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An initial investigation of individual rate-of-play preferences and associations with EGM gambling behavior

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Abstract

Electronic gambling machines (EGMs) show a strong association with gambling problems. The high speed of gaming offered by modern EGMs allows playing numerous games in a short span of time, which is thought to contribute to attentional distraction, increased spending and prolonged play. However, the relationship between EGM speeds and potentially risk-related gambling behavior remains unclear. We introduce a novel approach to investigating the role of gaming speed in EGM gambling behavior by examining 'individual rate-of-play' (I-ROP) during simulated EGM gambling. A community sample of male regular gamblers (N=72) played virtual slot machines in pairs offering sequentially adjusted game speeds towards the estimation of a behaviorally expressed preference speed, or I-ROP. This initial experiment aimed to explore the variability of I-ROPs during simulated EGM gambling, and examine behavior while playing EGMs at speeds relative to their I-ROP. Estimated I-ROPs ranged from less than one half second to over seven seconds and were negatively associated with cognitive ability, but not related to problem gambling severity, impulsiveness, or gambling-related cognitions. Subsequent gambling sessions on EGMs offering individually calibrated faster and slower gaming speeds were associated with greater and reduced risk-related gambling behaviors respectively. I-ROPs represent a potentially informative construct for exploring influences of gaming speed on gambling behavior, and may lend insight into potential risk-related behavior an individual vulnerability with respect to commercially available EGMs that warrants additional research.

Key words: electronic gambling machines; rate of play; gambling behavior; gambling preferences; problem gambling; gambling disorder

Introduction

Electronic gambling machines (EGMs) are linked to problematic patterns of gambling behavior, though the nature of this relationship remains unclear (Blaszczynski 2013). Evidence suggests structural characteristics of EGMs may enhance the risk of gambling-related harm (Parke and Griffiths 2006). In particular, the rate-of-play (ROP), or time per single game from wager to outcome, offered by modern EGMs is much shorter relative to other forms of gambling, and is thought to encourage risky gambling (Cloutier et al. 2006; Diskin 1999; Griffiths 1993). The ability to complete high numbers of games in a short amount of time may contribute to distraction, increase expenditure, prolong play and discourage players from reflecting properly on accumulating expenditure (Cloutier et al. 2006). However, evidence regarding the influence of ROP on gambling behaviors during EGM play is mixed. As the prevalence of electronic gambling options is expanding (Armstrong et al. 2016), a better understanding of possible links between ROP and potentially risky gambling behavior is needed.

Individuals with gambling problems, and those at-risk, tend to prefer EGMs offering faster ROPs relative to individuals without gambling problems (Linnet et al. 2010; Blaszczynski et al. 2001; Choliz 2010; Ladoucer and Sevigny 2006; Mentzoni et al. 2012). In pathological gamblers, preferences for fast ROPs during EGM gambling is associated with greater striatal dopamine release (Boileau et al. 2014), suggesting faster ROP gambling may be linked to reinforcing and/or pleasurable effects in individuals with gambling problems. EGM ROP may also influence cognitive and motivational processes during gambling sessions. In occasional gamblers, a fast ROP is associated with an underestimation of the number of games played, suggesting an influence of ROP on awareness of gambling activity (Ladoucer and Sevigny 2006). At-risk gamblers tend to place larger bets on machines with a fast ROP, suggesting ROP may influence risk-taking and/or the intensity of a gambling experience (Mentzoni et al. 2012). Similarly, individuals with gambling problems experience greater excitement and a stronger desire to continue gambling on machines offering a faster ROP (Linnet et al. 2010; Blaszczynski et al. 2001).

However, the preference for EGMs with fast ROPs may not always translate to prolonged durations of gambling or increases in other risky gambling behaviors (Linnet et al. 2010; Blaszczynski et al. 2005; Sharpe et al. 2005; Ladouceur and Sévigny 2006; Mentzoni et al. 2012). Adding to the complexity of interpreting prior findings, previous investigations of ROP influences on gambling behavior have compared a range of discreet game speeds. That is, 'fast' ROPs have ranged from 400ms (Mentzoni et al. 2012) to 5sec (Ladoucer and Sevigny 2006) per game, while 'slow' ROPs have ranged from 3sec (Linnet et al. 2010; Mentzoni et al. 2012) to 15sec (Ladoucer and Sevigny 2006) per game. Of note, regulations in the United Kingdom (Gambling Commission 2012) and Australia (Productivity Commission 2010) limit EGM ROPs to approximately 2.5 to 3.5sec per game on average, or speeds that would be considered fast in some prior research and slow in others.

In the current study, we propose an alternative approach to investigating potential influences of ROP on EGM gambling behavior. We describe a preliminary experiment to explore the variability of individual preferences for EGM ROPs in a community sample of regular gamblers, and compare behavior when gambling at speeds relative to this 'individual rate-of-play' (I-ROP). To achieve this, we first used an adapted staircase method to estimate a participant's I-ROP by examining playing patterns on pairs of simulated slot-machine games that differed in gaming speed but were otherwise identical. Subsequently, participants completed EGM sessions with simulated machines calibrated to run at their I-ROP, and sessions with machines set to run at significantly faster or slower speeds. We examined the average bet size, response times between plays, play durations and abilities to recall game events (spending and winning outcomes), and beliefs regarding luck as a function of the different EGM ROPs on these markers of risky gambling behavior.

Methods

All study procedures were approved by the [deidentified Human Research Ethics Committee] and participants provided written informed consent.

Participants

Participants were 72 adult males reporting at least monthly gambling during the past 6 months and were recruited from the local [deidentified] community (Table 1). A semi-structured clinical interview was used to assess current and lifetime history of mood and anxiety disorders (DSM-IV SCID; (First et al. 2002)). Information regarding involvement in gambling activities was collected using an in-house assessment and past-year gambling-related problems were collected using the National Opinion Research Center DSM-IV Screening instrument (NODS) (Wickwire et al. 2008; Hodgins 2004)

[Table 1]

Psychometric assessments

Participants completed a series of self-administered measures to explore potential relationships between gambling behavior impulsivity (Barratt Impulsiveness Scale (BIS-11; (Patton et al. 1995)) and gambling-related beliefs (Gambling-related Beliefs Questionnaire (GBQ; (Steenbergh et al. 2002)). Participants also completed the Standard Raven's Matrices as a measure of cognitive ability (Raven et al. 1998).

Simulated slot-machines

Participants played a series of computerized simulated slot-machine games (Figure 1). Each machine consisted of a single pay-line design with three reels displaying a series of six numbers indicating prize values (e.g. 3, 5, 10, 20, 25, 30) in the place of traditional non-numeric symbols. Participants gambled 'credits' on each play, with options to place single, double or triple bet sizes (i.e. 2, 4 or 6 credits) to increase the prize values. To begin each game, participants used a mouse to select their bet, which was immediately drawn from their total-credits display, and all three reels of the slot-machine began spinning. Reels stopped at evenly spaced intervals in a sequential order from left-to-right to enhance the expectation of game outcomes (Strickland and Grote 1967). Once the third reel stopped, indicating the game outcome, participants could immediately proceed to the next game.

[Figure 1]

Winning outcomes (indicated by matching numbers on all three reels) were accompanied by brief audio feedback and instantaneous update of the total-credits display. To discourage participants from playing machines based on perceived pay-out rates, slot-machines were calibrated at a generous reinforcement schedule (delivering winning outcomes according to a variable ratio (VR) of 1:6, returning approximately 130% of credits wagered). Total credits accumulated over a series of games were shown above the slot machine display throughout game play. Prior to the experiment, participants were informed that they would receive payment commensurate with their total winnings summed across all machines played; however, all participants received equal compensation (£30) for participation following debriefing. Further details of the simulated slot machines are provided in the Supplemental Materials.

Estimation of individual rate-of-play (I-ROP)

Estimation of I-ROPs was performed using a parameter estimation by sequential testing procedure (PEST) (Taylor and Creelman 1967). Briefly, in a block-wise manner, participants were presented with pairs of slot-machines (Figure 1a) that differed only in their gaming speed. Adjustments to the offered ROPs were sequentially adjusted between blocks toward convergence on an estimated I-ROP. Each block began with forced-choice plays (at no cost in credits) on each slot-machine to provide an experience of the ROPs offered. Participants were then allowed to play the pair of machines ‘as they desired’ with no further instruction, until play was interrupted and the next block of paired machines was presented. Participant choices of which machine to play were tracked within each block to determine a behavioral preference for either machine. Preference was defined as playing one machine more frequently than the other in a series of at least 10 consecutive games. Once criteria for a preference was met (or a total of 20 games were played), the block was terminated.

Adjustments to the gaming speeds of subsequent machine pairs were based on previous choices by sequentially shifting and narrowing a ‘search range’ (Figure 2). An initial search range was predefined between 0s and 6s for all participants, and depending on machine preferences, the search range would adjust accordingly to estimate a participant’s I-ROP. The PEST procedure continued until the pair of slot-machines differed in ROP by less than 250ms (i.e., converged), or a maximum of 11 blocks had been played (i.e., non-converged). Given potential variability in the estimation procedure, I-ROPs were calculated as the mean ROP across the four machines presented in the final two pairings before the experiment was terminated. The standard deviation of this mean was used to determine gaming speeds relative to I-ROP in the next stage of the experiment (Figure 2c). A full description of the PEST adjustment rules and procedures are provided in the Supplemental Materials. Following I-ROP estimation, and prior to the next stage, participants completed the Raven’s Matrices as a cognitive-load task to reduce any carry-over effects.

[Figure 2]

Slot-machine play relative to I-ROP

To assess how EGM gaming at speeds relative to I-ROP might influence gambling behavior, participants played single slot machines (Figure 1b) in three consecutive conditions. These slot-machines were calibrated to play at the participant's I-ROP, and speeds that were three standard deviations (from the estimation procedure described above) faster (F-ROP) and slower (S-ROP) than their estimate I-ROP. Participants were given the opportunity to play each slot-machine for a minimum duration of 2 minutes, followed by a maximum of 2 additional minutes of optional 'continued-play'. During the continued-play period, participants could leave the current machine at any time and proceed to the next machine. The presentation order of machine ROPs was counter-balanced across participants.

Following completion of play on all three slot-machines, participants were asked to recall their gambling experiences. For each of the three slot-machines (indicated as 'first', 'second' and 'third'), participants were asked to estimate the total number of credits bet and the number of winning outcomes delivered, and rate how lucky they felt (using a Likert scale with 1=very unlucky, 4=neither lucky or unlucky and 7=very lucky) on each machine. Finally, participants were asked which of the slot-machines they would 'most want to play again' with the option to answer 'first', 'second', 'third' or 'all equally').

Measurement and analysis of gambling behavior

Behavioral measures during slot-machine play included those previously examined in relation to ROP influences on gambling. Measures of arousal or gambling intensity included average bet size (Mentzoni et al. 2012) and inter-play reaction times (VaezMousavi et al. 2009). Reaction-time outliers were removed according to shifting z-score criterion that accounts for the different numbers of observations of each outcome type (Dixon et al. 2013; Thompson 2006), removing a total of 5.7% of the original reaction times. Given potential cognitive and motivational complexities of post-reinforcement pauses follow wins and near-misses (i.e., outcomes that ‘appear closer’ to wins; e.g., AAB) (Belisle and Dixon 2016), only inter-play reaction times following full-losses (e.g. ABC) were examined. Measures of self-control or engagement included the duration of optional continued-play and total spending during continued-play. Measures of cognitive awareness or dissociation included accuracy in recalling total credits spent and recollection of winning outcomes. Estimation accuracies for amount of credits bet and number of winning outcomes were computed as proportionate differences from the true values. One participant was identified as an outlier (over 5 SDs from the sample average) for win estimations on all machines, and was included in analyses using the sample mean. Finally, luck ratings were examined as an indicator of the elicitation of gambling-related beliefs.

Multivariate repeated-measures analyses were performed in SPSS 22.0 (IBM Corporation, Armonk, NY) across the seven behavioral measures to assess effects of gaming at speeds relative to I-ROP on EGM gambling. Subsequent mixed-effects analyses were performed to examine behavioral differences by PEST-estimate convergence and by problem gambling severity. To explore relationships between I-ROP and behavior, participants were divided into three equal-sized groups relative to their estimated I-ROP (i.e., ‘rapid’, ‘moderate’ and ‘extended’ rate players). Post-hoc pairwise and univariate and analyses were performed to explore significant within-subject effects of EGM speed and any between-subjects effects of PEST convergence, gambling severity or player-group on measures of gambling behavior.

Sixty-three (87.5%) participants reported a desire to play one machine again (i.e., ‘subjectively preferred’ EGM) relative to the other two presented options (i.e., ‘non-preferred EGMs’). To investigate if gambling behavior differed by subjective preference, a multivariate repeated-measures analysis was performed across the seven measures comparing behavior on the subjectively-preferred EGM as compared to average behavior on the non-preferred machines, including a between-subjects factor of the preferred machine to control for main effects of ROP.

Results

Participant characteristics

The 72 male regular gamblers (Table 1) ranged in age from 18-60 years. The average NODS score was 2.7 (SD=3.0), with 27 participants reporting a lifetime history of problem or pathological gambling (NODS≥3), 24 classifying as at-risk gamblers (NODS=1 or 2) and 21 reporting no lifetime gambling problems (NODS=0). No participants reported daily EGM gambling, 20 (27.8%) reported EGM gambling at least monthly, and 38 (52.8%) reported EGM gambling at most once in the past year. Impulsivity (BIS-11) and gambling-related beliefs (GBQ) scores were consistent with gambling samples (Ledgerwood et al. 2009; Steenbergh et al. 2002).

[Table 1]

Estimation of individual rate-of-play (I-ROP) during simulated EGM gambling

The PEST procedure reached estimate criteria, or 'converged' (i.e., final probe machines differed by less than 250ms within 11 blocks), for 34 (47%) participants after an average of 6.7 (SD=1.9) blocks and a testing duration of 4.9 (SD=2.2) minutes. Of the 38 participants for whom estimation did not converge after the 11-block limit and a testing duration of 12.2 (SD=4.6) minutes, the average difference in speed between final probe machines was 371ms (SD=62) from reaching criteria. I-ROPs estimated following convergence were faster (1139ms, SD=1234) than those that did not reach convergence (3096ms, SD=2007; t_{70}=4.91, $p<0.001$). Participants for whom I-ROP estimation did not converge scored lower on the Raven's matrices (t_{70}=3.86, $p<0.001$), reported fewer years of education (t_{70}=2.81, p=0.006), had higher NODS scores (t_{70}=2.05, p=0.044), and were more likely to report EGM gambling in the past year ($\chi^2_{2,72}$=9.24, p=0.002) than participants with converged I-ROP estimates. Participants with converged and non-converged I-ROP estimates did not differ in BIS impulsiveness, GBQ luck or GBQ illusions of control (p's>0.10) (Supplemental Table S1).

I-ROPs in male regular gamblers

Estimated I-ROPs ranged from 315ms to 7331ms per EGM game and are displayed in Figure 3. Across participants, I-ROPs were negatively correlated with Raven's matrices scores (r=-0.28, p=0.015). I-ROPs were not related to age or years of education (p>0.1), not different between problem gambling severity groups ($F_{2,71}$=0.13, p=0.88), and did not correlate with NODS scores, BIS total impulsiveness, GBQ luck or GBQ illusions of control (p's>0.2). To further investigate potential associations between I-ROPs and behavioral and psychometric measures, participants were equally divided into three groups relative to estimated I-ROP: rapid-players (I-ROP=315-502ms), moderate-players (I-ROP=552-2526ms) and extended-players (I-ROP=2674-7331ms). There were no differences between player-groups in NODS scores ($F_{2,71}$=0.59, p=0.56), past-year frequency of gambling ($\chi^2_{6,72}$=2.91, p=0.82) or EGM use ($\chi^2_{6,72}$=4.03, p=0.13). There were no player-group differences in BIS impulsiveness, GBQ luck or GBQ illusions of control (p's>0.15). (Supplemental Table S2).

[Figure 3]

Gambling behavior relative to I-ROP

Participants completed gambling sessions on individual simulated slot machines with a gaming speed calibrated to their estimated I-ROP, and machines operating at relatively faster (F-ROP) and slower (S-ROP) gaming speeds. On average, single games played on the F-ROP machines were 841ms (SD=545) shorter than I-ROP, and S-ROP games were 931ms

(SD=503) longer than I-ROP. The actual time-per-play experienced on each machine (calculated as total-play-duration / number-of-plays), averaged 752ms (SD=350) longer than the calibrated EGM speed and did not differ between machines within participants ($F_{2,70}$=0.93, p=0.40), indicating participants played all EGMs equally relative to the calibrated gaming speed (as opposed to self-pacing play regardless of the ROP offered).

Effects of ROP on gambling behavior

Multivariate repeated-measures analysis across the seven measures of gambling behavior indicated a main within-subjects effect of ROP on gambling behavior ($F_{14,272}$=6.65, p<0.001). Post-hoc analysis revealed an effect of ROP on spending during continued-play, accuracy of estimates of total expenditure and estimates of winning outcomes, with an effect on inter-play reaction times approaching significance (Table 2). Pairwise comparisons revealed inter-play reaction times on S-ROP machines were longer than on I-ROP machines (p=0.038), and tended to be longer than on F-ROP machines (p=0.065) (Figure 4a). Continued-play spending was greater on F-ROP machines relative to I-ROP (p=0.012) and S-ROP machines (p=0.010) (Figure 4b), with greater continued-play spending on I-ROP machines relative to S-ROP machines approaching significance (p=0.066).

Participants underestimated total amounts spent on all machines (one-sample t-tests, H_o=0; t_{71}'s>3.35, p's<0.001), with greatest inaccuracy on F-ROP machines and significant pairwise differences between all three machines (p's<0.001) (Figure 4c). Participants underestimated winning outcomes on F-ROP and I-ROP machines (one-sample t-tests, H_o=0; t_{71}'s>2.8, p's<0.01) and accurately recalled number of wins on S-ROP machines (one-sample t-test, H_o=0; t_{71}=1.40, p=0.17), with significant pairwise differences between all three machines (p's<0.01) (Figure 4d). There was no effect of ROP on average bet size, continued-play duration or ratings of luck (Table 2). Within-subjects effects of ROP on continued-play spending and estimation accuracies of total spending and winning outcomes survived controlling for I-ROPs (p's<0.01).

[Table 2][Figure 4]

Differences by I-ROP estimation convergence

I-ROP estimation convergence criteria were not achieved in more than half of the participants. Gambling behavior by convergence of the estimation procedure is provided in Supplemental Table S1. Briefly, mixed-effects analysis revealed a between-subjects effect of estimation convergence ($F_{6,64}$=3.79, p=0.002) and a convergence-by-ROP within-subjects interaction effect on gambling behavior ($F_{14,268}$=1.81, p=0.037). Post-hoc analyses revealed convergence-related differences and interaction effects on inter-play reaction times and continued-play spending. However, and notably, all between- and within-subjects effects of estimate-convergence on gambling behavior did not survive controlling for individual differences in I-ROP (p's>0.1), and significant effects of ROP across the sample (described above) survived in analyses controlling for convergence (p's<0.01).

Gambling behavior by player-group and gambling severity

The estimation procedure identified a range of I-ROPs from 315ms to over 7sec. To explore if gambling behavior differed between individuals grouped by I-ROP, participants were median-split into 'rapid', 'moderate' and 'extended' gaming speed players (Figure 3). This grouping strategy also separated what appeared to be two normal distributions of I-ROPs (i.e., less than 500ms, and greater than 500ms). Gambling behavior by player-group is provided in Supplemental Table S2. Mixed-effects analysis indicated a between-subjects effect of player-group ($F_{14,126}$=3.75, p<0.001) on gambling behavior and no player-group-by-ROP interaction on within-subjects effects of ROP ($F_{28,477}$=1.41, p=0.08). On average across machines, rapid-speed players exhibited shorter inter-play reaction times and greater continued-play spending than both moderate- and extended-speed players (pairwise p's$\leq$0.001). Extended-speed players more accurately estimated number of winning outcomes than rapid-speed players (pairwise p=0.009) on average across machines. Within-subjects effects of ROP on gambling behavior survived controlling for player-group (p's<0.01), and between-subjects effects of player-group on behavior survived controlling for estimate convergence (p's<0.01).

There were no between- or within-subjects effects of problem gambling severity on gambling behavior at EGM ROPs relative to I-ROP (F's$\leq$1, p's>0.4). Gambling behavior by problem gambling severity is provided in Supplemental Table S3.

Gambling behavior by subjectively-preferred EGM

Sixty-three (87.5%) participants reported a desire to play one machine again relative to the other two presented options (Table 2). Behavior on the subjectively-preferred machine was compared to the average performance on the non-preferred machines in a mixed effects model that included a between-subjects factor of the preferred machine to control for main effects of ROP. Gambling behavior by subjective-preference is provided in Supplemental Table S4. There was a significant within-subjects effect of subjective preference across the seven behavioral measures ($F_{7,54}$=7.68, p<0.001). Subjectively-preferred machines were played longer during optional continued-play ($F_{1,60}$=5.86, p=0.019), and were rated as more lucky ($F_{1,60}$=46.22, p<0.001) than non-preferred machines (Figure 5).

[Figure 5]

Discussion

The relatively fast pace of EGM gambling has been suggested as a feature that encourages problematic gambling (Cloutier et al. 2006; Diskin 1999; Griffiths 1993); however, links between rates-of-play (ROPs) and gambling behavior remain unclear. The current study introduces a novel approach to investigate ROP influences on EGM gambling by estimating an individual rate-of-play (I-ROP) through behaviorally expressed preferences during simulated EGM gambling. Male regular gamblers of differing levels of problem-gambling severity exhibited a diverse range of I-ROP, from less than one half-second to over seven seconds per game. I-ROPs were negatively associated with cognitive ability, but not related to problem-gambling severity, impulsiveness or gambling-related cognitive distortions. Participants then played EGMs calibrated to their I-ROP and machines offering relatively faster (F-ROP) and slower (S-ROP) gaming speeds. EGM play on F-ROP machines was associated with increased spending during an optional continued-play period, greater underestimations of total amount spent, and impaired recall of the number of winning outcomes experienced. By comparison, EGM play on S-ROP machines was associated with longer inter-play reaction times, less continued-play spending, and improved recall of total spending and winning outcomes. Bet sizes, duration of continued-play, and luck ratings were not influenced by ROP. Self-reported, subjectively-preferred machines were associated with longer continued-play and higher luck ratings than non-preferred machines. I-ROPs may represent a new avenue for investigating EGM gambling behavior and lend insight into potential individual differences in vulnerability for problematic EGM gambling.

Estimating I-ROP during EGM gambling

A sequential parameter estimation procedure was developed to estimate I-ROPs from behaviorally expressed preferences for EGM gaming speeds. In an attempt to balance the precision of an I-ROP estimate with a rapid testing procedure, a set of step-wise adjustment rules, convergence criteria and maximum testing limits were developed for the current study. Across participants, the I-ROP estimation testing period was less than nine minutes; however, convergence was achieved in less than half of participants. Results suggest that extending the testing past the 11-block limit, or relaxing the strict 250ms precision criteria, would likely have produced successful convergence in nearly all participants with relatively minor increases in total testing time. The estimation procedure displayed a lower sensitivity to precisely detect longer-duration I-ROPs, which may reflect a larger range of 'indifference' toward gaming speeds for individuals with extended I-ROPs (i.e., selection between EGMs with speeds several seconds in duration may become impartial at an ROP difference greater than the 250ms estimation criteria). I-ROP estimation was also less likely to achieve convergence in gamblers reporting regular EGM play. Several factors can contribute to machine preferences in regular EGM gamblers (Parke and Griffiths 2006). Thus, machine selections may not have been based primarily on gaming speeds being offered, complicating search adjustments with irregular preference patterns, and impeding progress toward convergence criteria within the allotted testing period.

The rate of estimate non-convergence represents a notable limitation of the testing procedure used to estimate I-ROPs. However, influences of EGM gaming speeds relative to I-ROP (discussed below) largely remained significant in participants with converged and non-converged estimates when analyzed separately. Importantly, group differences in behavior between participants with converged and non-converged estimates did not survive controlling for I-ROP, suggesting these differences were more likely related to individual variation in I-ROP rather than the convergence of the estimate. Nonetheless, future research directed towards improving I-ROP estimation procedures (e.g., allowing for longer testing periods, including adaptable convergence criteria relative to I-ROP, and implementing search adjustments based on inference methods less susceptible to irregular selection patterns) is needed to improve accuracy and reliability of estimations across the wide range of I-ROPs detected in the current study.

I-ROP diversity in regular gamblers

Male regular gamblers displayed a wide range of I-ROPs, from less than one half second per play to over seven seconds per play. I-ROPs were negatively associated with reasoning abilities, suggesting global cognitive functioning may influence the rate at which individuals prefer EGM gambling. Participants reporting problem/pathological gambling were no more likely to express fast I-ROPs than participants reporting no problems gambling. Similarly, I-ROPs were not associated with impulsiveness or gambling-related cognitive distortions. However, the distribution of I-ROPs estimated in the current study may reflect the heterogeneity of gambler profiles (Cunningham-Williams and Hong 2007; Lloyd et al. 2010). Qualitative examination of the frequencies of I-ROPs in the current study (Figure 3) suggests there may have been two distinct sub-populations of regular gamblers with respect to I-ROP (i.e., a normal distribution of rapid-speed players, and a normal distribution of moderate- and extended-speed players). Research comparing I-ROPs between subtypes of gamblers (e.g., ‘behaviorally conditioned’ vs. ‘emotionally vulnerable’) (Blaszczynski and Nower 2002) may provide insight into possible subtypes of regular gamblers relative to I-ROP.

EGM gambling behavior relative to I-ROP

Gambling behavior in regularly gambling participants differed during EGM play at gaming speeds relative to their estimated I-ROPs. Models of how EGMs may promote problematic behavior suggest fast gaming speeds may encourage immersive and dissociative experiences, and slowing the ROP may minimize harm by lessening the potential for intensive gambling (Blaszczynski et al. 2001; Cloutier et al. 2006; Griffiths 1993). Broadly, the current study supports these models as EGM gambling at F-ROP speeds tended to increase continued-play spending and impaired recall of amounts spend and the number of winning outcomes. These findings are consistent with previous research of ROP effects on gambling behavior (Ladoucer and Sevigny 2006) and are consistent with a dissociative gambling experience (Diskin 1999). Gambling on S-ROP machines was associated with longer inter-play reaction times, reduced continued-play spending, and improved recollection of amount spend and winning outcomes; behavior that it consistent with a less arousing or intensive gambling experience (VaezMousavi et al. 2009). EGM gambling at I-ROP was associated with inter-play intervals equivalent to F-ROP gambling, with an intermediate impact on continued-play spending and recall of game events. This suggests I-ROPs in regular gamblers may represent a balance between achieving an arousing gambling experience, while minimizing impact the ability to track game events.

Notably, influences of EGM gaming speed were observed with adjustments that were less than one second different from I-ROP on average. Previous research investigating behavioral influences of ROP examined machines differing by several seconds per play (Blaszczynski et al. 2001; Blaszczynski et al. 2005; Choliz 2010; Ladoucer and Sevigny 2006; Linnet et al. 2010; Mentzoni et al. 2012). Furthermore, ROPs tested in the current study were calibrated relative to I-ROP, with F-ROP machines ranging from 60ms to over 6s per play, and S-ROP machines ranging from 765ms to nearly 10s per play. That is, for some rapid-speed players, the influence of S-ROP play was assessed on EGMs with a gaming speed twice as fast as commercially available machines (Gambling Commission 2012). By comparison, for some extended-speed players, the speed of F-ROP machines was several seconds longer than commercially available EGMs. Importantly, there were no differences between player-groups on gambling behavior relative to their I-ROPs. Thus, commercially available EGMs may represent a low-risk ROP for rapid-players, and a potentially high-risk ROP for extended-players.

Subjective preferences during EGM gambling

Following EGM play on the three machines with identical presentations and pay-out schedules, participants rated which machine they would most want to play again. The self-reported 'subjective preference' for one EGM over another was not related to gaming speed. However, the duration of continued-play was longest on, and rating of luck highest for, the subjectively preferred machine. There were no differences between subjectively-preferred machines and the two other EGM options on measures of dissociation or arousal, and only half of the participants subjectively preferred the machine on which they collected the greatest winnings. These findings highlight the potential role of gambling-related cognitions in encouraging gambling behavior, extending gambling sessions independent of winning outcomes. Efforts to minimize the elicitation of gambling-related cognitions during EGM play, which in the current study were independent of ROP, may serve to reduce risky EGM gambling behavior.

Limitations

The current study represents an initial investigation of behaviorally estimated I-ROPs in regular gamblers, and an exploration of EGM gambling behavior at individually calibrated gaming speeds. Limitations include the inclusion of only male regular gamblers. Prevalence studies suggest EGM gambling is a substantial problem in female gamblers (e.g. Potenza 2001) and further research is needed to explore I-ROPs and the effects of gaming speeds in female gamblers. The computerized slot-machines were designed simulate real-world EGM gaming; however, all procedures were completed in a laboratory environment, and replication of I-ROP estimations in a more etiologically valid scenario is warranted. Similarly, additional research is needed to explore the reliability and stability of I-ROP estimations. Many regular and problem gamblers participate in multiple gambling activities of varying ROPs, and the I-

ROPs identified in the current study may be specific to an individual's EGM gaming experience, perhaps falling with a range of preferred-gaming-rates that are likely influenced by motivational and affective factors.

As discussed above, the sequential adjustment procedure used to estimate I-ROPs did not reach convergence criteria in over half of the participants. Estimation procedures displayed a reduced sensitivity to I-ROPs several seconds in length, but differences in behavior between gamblers with non-converged as compared to converged estimates appear to be more related to I-ROP differences than the convergence status of the estimate. Efforts are currently underway to develop and implement an improved sequential adjustment algorithm to increase detection rates of longer I-ROPs and reduce the frequency of non-convergence estimates.

Conclusions

A wide range of I-ROPs were estimated using a stepwise behavioral testing paradigm in a community sample of male regular gamblers. I-ROPs were negatively related to cognitive ability, but were not associated with problem gambling severity, impulsiveness, or gambling-related beliefs. Although the sequential testing procedure displayed a limited ability to achieve convergence criteria in individuals with longer I-ROPs (i.e., a few seconds per play), behavioral differences when playing EGMs at gaming speeds relative to I-ROPs appeared more related to individual differences in I-ROP rather than the convergence of the estimate. EGM gambling at speeds faster than I-ROP was associated with increased risk-related gambling behavior (i.e., greater continued-play spending and impaired ability to recall total spending and winning outcomes). EGM gambling at speeds slower than I-ROP decreased risk-related gambling behavior (i.e., reduced inter-play reaction times and continued-play spending, and improved ability to recall total spending and winning outcomes). There were no influences of ROP on the duration of EGM gambling or gambling-related cognitions; however, self-reported, subjectively-preferred machines were played longest and rated as being more lucky than non-preferred machines. This initial investigation suggests I-ROPs may represent a risk-related construct of gambling behavior (particularly with respect to individual differences in I-ROP relative to commercially available EGMs) that warrants additional research.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Table 1. Participant characteristics.

Variable	**N=72**
Age, years (SD)	30.1 (10.8)
Education, years (SD)	14.7 (3.0)
Cognitive ability (RM), mean (SD)	47.4 (9.7)
Lifetime gambling severity (NODS), N(%)	
No problem	21 (29.2)
At-risk	24 (33.3)
Problem/pathological	27 (37.5)
Past year, any gambling, N(%)	
Daily	8 (11.1)
1-3 per week	45 (62.5)
1-3 per month	14 (19.4)
Less than once per month	5 (6.9)
Past year, EGM gambling, N(%)	
Daily	0 (0.0)
1-3 per week	12 (16.7)
1-3 per month	8 (11.1)
A few times	14 (19.4)
Once or not at all	38 (52.8)
BIS Impulsiveness, total (SD)	65.7 (10.7)
GBQ Luck, mean (SD)	37.9 (13.8)
GBQ, Illusions of control, mean SD)	31.2 (11.0)

Abbreviations: RM, Raven’s Matrices; NODS, National Opinion Research Center DSM-IV Screening instrument; BIS, Barratt Impulsiveness Scale, version 11; GBQ, Gambling Beliefs Questionnaire.

Table 2. Gambling behavior during EGM play relative to I-ROP

Variable	**F-ROP**	**I-ROP**	**S-ROP**	$\mathbf{F_{2,142\ (p)}}$
Average bet size, credits (SD)	4.01 (1.26)	4.04 (1.22)	3.96 (1.21)	0.39 (0.67)
Inter-play reaction time, ms (SD)	499 (278)	497 (283)	542 (317)	2.78 (0.065)
Continued-play spending, credits (SD)	231 (633)	108 (221)	49 (88)	5.40 (0.005)
Continued-play duration, sec (SD)	40.5 (48.0)	41.6 (46.9)	33.5 (42.5)	1.36 (0.26)
Accuracy of amount spent, % (SD)	-67.2 (32.7)	-48.3 (63.9)	-31.9 (73.4)	25.70 (<0.001)
Accuracy of winning outcomes, % (SD)	-35.6 (66.1)	-15.6 (46)	12.2 (74.1)	21.60 (<0.001)
Luck rating, mean Likert 1-7 (SD)	4.3 (1.5)	4.3 (1.2)	4 (1.2)	1.72 (0.18)
Desire to play again, N (%)	28 (38.9)	22 (30.6)	13 (18.1)	-

Figure legends

Figure 1. (**a**) Screen-capture of paired slot-machines used during I-ROP estimation procedure. (**b**) Screen-capture of single-machine EGM play following I-ROP estimation. See Supplemental Figure S1 for full-color images.

Figure 2. Illustration of step-wise I-ROP estimation procedure for (**a**) a successfully converged participant (Subject A) and (**b**) a non-converged participant (Subject B). (**c**) I-ROP estimates were calculated as the mean 'probe' ROPs from the final two blocks ($S_{L-1/L}$/$F_{L-1/L}$) with F-ROP and S- ROP speeds calibrated to 3 SD faster and slower than I-ROP for each participant. Full details and adjustment rules for the PEST procude are provided as Supplemental Material.

Figure 3. Frequency of estimated I-ROPs by gambling severity, with approximate I-ROP ranges for 'rapid', 'moderate', and 'extended' speed players indicated.

Figure 4. Gambling behavior relative to I-ROP in male gamblers. (**a**) Inter-play reaction times following full losses on S-ROP machines were longer as compared to I-ROP machines and tended to be longer than F-ROP machines. (**b**) Credits spent during optional continued-play on F-ROP machines was greater than S-ROP machines, and tended to be greater than on I-ROP machines, which was greater than on S-ROP machines. (**c**) Recollection of amounts spent were underestimated on all machines, though this effect was greatest on F-ROP machines and least on S-ROP machines. (**d**) Recollection of the number of winning outcomes was underestimated on F-ROP more so than I-ROP machines, and accurate on S-ROP machines. Error bars indicate standard errors. $^{O}p<0.07$, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$.

Figure 5. Gambling behavior relative to subjectively preferred (Subj. Pref) machine (i.e. the machine selected as 'most desire to play again') as compared to the average of non-preferred (Non-pref) machines. (**a**) Duration of optional continued-play was longer on the subjectively-preferred machine and (**b**) luck ratings were greater on the subjectively-preferred machine compared to the non-preferred machines. $^{*}p<0.05$, $^{***}p<0.001$

Supplemental Materials

Simulated slot machine design

Participants played a computerized slot-machine game designed to simulate EGM gambling (Figure S1). Slot machines consisted of a simple three-reel, single pay-line design, with reels displaying a series of six numbers indicating prize values (in the place of traditional non-numeric symbols), to facilitate comprehension of prize structure. Participants gambled with 'credits' that were displayed at the top of the screen and were updated immediately following placement of bets. Each machine afforded the option of single, double or triple bet sizes (i.e. 2, 4 or 6 'credits') in order to increase available prize values, and participants played each machine by using a mouse to click on the button indicating the desired bet size. Following bets, all reels of the slot-machine began spinning and stopped in a sequential order from left to right. Winning outcomes were indicated with a brief (< 400ms) audio feedback and an instantaneous update of participants' total credits. Upon the third-reel stop indicating the play outcome, participants could immediately proceed to the next play. That is, similar to commercial devices, there were no forced delays interrupting continuous play.

To minimize the impact of different play durations on reinforcement experience, slot machine pay-out schedules were pre-determined in separate blocks of 36 plays each. Within each block of 36 plays, winning outcomes were delivered on a variable ratio of 1:6, with each of the 6 prize levels delivered once. Classic near-misses (e.g. AAB) were delivered at a variable ratio 1:6, other miss outcomes (e.g. split, ABA; and reverse misses, ABB) were delivered at a variable ratio of 1:12 each, with full losses (e.g. ABC) at a variable ratio of 1:2. Machines played at a single bet size would return approximately 130% of all credits wagered every 36 plays. To avoid game predictability, the order of outcomes was randomized before each block of 36 plays.

Parameter estimation by sequential testing (PEST) procedure

To estimate individual rate-of-play (I-ROP) preferences, participants were presented with pairs of slot-machines that differed only in gaming speed in a block-wise manner. Adjustments to the offered ROPs were sequentially adjusted between blocks towards 'convergence' on an estimate of the participant’s I-ROP. Participant choices of which machine to play were tracked within each block to determine a behavioral preference for either machine. Preference was defined as playing one machine more frequently than the other in a series of at least 10 consecutive games. Once criteria for a preference was met (or a total of 20 games were played), the block was terminated.

Adjustments to the ROPs of subsequent machine pairs were based on previous choices by sequentially shifting and narrowing a ‘search range’. The search range was considered to encompass the potential range of I-ROPs, and was tested using ‘ROP-probes’ calibrated to the 33rd and 67th percentiles of the search range. An initial search range was predefined between 0s and 6s for all participants, and depending on machine preferences, the search range would adjust accordingly to estimate a participant’s I-ROP. Two methods for adjusting search range anchors, ‘strong’ and ‘weak’ preference adjustments, were implemented in an effort to expedite preference-speed detection.

Strong preference adjustment. A strong preference adjustment was made if the final five plays, and a majority of any 10 consecutive plays, were made on a single ROP-probe machine. Strong preferences were assumed to indicate that the current search range was misaligned with a participant’s preferred speed and substantial adjustment was made toward that preference range. Strong preferences were used to restrict future anchor points such that the non-preferred ROP-probe speed became the maximum (or the minimum) allowed anchor for all subsequent search ranges. Following strong-preferences, the selected ROP-probe speed was placed at the first quartile from the respective anchor of the new range (if this was possible relative to any previous search-range anchor limits).

For example, in Figure S2, following block 1, which tested the predefined search range of 0s to 6s with ROP-probe machines offering 2s and 4s ROPs, the participant played the 2s machine more often, and for the final five of ten consecutive plays, indicating a strong preference for the faster ROP-probe machine. The subsequent search range was then anchored at the non-preferred ROP-probe speed (4s), and no subsequent search range would include rates-of-play greater than 4s. Thus, the search range for block 2 was 0s to 4s, with ROP-probe speeds for the next machine pair being 1.3s and 2.7s. Additionally, following the second block, a strong preference for the slower machine was exhibited, and thus the faster ROP-probe speed of 1.3s became the minimum possible anchor of all subsequent search ranges.

Weak preference adjustment. If a participant played one machine more frequently over ten consecutive plays, but not consecutively over the final five plays, a weaker preference was assumed, and a less aggressive adjustment to the search range was implemented. Following weak preferences, anchors of search ranges were shifted toward the preferred ROP-probe speed, such that 17th percentile of the current range became the new minimum anchor if the slower ROP-probe machine was preferred, or 83rd percentile became the new maximum if the faster ROP-probe machine was preferred. The width of search range was not narrowed following weak preferences, unless shifts were made toward previously identified maximum or minimum anchor limits.

However, if participants expressed a weak preference toward the same relative ROP-probe option in two consecutive blocks of the game (e.g. a weak preference was detected for the faster ROP-probe machine in two sequential pairings), this was assumed to resemble a strong preference. In this case, search ranges were adjusted as though a strong preference was expressed in the first of the two consecutive blocks, and thus subsequent search range anchors were limited to the non-preferred ROP-probe speed of that first machine pair.

For example, in Figure S2, during block 3 which had a search range from 1.3s to 4s and ROP-probes at 2.2s and 3.1s rates-of-play, the participant played 6 of 10 games on the faster ROP-probe machine, though non-consecutively, exhibiting a weak preference for the faster ROP-probe machine. Thus, the slow anchor of next search range was shifted to 3.5s, though the fast anchor remained at the 1.3s limit. Following the second consecutive weak preference for the faster ROP-probe machine in block 4 (which probed machines at 2.1 and 2.8s rates-of-play) the previous slow ROP-probe speed (i.e. 3.1s in block 3) was defined as a new maximum anchor limit for all subsequent search ranges.

No preference. If participants showed no behavioral preference in any ten consecutive plays after a total of 20 plays in one block, the search range was assumed to be roughly centred on the participant’s I-ROP speed, and the subsequent search range was narrowed to more accurately estimate the I-ROP. The subsequent search range was centred on the average speed of all 20 games played, and anchor points were placed at distances equivalent to the difference between ROP-probes from this center point. For example, following block 7 in Figure S2, no preference was exhibited between the 2.2s and 2.5s ROP-probe speeds, and the subsequent search range was defined from 2.1s to 2.7s.

Convergence and estimation. This process was repeated over a series of blocks until a convergence point was detected or a total of 11 blocks were completed. Convergence points were defined as ROP-probe machines that differed by less than 250ms in offered rates-of-play. For example, in block 8 in Figure S2, the ROP-probe speeds were 2278ms and 2488ms, differing by 210ms, and thus the procedure had reached predefined criteria for convergence and the ninth block was not presented.

Upon completion of this procedure, either by convergence or the maximum number of blocks were played, the estimated I-ROP was calculated as the average rate-of-play across the four ROP-probe machines presented in the final two blocks of testing. The standard deviation of this mean was also calculated to determine ROPs significantly faster (F-ROP) and slower (S-ROP) than the estimated I-ROP for implementation in the next stage of the experiment. To complete the example outlined in Figure S2, the final four ROP-probe machine rates-of-play were 2226ms and 2540ms in block 7 and 2278ms and 2488ms in block 8, thus the participant's I-ROP was estimated to be the average of these machines, 2383ms with a standard deviation of 154ms. Thus, during the next stage of the experiment, the participant would play single EGMs calibrated to their I-ROP (2383ms), F-ROP (1921ms) and S-ROP (2845ms) gaming speeds.

Table S1. Participant characteristics and gambling behavior relative to I-ROP estimate convergence.

Variable	Converged (N=34)	Non-converged (N=38)		t/χ^2(p)
Participant characteristics				
Age, years (SD)	29.2 (11.0)	30.9 (10.7)		0.66 (0.51)
Education, years (SD)	15.7 (2.7)	13.8 (3.0)		2.81 (0.006)
Cognitive ability (RM), mean (SD)	51.6 (6.9)	43.5 (10.3)		3.86 (<0.001)
Gambling severity (NODS), mean (SD)	1.9 (2.6)	3.3 (3.1)		2.05 (0.044)
Past year, any EGM gambling, N(%)	12 (35.3)	27 (71.1)		9.24 (0.002)
BIS Impulsiveness, total (SD)	63.8 (10.0)	67.4 (11.2)		1.41 (0.16)
GBQ Luck, mean (SD)	35 (12.6)	40.4 (14.4)		1.68 (0.10)
GBQ, Illusions of control, mean SD)	32.5 (9.7)	30.0 (12.0)		0.97 (0.34)
EGM gambling behavior			**convergence $F_{1,70}$ (p)**	**ROP*convergence $F_{2,140}$ (p)**
Average bet size, credits (SD)			0.81 (0.37)	0.43 (0.65)
F-ROP	4.2 (1.4)	3.9 (1.1)		
I-ROP	4.1 (1.3)	4.0 (1.1)		
S-ROP	4.1 (1.4)	3.8 (1.0)		
Inter-play reaction time, ms (SD)			15.26 (<0.001)	3.70 (0.027)
F-ROP	410 (248)	578 (283)		
I-ROP	371 (199)	610 (301)		
S-ROP	393 (197)	676 (346)		
Continued-play spending, credits (SD)			4.93 (0.030)	3.46 (0.034)
F-ROP	393 (894)	85 (107)		
I-ROP	148 (297)	72 (110)		
S-ROP	69 (120)	31 (36)		
Continued-play duration, sec (SD)			2.32 (0.13)	1.81 (0.17)
F-ROP	37.2 (52.3)	43.4 (44.2)		
I-ROP	28.4 (43.5)	53.4 (47.2)		
S-ROP	28.7 (43.7)	37.7 (41.4)		
Accuracy of amount spent, % (SD)			0.5 (0.48)	0.27 (0.77)
F-ROP	-70.0 (21.8)	-64.7 (40.1)		
I-ROP	-55.0 (32.2)	-42.3 (82.7)		
S-ROP	-36.7 (58.1)	-27.5 (85.4)		
Accuracy of winning outcomes, % (SD)			0.02 (0.88)	1.18 (0.31)
F-ROP	-33.5 (88.3)	-37.4 (37.6)		
I-ROP	-23.5 (46.7)	-8.6 (44.8)		
S-ROP	15.0 (85.7)	9.7 (62.9)		
Luck rating, mean Likert 1-7 (SD)			0.13 (0.72)	1.72 (0.18)
F-ROP	4.5 (1.3)	4.2 (1.7)		
I-ROP	4.1 (1.2)	4.5 (1.1)		
S-ROP	4.1 (1.1)	3.8 (1.3)		

Abbreviations: RM, Raven's Matrices; NODS, National Opinion Research Center DSM-IV Screening instrument; BIS, Barratt Impulsiveness Scale, version 11; GBQ, Gambling Beliefs Questionnaire. References provided in the main article text.

Table S2. Participant characteristics and gambling behavior relative to I-ROP player-group

Variable	Rapid (N=24)	Moderate (N=24)	Extended (N=24)		$F_{2,69}/\chi^2$(p)
Participant characteristics					
Age, years (SD)	27.1 (9.0)	34.0 (12.0)	29.2 (10.5)		2.63 (0.08)
Education, years (SD)	16.1 (2.5)	14.3 (3.5)	13.7 (2.4)		4.48 (0.015)
Cognitive ability (RM), mean (SD)	52.3 (7.8)	46.5 (7.0)	43.2 (11.7)		6.23 (0.003)
Gambling severity (NODS), mean (SD)	2.3 (2.8)	2.5 (2.3)	3.2 (3.7)		0.59 (0.56)
Past year, any EGM gambling, N(%)	9 (37.5)	15 (62.5)	15 (62.5)		4.03 (0.13)
BIS Impulsiveness, total (SD)	64.2 (10.1)	64.8 (10.5)	68.1 (11.5)		0.94 (0.40)
GBQ Luck, mean (SD)	38.7 (10.6)	34.0 (14.4)	40.9 (15.4)		1.57 (0.22)
GBQ, Illusions of control, mean SD)	34.7 (8.5)	29.4 (11.1)	29.5 (12.5)		1.89 (0.16)
EGM gambling behavior				**player-group $F_{2,69}$ (p)**	**ROP*group $F_{4,138}$ (p)**
Average bet size, credits (SD)				0.69 (0.51)	0.84 (0.50)
F-ROP	4.0 (1.4)	3.7 (1.2)	4.3 (1.2)		
I-ROP	4.0 (1.3)	3.9 (1.3)	4.2 (1.1)		
S-ROP	4.1 (1.4)	3.7 (1.1)	4.0 (1.1)		
Inter-play reaction time, ms (SD)				12.60 (<0.001)	1.92 (0.11)
F-ROP	318 (200)	586 (282)	592 (261)		
I-ROP	304 (170)	551 (306)	637 (249)		
S-ROP	336 (159)	573 (386)	717 (243)		
Continued-play spending, credits (SD)				8.03 (0.001)	3.78 (0.006)
F-ROP	565 (1023)	79 (115)	49 (68)		
I-ROP	233 (346)	53 (68)	38 (45)		
S-ROP	94 (135)	28 (36)	25 (32)		
Continued-play duration, sec (SD)				0.51 (0.60)	0.27 (0.90)
F-ROP	48.9 (54.3)	33.8 (43.3)	38.8 (46.4)		
I-ROP	43.3 (50.0)	38.5 (44.9)	43.1 (47.4)		
S-ROP	38.3 (48.8)	25.4 (37.6)	36.7 (40.8)		
Accuracy of amount spent, % (SD)				1.66 (0.20)	0.64 (0.63)
F-ROP	-72.8 (19.7)	-73.6 (21.3)	-55.2 (47.2)		
I-ROP	-58.4 (35.7)	-57.6 (24.4)	-28.9 (100.8)		
S-ROP	-34.2 (61.6)	-46.6 (36.3)	-14.8 (104.8)		
Accuracy of winning outcomes, % (SD)				3.68 (0.030)	1.1 (0.36)
F-ROP	-58.8 (20.2)	-33.3 (102.7)	-14.8 (38.6)		
I-ROP	-38.1 (24.6)	-21.3 (44.8)	12.5 (50.3)		
S-ROP	-3.3 (47.4)	20.3 (98.5)	19.6 (67.9)		
Luck rating, mean Likert 1-7 (SD)				0.85 (0.43)	0.53 (0.71)
F-ROP	4.6 (1.1)	4.2 (1.7)	4.3 (1.8)		
I-ROP	4.4 (1.0)	4.4 (1.2)	4.1 (1.3)		
S-ROP	4.1 (1.1)	3.7 (1.3)	4.1 (1.2)		

Abbreviations: RM, Raven's Matrices; NODS, National Opinion Research Center DSM-IV Screening instrument; BIS, Barratt Impulsiveness Scale, version 11; GBQ, Gambling Beliefs Questionnaire. References provided in the main article text.

Table S3. Participant characteristics and gambling behavior relative to problem gambling severity

Variable	No problem (N=21)	At-risk (N=24)	Prob./Path. (N=27)		$F_{2,69}/\chi^2$(p)
Participant characteristics					
Age, years (SD)	27 (13)	30.6 (8.9)	32.0 (10.4)		1.29 (0.28)
Education, years (SD)	15.6 (3.2)	14.9 (3.3)	13.9 (2.4)		2.2 (0.12)
Cognitive ability (RM), mean (SD)	51.7 (8.3)	46.2 (10.2)	45.0 (9.6)		3.22 (0.046)
Gambling severity (NODS), mean (SD)	0 (0)	1.5 (0.5)	5.9 (2.4)		97.98 (<0.001)
Past year, any EGM gambling, N(%)	6 (28.6)	12 (50.0)	21 (77.8)		11.77 (0.003)
BIS Impulsiveness, total (SD)	60.8 (9.3)	65.7 (9.4)	69.6 (11.6)		4.34 (0.017)
GBQ Luck, mean (SD)	32 (13.1)	36.9 (11.2)	43.4 (14.6)		4.58 (0.014)
GBQ, Illusions of control, mean SD)	29.7 (11.0)	32.0 (11.1)	31.7 (11.1)		0.29 (0.75)
EGM gambling behavior				**Severity $F_{2,69}$ (p)**	**ROP*Severity $F_{4,138}$ (p)**
Average bet size, credits (SD)				1.91 (0.16)	1.41 (0.23)
F-ROP	3.6 (1.2)	4.0 (1.4)	4.3 (1.1)		
I-ROP	3.7 (1.1)	4.3 (1.3)	4.1 (1.2)		
S-ROP	3.5 (1.3)	4.0 (1.3)	4.2 (1.1)		
Inter-play reaction time, ms (SD)				0.96 (0.39)	0.98 (0.42)
F-ROP	542 (304)	466 (263)	494 (277)		
I-ROP	557 (326)	416 (218)	523 (291)		
S-ROP	617 (404)	495 (264)	526 (284)		
Continued-play spending, credits (SD)				1.34 (0.27)	0.44 (0.78)
F-ROP	122 (245)	344 (875)	215 (593)		
I-ROP	56 (100)	187 (341)	78 (119)		
S-ROP	26 (48)	68 (127)	51 (64)		
Continued-play duration, sec (SD)				0.67 (0.52)	1.57 (0.19)
F-ROP	39.0 (50.4)	37.7 (48.7)	44.1 (47.0)		
I-ROP	25.5 (39.4)	55.0 (50.5)	42.3 (46.6)		
S-ROP	27.1 (43.1)	32.8 (41.2)	39.0 (43.8)		
Accuracy of amount spent, % (SD)				0.81 (0.45)	0.44 (0.78)
F-ROP	-62.0 (29.6)	-73.1 (23.5)	-66.0 (41.2)		
I-ROP	-38.2 (49.3)	-60.4 (32.1)	-45.4 (90.3)		
S-ROP	-19.8 (70.1)	-46.4 (48.1)	-28.4 (92.5)		
Accuracy of winning outcomes, % (SD)				1.77 (0.18)	0.62 (0.65)
F-ROP	-15.4 (107.8)	-49.6 (30.6)	-38.8 (40.3)		
I-ROP	-4.0 (46.6)	-33.1 (34.5)	-9.2 (51.3)		
S-ROP	17.3 (90.9)	-2.7 (70.2)	21.5 (62.8)		
Luck rating, mean Likert 1-7 (SD)				0.98 (0.38)	1.73 (0.15)
F-ROP	4.5 (1.4)	4.4 (1.6)	4.1 (1.6)		
I-ROP	4.0 (1.0)	4.4 (1.2)	4.5 (1.2)		
S-ROP	3.7 (1.2)	3.7 (1.0)	4.4 (1.3)		

Abbreviations: Prob./Path., problem or pathological gambling; RM, Raven's Matrices; NODS, National Opinion Research Center DSM-IV Screening instrument; BIS, Barratt Impulsiveness Scale, version 11; GBQ, Gambling Beliefs Questionnaire. References provided in the main article text.

Table S4. Gambling behavior relative to self-reported, subjectively preferred EGM

Variable	Subj. pref.	Non-pref.	$F_{1,60\ (p)}$
Average bet size, credits (SD)	4.1 (0.2)	4 (0.2)	0.79 (0.38)
Inter-play reaction time, ms (SD)	530 (39)	552 (35)	1.01 (0.32)
Continued-play spending, credits (SD)	185 (76)	68 (18)	3.13 (0.08)
Continued-play duration, sec (SD)	47 (6.7)	31.9 (5.3)	5.86 (0.019)
Accuracy of amount spent, % (SD)	-53.3 (6.1)	-47.4 (8.7)	0.93 (0.34)
Accuracy of winning outcomes, % (SD)	-9.5 (9.6)	-13.7 (6.3)	0.31 (0.58)
Luck rating, mean Likert 1-7 (SD)	4.9 (0.2)	3.8 (0.1)	46.22 (<0.001)

Abbreviations: Subj. Pref., self-reported, subjectively preferred EGM machine (i.e. the machine selected as 'most desire to play again'); Non-pref., average behavior across the two non-preferred EGM machines.

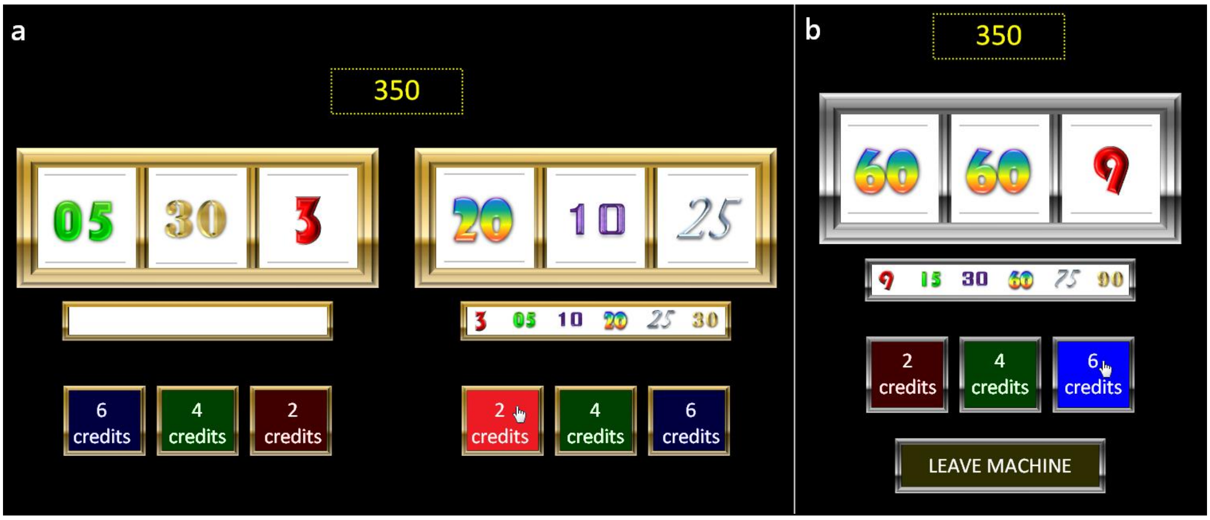

Figure S1. Full-color version of Figure 1 in the main article. (a) Screen-capture of paired slot-machines used during I-ROP estimation procedure. (b) Screen-capture of single-machine EGM play following I-ROP estimation.

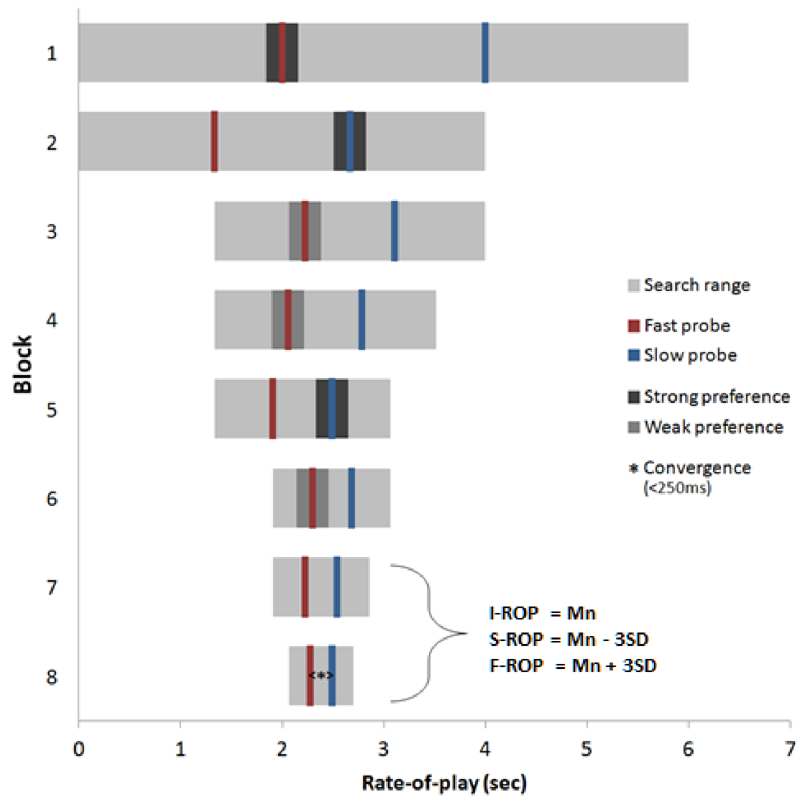

Figure S2. Schematic example of PEST procedure used to estimate I-ROPs. Search range adjustments following strong and weak preferences, or no preference are illustrated. I-ROPs and relative rates-of-play (faster: F-ROP; slower S-ROP) were calculated from the mean and standard deviations of the final four probe machines (presented in the final two blocks, e.g. blocks 7 and 8 in this example).