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International Gambling Studies

ISSN: 1445-9795 (Print) 1479-4276 (Online) Journal homepage: http://www.tandfonline.com/loi/rigs20

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To cite this article: Gaëtan Devos, Luke Clark, Pierre Maurage, Marlena Kazimierczuk & Joël Billieux (2015) Reduced inhibitory control predicts persistence in laboratory slot machine gambling, International Gambling Studies, 15:3, 408-421, DOI: 10.1080/14459795.2015.1068351

To link to this article: http://dx.doi.org/10.1080/14459795.2015.1068351

Published online: 15 Nov 2015.

International Gambling Studies, 2015
Vol. 15, No. 3, 408–421, http://dx.doi.org/10.1080/14459795.2015.1068351

Reduced inhibitory control predicts persistence in laboratory slot machine gambling

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(*Received 23 December 2014; accepted 16 June 2015*)

Impairments in inhibitory control characterize a range of addictive behaviours including gambling disorder. This study investigated the relationship between a neuropsychological measure of inhibitory control and behaviour on a simulated slot machine that included a measure of gambling persistence, in a non-clinical sample of regular gamblers. Regular gamblers ($n = 75$) performed a laboratory slot machine task for 30 trials where they could win real money, followed by a persistence phase under extinction (i.e. without wins). Participants also completed a stop-signal task, along with measures of gambling-related cognitions, social desirability, and symptoms of disordered gambling. In hierarchical regression models, reduced inhibitory control was found to predict greater persistence and a higher subjective desire to play again after both wins and near-misses (i.e. unsuccessful outcomes close to the jackpot). These data illustrate the impact of low inhibitory control on relevant behavioural tendencies in a group of regular gamblers. Our results help elucidate a cognitive process that may contribute to problem gambling, with implications for screening and treatment.

Keywords: gambling; disordered gambling; inhibition; persistence; slot machine; laboratory gambling; pathological gambling

Introduction

Gambling is a common recreational activity in the general population. In most cases, gambling can be considered as an unproblematic source of mainstream entertainment (Shaffer, LaBrie, LaPlante, Nelson, & Stanton, 2004). However, for a subset of individuals, gambling can become persistent and uncontrolled, with substantial impacts upon social and occupational function (Ladd & Petry, 2002; Potenza et al., 2001). Although initially classified in the impulse control disorders, 'Gambling Disorder' was recently realigned to the 'Substance-Related and Addictive Disorders' in the DSM-5 (American Psychiatric Association [APA], 2013). One line of evidence supporting this reclassification was neurocognitive studies illustrating similar impairments in self-control (e.g. impulsivity traits, inhibitory control) in problem gambling to those seen in substance addictions (Goudriaan, Oosterlaan, de Beurs, & Van den Brink, 2004; Groman, James, & Jentsch, 2009; Smith, Mattick, Jamadar, & Iredale, 2014; Verdejo-García, Lawrence, & Clark, 2008). These characteristics play a role in etiological models of problem gambling (e.g. Blaszczynski & Nower, 2002).

One facet of self-control that has received major attention is prepotent response inhibition; that is, the ability to suppress dominant or automatic motor responses

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(Friedman & Miyake, 2004). While deficits in response inhibition (using stop-signal and go/no-go tasks) are a replicated effect in groups of problem gamblers compared to healthy control participants (Brevers et al., 2012; Fuentes, Tavares, Artes, & Gorenstein, 2006; Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005, 2006; Kertzman et al., 2008; Roca et al., 2008), it is also a heterogeneous effect. Some studies have failed to detect significant group impairments, often in less severe, non-clinical samples (Carlton & Manowitz, 1992; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009; Rodriguez-Jimenez et al., 2006). Using both between-groups (i.e. case-control) and intra-group (i.e. within the pathological gamblers) analyses, Billieux, Lagrange, et al. (2012) found that only 40% of pathological gamblers reached a criterion for impairment on the stop-signal task,[1] despite a statistically significant overall group impairment relative to healthy controls. This variability in response inhibition may have value as a marker for relapse prediction in problem gamblers (Goudriaan, Oosterlaan, De Beurs, & Van Den Brink, 2007). Within the Pathways Model by Blaszczynski and Nower (2002), neurocognitive manifestations of impulsivity were posited to be restricted to a subgroup of 'antisocial impulsive' gamblers, who were further characterized by ADHD (attention deficit hyperactivity disorder) co-morbidities and frontal lobe dysfunction.

Despite the emerging role for impulsivity and inhibitory control in problem gambling, few studies have examined the role of these neurocognitive markers in shaping gambling tendencies. The aim of the current study was to examine the relationship between inhibitory control and gambling persistence in regular gamblers, using an experimental slot machine task that has proven useful to simulate gambling in the laboratory (Billieux, Van der Linden, Khazaal, Zullino, & Clark, 2012; Clark, Lawrence, Astley-Jones, & Gray, 2009). In this task, participants gamble on a simplified two-reel device and earn small amounts of real money. After a fixed period of play (30 trials), participants enter a persistence phase in which they can continue to play, or quit the game whenever they want. Unknown to participants, no further wins are delivered in the persistence phase (this is termed responding under extinction). Prepotent response inhibition was measured with the stop-signal task (Dougherty, Mathias, Marsh, & Jagar, 2005). This procedure was favoured over the alternative go/no-go test because the two tasks are increasingly linked to distinct cognitive constructs (Hamilton et al., 2015; Verbruggen & Logan, 2008). The go/no-go task assesses refraining from action initiation, using a fixed stimulus-stop mapping that is likely to become automatized over the course of the task. The stop-signal assessed the cancellation of an ongoing response, such that a go process is initiated on every trial, and must be curtailed following a subsequent stop-signal. The stop-signal task is thus better suited to measuring inhibitory control as an executive (or controlled) process. An advantage of the current study is thus the use of recognized laboratory tasks to operationalize the key constructs.

We hypothesized that poor stop-signal inhibition would predict persistent play on the slot machine task. We assessed the incremental predictive value of inhibitory control over trait gambling-related cognitions, which we have previously found to predict behaviour on the slot machine task (Billieux, Van der Linden, et al., 2012), as well as social desirability, differences in win reactivity on the slot machine task, and symptoms of problem gambling.

Method

Participants and procedure

Participants were regular gamblers recruited via advertisement. The sample comprised undergraduate students (52.6%), employees (33.3%) and others (14.1%; e.g. retired, unemployed and self-employed people). The main inclusion criterion was that participants must have gambled at least once per month in the last year on games of chance. In addition, further inclusion criteria were to be fluent in French and to be at least 18 years old. Exclusion criteria were being psychology students (given potential familiarity with some of the study instruments), recent or ongoing self-reported depression or anxiety, and any self-reported neurological disorder. Thirty-five participants were tested in Belgium and 40 were tested in Switzerland. The sample comprised 75 participants (45 female) with an average age of 28.5 years (SD = 11.1, range 18–68). The average length of education was 13.5 years (SD = 2.6, range 6–18). The protocol was approved by the ethical committee of the Psychological Sciences Research Institute (IPSY) of the Université Catholique de Louvain. All participants provided written informed consent.

Participants were tested individually in a quiet laboratory. They first completed a questionnaire assessing socio-demographic variables and gambling behaviour (types and frequency of different gambling activities). Next, participants performed two computerized tasks: the stop-signal task followed by the slot machine task. Our rationale for administrating the stop-signal task first was that it comprises a fixed number of trials, whereas the slot machine task contains a variable persistence phase that is controlled by the participant. It can thus be assumed that 'resource depletion' or boredom effects of the initial task are better with the stop-signal administered first. In addition, we reasoned that the slot machine task could induce affective states (either positive or negative), which are known to influence subsequent inhibitory control (Rebetez, Rochat, Billieux, Gay, & Van der Linden, 2015; Verbruggen & De Houwer, 2007). After performing the laboratory tasks, participants completed the following self-reported questionnaires in a randomized order: Gambling-Related Cognitions Scale (GRCS), South Oaks Gambling Screen (SOGS) and Social Desirability Scale (DS-36). After completing the questionnaires, participants were debriefed and received their winnings from the slot machine task.

Slot machine task

The slot machine task (Clark et al., 2009) was originally designed to compare three types of gambling outcomes: wins, near-misses (i.e. unsuccessful outcomes close to the jackpot) and full-misses. Rates of near-misses around 30% have previously been linked to greater levels of gambling persistence (Côté, Caron, Aubert, Desrochers, & Ladouceur, 2003; Kassinove & Schare, 2001), and thus our task used a pseudo-random trial sequence to ensure a 2/6 (i.e. 30%) rate of near-misses, with a proportionate number of wins (1/6) and full-misses (3/6). After 4 practice trials, participants played 30 trials with monetary reward available. The participant was given an endowment of 5 euros[2] (Belgian participants) or 5 CHF (Swiss francs, Swiss participants) to play the task. Participants were told that their profits would be honoured in real money, as a prerequisite for ecological validity in gambling research (e.g. Ladouceur, Sévigny, Blaszczynski, O'Connor, & Lavoie, 2003; Wulfert, Franco, Williams, Roland, & Maxson, 2008). The pay-off structure of the task (0.15 cent wager for 1 euro/CHF win) meant that participants completed the fixed period with a modest profit. After these 30 trials, participants entered a persistence phase in which they could continue to play, or quit the game at any time. No further wins were delivered in the persistence phase, so that there was a direct inverse relationship between length of play and final profit, and continued play would ultimately lead to 'bankruptcy'. Near-misses continued to occur on one-third of trials in the persistence phase.

Before starting the task, participants selected their 6 'play icons' for the slot machine (objects like a banana or cowboy boot) from 16 alternatives (arranged in a 4 × 4 matrix),

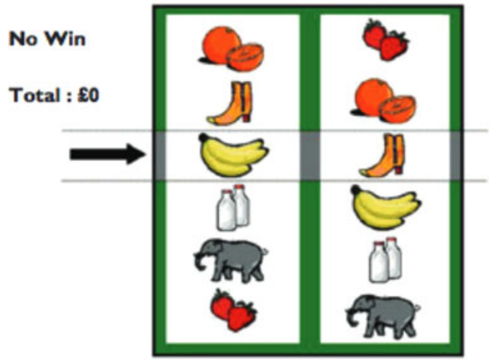

Figure 1. Slot machine task, reprinted from Clark et al. (2009). The actual task used in the present experiment used a French translation of all text, with wins in euros or Swiss francs (CHF).

to enhance their level of involvement. Participants were informed that the icons could vary in the chances of winning during the game.

The task display (see Figure 1) resembles a two-reel slot machine. On each trial, the participant chooses a play icon on the left reel, which is then held in position. If the participant failed to choose an icon within a 5-second window, 0.15 euro/CHF was wagered automatically. The right reel then spun for 2.8–6 seconds, and decelerated to a standstill on one of the 6 icons. If the two reels align on the central 'payline', the participant wins 1 euro/CHF. Trials where the right-hand reel stopped one position from the payline were classified as near-misses, and our analysis contrasted these against trials where the right-hand reel stopped from more than one position from the payline ('full-misses'). The outcome was displayed for 4 seconds, followed by an inter-trial interval (2–7 seconds). Three subjective ratings were acquired on each trial. After the selection phase, participants were asked 'How do you rate your chances of winning?' (21-point scale, from 0 to 100). After the outcome phase, participants were asked 'How pleased are you with the result?' (21-point scale, from − 100 to 100) and 'How much do you want to continue to play the game?' (21-point scale, from 0 to 100). No time limit was imposed on the ratings. This task thus combines subjective measures (expectancy of winning, pleasantness, and desire to play again after each type of outcome) with an objective behavioural index of persistence. Data for three participants were removed as outliers, as they showed very low variability in their ratings ($SD < 5$) on the task (for a similar procedure, see Billieux, Van der Linden, et al., 2012).

Stop-signal task

We used a version of the stop-signal procedure by Dougherty et al. (2005). In this task, two blocks of 175 trials were presented, in which a cue stimulus (a black 5-digit number) was followed (after a 1-second blank screen) by a target stimulus (either the same or a different 5-digit number). Each stimulus was presented for 500 milliseconds. Participants were instructed to press a button as fast as possible if the target stimulus matched the cue stimulus (the go signal). Sometimes, the matching target changed from black to red after a short delay (the stop-signal delay, SSD), indicating a 'stop-signal' to which the participant was instructed to withhold their response. The combination of go and stop signals resulted in three types of trials: (1) *no-stop trials*, in which the cue and the target stimulus are identical (50 trials per block, 28.6% of the trials); (2) *non-match trials*, in which the cue and the target stimulus are non-identical (100 trials per block, 57.1% of the trials); and (3) *stop-signal trials*, in which the stop signal was presented after the matching target (25 trials per block, 14.3% of the trials). The SSD started at 250 ms and was adjusted dynamically depending on the participant's performance: the delay increased by 50 ms following a successful inhibition and decreased by 50 ms following a failed inhibition. The tracking algorithm ensures that the overall inhibition rate stabilizes around 50%. This enables the key dependent variable, the stop-signal reaction time (SSRT), to be estimated by subtracting the mean SSD from the go reaction time (for derivation and assumptions, see Logan, 1994). The SSRT corresponds to the efficiency of the inhibitory process, such that higher SSRTs correspond to poorer inhibitory capacity. To reduce the impact of extreme values, go reaction times more than 2.5 SD from the average were excluded (see Billieux et al., 2010). Reaction time distributions are typically positively skewed. However, in the current study, reaction times did not depart significantly from a normal distribution after having removed extreme values, as confirmed by a Shapiro-Wilk test ($p = .229$).

Gambling-Related Cognitions Scale (GRCS)

The French translation of the GRCS (Grall-Bronnec et al., 2012) from the Raylu and Oei (2004) scale was used, as gambling-related cognitions were previously shown to predict behaviour on the slot machine task (Billieux, Van der Linden et al., 2012). The GRCS measures five facets of gambling-related beliefs (Interpretative bias, Illusion of control, Predictive control, Gambling-related expectancies and Perceived inability to stop gambling). The total GRCS score was used in the current study. Cronbach's alpha of the scale in the current study is 0.88.

South Oaks Gambling Scale (SOGS)

The French version (Lejoyeux, 1999) of the SOGS (Lesieur & Blum, 1987) was used as a dimensional measure of problem gambling symptoms. This scale is composed of 16 binary items ('Yes' or 'No') based on the DSM-III (American Psychiatric Association [APA], 1980) symptoms for pathological gambling. The internal consistency was high (Cronbach's alpha = .95).

Social Desirability Scale (DS-36)

The DS-36 (Tournois, Mesnil, & Kop, 2000) is a 36-item questionnaire developed to measure two aspects of social desirability, auto-deception (i.e. the tendency to give favourable but honest self-deception) and hetero-deception (i.e. the tendency to give an excessively favourable self-description to others). We used the hetero-deception subscale, which was shown previously to influence self-report descriptions of gambling behaviours (Billieux, Van der Linden, et al., 2012; Kuentzel, Henderson, & Melville, 2008). Each item is scored on a Likert scale ranging from 0 (totally false) to 6 (totally true). In the current sample, Cronbach's alpha for the hetero-deception subscale was 0.74.

Statistical analyses

One-way repeated-measures ANOVAs were used to compare subjective ratings on the slot machine task across the three types of outcomes (wins, near-misses and losses). Pearson correlations were used to evaluate relationships between the study variables. All analyses were considered as statistically significant at $p < .05$.

Our key hypotheses regarding the relationships between inhibitory control and the slot machine task were tested using two-step hierarchical multiple regressions. Hierarchical regression is a variant of basic multiple regression that allows specification of additional variables in a fixed entry order, to control for effects of covariates and to test the additional value (in terms of variance explained) of the hypothesized predictors. In the current study, this technique allowed us to test the unique contribution of inhibitory control, while controlling for the influence of potential confounding factors. All predictors were selected *a priori* and entered simultaneously (forced entry) at each stage of the regression (stages 1 and 2). Four regressions were computed, with the following dependent variables: (1) persistence score; (2) subjective rating of continue to play after wins; (3) subjective rating of continue to play after near-misses; and (4) subjective rating of continue to play after losses. The following independent predictors were entered as control variables at stage 1: symptoms of problem gambling (SOGS), gambling-related cognitions (GRCS Total), social desirability (DS-36 hetero-deception subscale), and pleasantness ratings following wins in the slot machine task. Our rationale for including the pleasantness ratings as a control variable was that these constitute an indirect measure of individual differences in reward sensitivity (Billieux, Van der Linden, et al., 2012). The main independent variable, the SSRT from the stop-signal task, was then entered at stage 2 to examine its unique contribution to the four dependent variables. Pairwise treatment of missing data was applied on all analyses.

Results

Variation in gambling behaviour

Our sample was composed of occasional and regular gamblers: 34.6% ($n = 26$) played at least weekly and are thus considered regular gamblers, and 65.3% ($n = 49$) played at least monthly and thus considered occasional gamblers. The endorsed forms of gambling were lotteries (86.7%), scratch-cards (81.3%), table poker (58.7%), slot machines (40%), online poker (18.7%), sports betting (16%) and others (14.7%). SOGS scores ranged from 0 to 5 ($M = 0.81$, SD = 1.24): 43 participants (56.6%) scored 0, 32 participants (43.4%) scored 1 to 5.

Results for the slot machine task

The persistence score (numbers of trials played in extinction) varied from 0 to 41 ($M = 7.28$, SD = 10.6), with a positive skew such that 28.9% of participants quit immediately.

Descriptive analyses from the subjective ratings are reported in Table 1. On the slot machine task, ANOVAs tested for differences between the three types of outcomes on the subjective ratings. For the 'chances of winning' ratings (on the next trial), no significant differences exist between the three outcomes, $F(2,128) = 2.59$, $p = .079$, $\eta^2 = .04$. For the 'pleased with outcome' rating, there was a significant difference between the three conditions ($F(2,144) = 232.90$, $p < .001$, $\eta^2 = .31$) such that participants reported higher pleased ratings after wins compared to both near-misses ($t(72) = 15.37$, $p < .001$) and losses ($t(72) = 15.38$, $p < .001$). There was no significant difference between near-misses and losses ($t(72) = .96$, $p = .341$). On the 'continue to play' rating, the significant difference between the three conditions ($F(2,124) = 67.22$, $p < .0001$, $\eta^2 = .89$) was driven by participants being more willing to continue after wins compared to both near-misses ($t(66) = 7.30$, $p < .001$) and losses ($t(62) = 9.42$, $p < .001$), and after near-misses compared to losses ($t(62) = 4.90$, $p < .001$). Thus, near-misses and losses did not differ in

Table 1. Descriptives analyses from the subjectives ratings of the slot machine task.

Ratings	Types of outcomes	M (sd)
Pleased with outcome after	Wins	53.96 (37.14)
	Near misses	−46.12 (30.79)
	Full-misses	−47.23 (30.93)
Continue to play after	Wins	57.96 (18.97)
	Near-misses	46.52 (17.94)
	Full-misses	43.41 (19.37)
Chances of winning after	Wins	46.05 (18.05)
	Near-misses	43.53 (16.58)
	Full-misses	44.50 (18.45)

Note: Chances of winning = 21-point scale, from 0 to 100; Pleased with outcome = 21-point scale, from −100 to 100; Continue to play = 21-point scale, from 0 to 100.

reported (un)pleasantness, but the motivation to continue was significantly increased after near-misses compared to loss outcomes.

Inhibitory control and performance in the slot machine task

The mean go reaction time was 456.3 ms (SD = 96.8, range = 332–878) and the mean SSRT was 221.3 ms (SD = 36.8, range = 81–285). The mean inhibition rate was 50.9% (SD = 4.3, range = 36–60), confirming successful stabilization by the tracking algorithm.

In the hierarchical regression model for persistence on the slot machine task, persistent play was significantly predicted by longer SSRTs at stage 2 ($\Delta R^2 = .099$; $F(1,55) = 6.47$; $p < .05$), after controlling for symptoms of problem gambling (SOGS), gambling-related cognitions (GRCS), hetero-deception (DS36-HD), and pleasantness ratings after a win at stage 1. The SOGS score also predicted persistence at stage 2 ($F(1,55) = 5.12$; $p < .05$).

Three hierarchical regression models using the same structure tested whether inhibitory control predicted the subjective ratings of 'continue to play' after each type of gambling outcome (wins, near-misses, losses). These models revealed that low inhibitory control (longer SSRTs) predicted increased desire to play again after wins ($\Delta R^2 = .070$; $F(1,48) = 6.37$; $p < .05$) and near-misses ($\Delta R^2 = .079$; $F(1,48) = 4.83$; $p < .05$), while taking into account the covariates. Symptoms of problem gambling (SOGS score) also predicted desire to play after win outcomes ($F(1,48) = 8.30$; $p < .01$). Regression analyses are reported in Table 2.

Discussion

The aim of this study was to examine whether response inhibition capacity influences gambling behaviours on a laboratory measure of slot machine gambling that assessed persistence. Our main hypothesis was confirmed: poorer inhibitory capacity (longer SSRTs) predicted a greater number of trials played in the extinction phase of the slot machine task, after controlling for several potential confounds (symptoms of problem gambling, gambling-related cognitions, social desirability and win reactivity). This study demonstrates the relationship between a neurocognitive measure of inhibitory control and persistence on a quasi-realistic laboratory gambling task. Additional analyses revealed that poorer response inhibition also predicted the subjective ratings of the desire to continue play, after both wins and near-misses, strengthening the link between inhibitory control

Table 2. Standardized regression coefficient for the multiple hierarchical regression analyses.

Dependent variable	Independent predictors	*B*	*t*	*ρ*	R^2	R^2 change	Sig *F* change
Persistence	DS36-HD	.068	.480	.633	.055		
Step 1	SOGS	.240	1.736	.088			
	GRCS-TOT	.004	.031	.975			
	Pleased-W	.079	.603	.549			
	DS36-HD	.139	1.011	.317			
Step 2	SOGS	.304	2.262	.028			
	GRCS-TOT	.005	.034	.973			
	Pleased-W	.091	.727	.470			
	SSRT	.326	2.544	.014	.154	.099	.014
Desire to play again after a Win	DS36-HD	.173	1.464	.150	.403		
Step 1	SOGS	.295	2.473	.017			
	GRCS-TOT	−.028	−.236	.815			
	Pleased-W	.630	5.560	.000			
	DS36-HD	.236	2.048	.046			
Step 2	SOGS	.329	2.882	.006			
	GRCS-TOT	−.019	−.172	.864			
	Pleased-W	.654	6.051	.000			
	SSRT	.272	2.525	.015	.473	.070	.015
Desire to play again after a NM	DS36-HD	.163	1.141	.260	.132		
Step 1	SOGS	.141	.979	.333			
	GRCS-TOT	.135	.958	.343			
	Pleased-W	.334	2.446	.018			
	DS36-HD	.229	1.628	.110			
Step 2	SOGS	.177	1.266	.212			
	GRCS-TOT	.144	1.061	.294			
	Pleased-W	.359	2.718	.009			
	SSRT	.289	2.197	.033	.211	.079	.033
Desire to play again after a FM	DS36-HD	.140	.970	.337	.117		
Step 1	SOGS	.104	.713	.479			
	GRCS-TOT	.135	.951	.346			
	Pleased-W	.320	2.324	.024			
	DS36-HD	.197	1.370	.177			
Step 2	SOGS	.135	.943	.350			
	GRCS-TOT	.143	1.031	.308			
	Pleased-W	.342	2.532	.015			
	SSRT	.251	1.863	.069	.177	.060	.069

Note: $N = 75$. Pleased-W, pleasure ratings after a win in the slot machine task; Persistence, number of trials played during the extinction phase of the slot machine task; SOGS, South Oaks gambling screen; DS36-HD, Social Desirability scale – hetero-deception; GRCS-Total, Gambling-Related Cognitions Scale; SSRT, Stop-Signal Reaction time in the stop-signal task.
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

and motivational aspects of gambling behaviour. Finally, the symptoms of problem gambling (SOGS score) also predicted both persistence on the slot machine task and self-reported desire to play after a win.

Our results complement existing studies that demonstrate impaired performance on neurocognitive measures of inhibitory control in pathological gamblers (Billieux, Van der Linden, et al., 2012; Goudriaan et al., 2006; Odlaug, Chamberlain, Kim, Schreiber, & Grant, 2011). By showing these relationships in a community sample of regular gamblers, our findings support the continuous nature of gambling pathology (see Strong & Kahler, 2007), which is further substantiated by our observation that sub-threshold scores on the SOGS (ranging from 0 to 5) also predicted persistence. Our study sheds some new lights on the cognitive processes involved in gambling persistence. Translating these findings to the context of problematic gambling, our results suggest that reduced inhibitory control may play a role in the phenomenon of 'chasing' (uncontrolled betting in a desperate attempt to recoup their mounting debts), which occupies a prominent role in contemporary models of gambling disorder and is considered a key clinical sign of the condition (Gainsbury, Suhonen, & Saastamoinen, 2014; O'Connor & Dickerson, 2003; Stinchfield, Govoni, & Ron Frisch, 2005).

Low inhibitory control also predicted self-reported desire to play again after two types of outcomes, wins and near-misses. Although surprising at first sight, this result can be interpreted in light of previous studies conducted with the slot machine task. In an initial brain imaging study, Clark et al. (2009) showed that when participants could choose their play icon (as was the case for all trials in our study), near-misses recruited reward-related brain regions that also responded to the monetary wins. Thus, near-misses appear to trigger appetitive processing in the brain, which may invigorate play and promote persistence in the absence of objective reinforcement. Clark, Crooks, Clarke, Aitken, and Dunn (2012) and Dixon, Maclaren, Jarick, Fugelsang, and Harrigan (2013) found that wins and near-misses also elicited increased electrodermal activity. According to these studies, near-misses are physiologically arousing and have pro-motivational effects that are similar to the response to winning. Given that emotional arousal impairs the effectiveness of inhibitory control (Pessoa, 2009; Rebetez et al., 2015; Verbruggen & De Houwer, 2007), this may provide a mechanism for how the response to wins and near-misses is related to inhibitory impairment. This is consistent with dual-processes models (Bechara, 2005; Evans, 2003; Strack & Deutsch, 2004), which posit that self-regulation failures are due to an imbalance between impaired top-down (i.e. inhibitory) control and heightened bottom-up influences (e.g. reward sensitivity, reactivity to salient cues), rather than impaired top-down control alone.

One limitation of our study is that the slot machine task is greatly simplified compared to modern electronic gambling machines, which limits its external (ecological) validity. Nevertheless, the finding that both inhibitory control and symptoms of problem gambling predicted persistence on the task provides an indication that fundamental aspect of gambling behaviours can be modelled in the laboratory. Although our two-reel simulation has the advantage of limiting the different types of near-miss that could occur, future studies should devise more ecologically valid tasks with three-reels or multi-line formats (Dixon et al., 2014) as well as more sophisticated sensory features (Dixon, Bihler, & Nastally, 2011). Another potential limitation of the study is that we chose not to include a measure of self-reported impulsivity (e.g. Barratt Impulsivity Scale or UPPS-P Impulsive Behavior Scale) in the analysis. Indeed, behavioural and self-report measures capture both distinct and overlapping variance of impulsive behaviours (Gay, Rochat, Billieux, D'acremont, & Van der Linden, 2008). It is increasingly recognized that impulsivity is an umbrella construct associated with a wide range of affective, executive and motivational processes, including prepotent response inhibition, delay discounting, emotional reactivity and reinforcement sensitivity; see, for example, Billieux, Gay, Rochat, and Van der Linden (2010); Dawe, Gullo, and Loxton (2004); Dick et al. (2010). Accordingly, we elected to focus on prepotent response inhibition as a specific executive measure of this construct, rather than on broader, multi-determined traits assessed by self-reported measures of impulsivity.

In conclusion, this study highlighted that low inhibitory control predicts persistence behaviours in a simulated slot machine task. Future studies should aim to corroborate these correlational results in regular gamblers from the community using case-control designs that include more severe problem gamblers including treatment-seeking individuals. Our results nevertheless encourage the development of empirically based interventions aiming to reduce persistence (and potentially loss chasing) through improving inhibitory control, building upon recent advances in self-regulation rehabilitation techniques (see e.g. Friese, Hofmann, & Wiers, 2011).

Acknowledgements
The authors thank Gabrielle Gemma for her help in data collection.

Conflicts of interest
Funding sources: This research was supported by a grant obtained from the Belgium National Lottery. The funding agency had no role in the design and conduct of the study, collection, management, analysis and interpretation of the data, or with the preparation, review, or approval of the manuscript. The Centre for Gambling Research at UBC is supported by funding from the Province of BC government and the British Columbia Lottery Corporation, which is a Crown Corporation. Pierre Maurage (Research Associate) is founded by the Belgian Fund for Scientific Research (F.R.S.-FNRS, Belgium). None of the authors have received any direct or indirect payments from the gambling industry or any other groups substantially funded by gambling to conduct research, or to speak at conferences or events.

Competing interests: No potential conflict of interest was reported by the authors.

Constraints on publishing
No constraints on publishing were reported by the authors.

Notes
1. In Billieux, Lagrange, et al. (2012), impaired performance was operationalized as falling more than 1.65 standard deviations below the mean of the control group, corresponding to the fifth percentile in a normal distribution.
2. Participants rated the personal value of gaining 1 euro (Belgian participants) or 1 Swiss franc (Swiss participants). An independent samples t-test compared the two samples. As no significant difference was observed ($t(73) = -.494$, $p = .623$), we proceeded to merge the two samples.

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