	1	0.43
2	102	4	0	4	3.92	0	0	0	0.00
3	175	17	2	19	10.86	0	0	0	0.00
4	201	21	1	22	10.95	1	0	1	0.50
5	209	11	2	13	6.22	1	0	1	0.48
6	245	6	9	15	6.12	1	1	2	0.82
7	196	24	0	24	12.24	1	0	1	0.51
8	237	12	5	17	7.17	0	1	1	0.42
9	206	18	1	19	9.22	1	0	1	0.49
10	173	16	2	18	10.40	0	0	0	0.00
11	225	4	1	5	2.22	0	0	0	0.00
12	132	7	4	11	8.33	0	0	0	0.00
13	211	20	8	28	13.27	0	0	0	0.00
14	230	10	14	24	10.43	0	0	0	0.00
15	180	19	0	19	10.56	3	0	3	1.67
16	223	12	0	12	5.38	1	0	1	0.45
17	185	22	2	24	12.97	0	0	0	0.00
18	178	10	4	14	7.87	0	0	0	0.00
19	293	10	22	32	10.92	1	1	2	0.68
20	121	10	0	10	8.26	0	0	0	0.00
21	180	6	15	21	11.67	0	1	1	0.56
22	372	9	19	28	7.53	0	3	3	0.81
23	265	13	11	24	9.06	0	0	0	0.00
24	186	13	4	17	9.14	0	4	4	2.15
25	346	0	30	30	8.67	0	0	0	0.00
26	186	18	2	20	10.75	1	0	1	0.54
27	178	4	7	11	6.18	0	1	1	0.56
28	237	20	0	20	8.44	0	0	0	0.00
29	145	8	0	8	5.52	0	0	0	0.00
30	212	17	0	17	8.02	0	0	0	0.00
31	119	11	0	11	9.24	0	1	1	0.84
Mean	205.9	12.3	5.7	18.0	8.7	0.35	0.45	0.8	0.38
Max.	372	24	30	32	13.3	3	4	4	2.2
Min.	102	0	0	4	2.22	0	0	0	0

	Total spins	Near-miss No Stop	Stop	NM total	NM (%)
1	231	3	2	5	2.16
2	102	5	0	5	4.90
3	175	8	0	8	4.57
4	201	10	0	10	4.98
5	209	7	0	7	3.35
6	245	7	5	12	4.90
7	196	12	0	12	6.12
8	237	3	2	5	2.11
9	206	8	1	9	4.37
10	173	3	1	4	2.31
11	225	7	0	7	3.11
12	132	2	4	6	4.55
13	211	11	2	13	6.16
14	230	2	10	12	5.22
15	180	8	0	8	4.44
16	223	8	1	9	4.04
17	185	8	0	8	4.32
18	178	2	4	6	3.37
19	293	5	12	17	5.80
20	121	4	0	4	3.31
21	180	2	1	3	1.67
22	372	3	12	15	4.03
23	265	3	5	8	3.02
24	186	1	7	8	4.30
25	346	0	14	14	4.05
26	186	4	5	9	4.84
27	178	0	6	6	3.37
28	237	10	1	11	4.64
29	145	4	2	6	4.14
30	212	10	0	10	4.72
31	119	1	3	4	3.36
Mean	205.9	5.2	3.2	8.4	4.1
Max.	372	12	14	17	6.2
Min.	102	0	0	3	1.7

Supplemental Table 2.

Correlation matrix for the GEQ subscales, GBQ, PGSI and stop button presses in the pilot study (student participants)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Stop presses	-											
2. PGSI	.21	-										
3. GEQ - Competence	.20	.46**	-									
4. GEQ - Immersion	.06	.11	.36	-								
5. GEQ - Flow	.20	.15	.23	.31	-							
6. GEQ - Tension	.02	.28	-.20	.01	.27	-						
7. GEQ - Challenge	.37*	.26	.18	.18	.57**	.07	-					
8. GEQ - Negative Affect	-.04	.17	.05	.09	.22	.36	.07	-				
9. GEQ - Positive Affect	.22	.45*	.68**	.30	.40*	-.17	.48**	.06	-			
10. GBQ - IoC	.22	.38*	-.02	-.15	.10	.02	.10	-.29	-.02	-		
11. GBQ - Luck	.23	.33	.20	.07	.48*	.11	.27	-.10	.18	.74**	-	
12. GBQ - Full score	.25	.38*	.12	-.02	.34	.08	.21	-.19	.10	.91**	.96**	-

*p < .05
**p < .01

Supplemental Table 3.

Correlation matrix for the GEQ subscales, GBQ, PGSI and stop button presses for the regular slot machine gamblers

	1	2	3	4	5	6	7	8	9	10	11	12
1. Stop presses	-											
2. PGSI	.10	-										
3. GEQ - Competence	-.19	-.21	-									
4. GEQ - Immersion	.07	.15	.45*	-								
5. GEQ - Flow	-.07	.35	.39*	.64**	-							
6. GEQ - Tension	.33	.57**	-.32	-.17	-.04	-						
7. GEQ - Challenge	-.13	.26	.53**	.62**	.55**	.11	-					
8. GEQ - Negative Affect	.15	.08	-.17	-.54**	-.49**	.59*	-.39*	-				
9. GEQ - Positive Affect	-.46**	-.39*	.69**	.34	.41*	-.52**	.32	-.46**	-			
10. GBQ - IoC	.04	.18	.17	.25	.20	.07	.29	-.14	.18	-		
11. GBQ - Luck	-.16	.24	.05	.13	.36*	.02	.31	-.23	.08	.61**	-	
12. GBQ - Full score	-.09	.24	.11	.20	.32	.05	.34	-.21	.13	.85**	.93**	-

*p < .05
**p < .01

Supplemental Figure 1: Distribution of stop button presses in (top) the student pilot sample (M = 84.4, SD = 89.7), (bottom) the community sample (M = 74.5, SD = 89.8).