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Review

A neurocomputational account of multi-line electronic gambling machines

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Multi-line electronic gambling machines (EGMs) are strongly associated with problem gambling. Dopamine (DA) plays a central role in substance-use disorders, which share clinical and behavioral features with disordered gambling. The structural design features of multi-line EGMs likely lead to the elicitation of various dopaminergic effects within their nested anticipation-outcome structure. The present account draws an analogy between EGM gambling and latent state inference accounts of conditioning, and links maladaptive gambling-related beliefs and expectancies to a process of erroneous latent state inference that may be exacerbated by EGM design features and associated dopaminergic processes. Over the course of repeated exposure to gambling, these processes may foster the emergence of maladaptive state priors, which clinically manifest as gambling-related cognitions, beliefs, and expectancies.

Highlights

Maladaptive and erroneous gambling-related beliefs and cognitions (e.g., magical and superstitious thinking, illusion of control) are core symptoms of disordered gambling.

Modern multi-line electronic gambling machines are associated with a high problem gambling risk profile. Their structural design features likely elicit various dopaminergic responses (e.g., related to salience, prediction error, and uncertainty).

It is argued that maladaptive gambling-related beliefs and cognitions may arise from the erroneous inference of latent states during gambling (reflecting, e.g., 'hot' vs. 'cold' machine states and beliefs regarding internal vs. external control).

Erroneous gambling-related beliefs may therefore directly arise from exposure to gambling and their emergence may be exacerbated by specific machine design features and associated dopaminergic processes.

The role of gambling formats in disordered gambling

Across many societies, gambling is a popular leisure activity. For the gambling industry, it is a lucrative business model [1]. For some individuals, gambling can lead to a range of financial, social, and mental health problems that can result in high costs for individuals and society. Gambling disorder shares clinical aspects with substance-use disorders [2], including loss of control over gambling, a preoccupation with gambling, and turning to gambling for the regulation of negative affect and stress. Disordered gambling is also linked to more specific behavioral and cognitive phenomena. 'Loss chasing' [3], a diagnostic criterion unique to gambling disorder, refers to intensified gambling in order to recoup one's losses. Individuals suffering from disordered gambling also endorse various irrational and superstitious beliefs about the role of skill in gambling, the nature of luck, and their own ability to influence or predict gambling outcomes [4–9].

Different games of chance are differentially linked to problem gambling. EGMs (modern variants of slot machines) are amongst the gambling products exhibiting the strongest association with problem gambling [10–13]. Individual cognitive and psychological factors likely contribute to disordered gambling [14,15], but it is widely appreciated that the structural design features of gambling products, likely in interaction with individual risk factors [15], play a central role in their addictive potential [10,15,16]. Which aspects of product design are at play, and what are the mechanisms through which they might affect behavior, cognition, and clinical outcomes? Addressing these issues requires the consideration of two aspects. First, one needs to carefully consider the design features of the specific gambling product. The present account focuses on modern multi-line EGMs, which show a particularly strong association with problem gambling. Second, design features need to be considered in the context of the underlying neurocomputational mechanisms that they might facilitate. To this end, this review will draw upon recent developments in neurocomputational theory.

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Multi-line EGMs

EGMs resemble classical mechanical slot machines, consisting of several reels with symbols. Pressing the spin button initiates the reel spin, and the objective is to obtain winning symbol combinations. Symbols vary in value, with lower-value card symbols (e.g., 10, J, Q, K, A) and higher-value image symbols (e.g., the sun in Figure 1B). The greater the number of identical symbols falling from left to right on any given payline, the larger the win. Outcomes on mechanical slot machines were restricted by the constraints of the physical reels and typically employed three reels with a single horizontal payline (Figure 1A). In contrast, multi-line EGMs are computer programs running on machines with touch screens, in a browser window, or on a mobile device, and employ much larger symbol matrices (e.g., 3 × 5 reel positions, see Figure 1A), such that vast numbers of symbol combinations are possible (e.g., a 3 × 5 EGM with ten different symbols has 10^{15} possible outcome combinations). This design allows players to wager on a much larger number of paylines (see Figure 1A for a subset of possible paylines on a 3 × 5 EGM). Both the wager (i.e., the betting amount) and the number of paylines can be adjusted by the player on each spin, but the maximum wager is often subject to regulation.

EGMs additionally use 'scatter' and 'wild' symbols. Scatter symbols are high-value symbols that count towards a winning combination regardless of where they appear on the reels. For example, obtaining at least three scatter symbols on any reel position might initiate a bonus game feature (Box 1). Wild symbols, by contrast, can substitute for any symbol to achieve a winning combination on a payline.

Spin outcomes can be differentiated with respect to the signaled versus the objective reward. The signaled reward on spin t ($R_{\text{sig},\,t}$) is the reward displayed to the player. The objective reward,

Glossary

Gambler's fallacy: the expectation that sequences of random events alternate more than they actually do.

Hot hand fallacy: the expectation that a series of successes is likely to be followed by another success.

Incentive salience: the motivational (appetitive) value of a stimulus.

Intermittent reinforcement: irregular delivery of reinforcement, leading to reward uncertainty.

Latent state: an individual's belief about a state of the environment.

Reward prediction error: the difference between received and predicted reward.

Sensory prediction error: the difference between experienced and predicted sensory input.

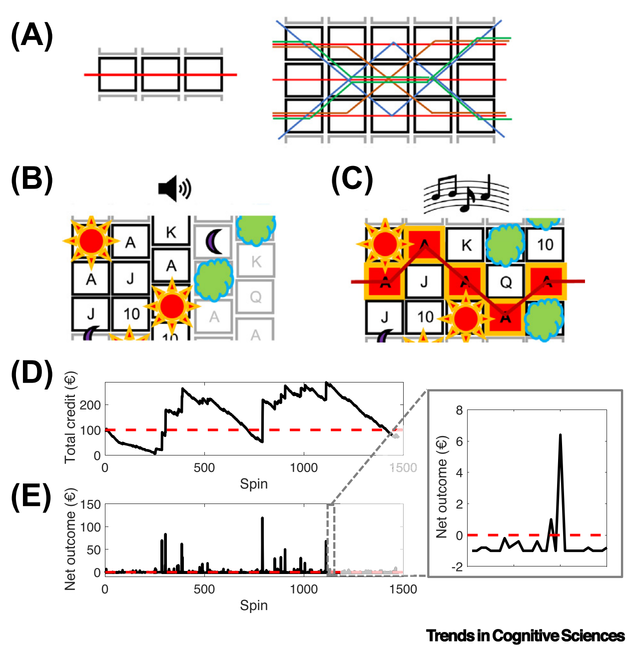

Figure 1. Paylines, feedback events, and reinforcement schedules in electronic gambling machines (EGMs). (A) Classical mechanical slot machines typically employed three physical reels with a single central payline on which winning symbol combinations could be obtained. In contrast, multi-line EGMs use at least five reels with at least three reel positions each, vastly increasing the number of symbol combinations and paylines. (B,C) Feedback is provided on several levels during EGM gambling. Outcomes of individual reel spins (B) and the total spin outcome (C) are signaled by audio-visual feedback that scales in salience and complexity with the magnitude of a win. Losses are typically associated with a complete absence of feedback. (D) Online casino transaction data (credit history) from the author (≈1500 high-volatility EGM spins with an initial credit of 100€) reflecting a classical intermittent reinforcement scheme [21]. (E) Replotting the data from (D) in terms of the objective reward (R_{obj} = amount won – amount wagered) per spin shows a large majority of losses, interspersed with a few large wins, as typical for high-volatility slots. The inset in (E) shows a magnified section of illustrating three outcome types for a wager of 1€ per spin: regular losses ($R_{\text{obj}} = -1$), wins ($R_{\text{obj}} > 0$), and losses-disguised-as-wins, where the amount won is larger than zero, but lower than the wager ($-1 < R_{\text{obj}} < 0$).

Box 1. Symbols, bonus features, and multipliers in EGM design

In addition to the design features outlined in the main text, several other structural features of EGMs deserve mention:

- Symbol design: perceptual symbol salience in EGMs typically scales with value, such that high-value image symbols (e.g., scatter and wild symbols) stand out in size, color, contrast, luminance, and depth features and are paired with salient audio-visual effects, ensuring prioritized processing [34,111]. High-value symbols also often cover an area beyond their reel positions, skewing the overall proportion of high-value symbols amongst all visible symbols [112].
- Emphasized stopping: the visualization and sound effects accompanying the reel spin often depend on the potential win magnitude. For example, if reels one, two, three, and four have already revealed the same high-value symbol on a particular payline, the reel-stopping phase for reel five will typically be accompanied by highly salient audio-visual effects to emphasize the potential for a big win.
- Bonus- and free-spin features: bonus games are usually initiated by hitting a specific symbol combination on a regular spin. They are often associated with a greater potential win magnitude (multiplier potential) along with audio-visual effects. 'Free-spins' do not require additional wagers and are often associated with an increased multiplier potential. The term 'free-spins' is of course in itself misleading, as they are obviously not free, but incorporated into the overall return-to-player calculation of the product [113].
- Hidden deductions: many EGMs deduct the wager from the balance at the time the spin button is pressed during demo play, but shift this time point to the reel spin phase during gambling for actual money [112]. Because attention is predominantly allocated to the reels [114], this may lead to an underestimation of cumulating losses.
- Double-or-nothing: this gives the player the option to 'gamble' following a win, receiving a 50% chance to double the win or lose everything. It thus constitutes a further multiplier potential mechanism that can increase outcome variance.
- Stop-button: in some products, all reels may be stopped immediately by pressing a stop button at any time during the reel spin phase. Since the outcome of the spin is determined *a priori*, this of course does not affect the result, but in some individuals may affect the perceived control over the outcome [115].

$R_{obj,\ t}$, is the amount won minus the amount wagered, leading to the following outcome types (see also Figure 1D):

(1) Regular wins ($R_{obj,\ t} > 0$) are celebrated via audio-visual effects that scale in complexity and salience with the magnitude of the win.
(2) Losses-disguised-as-wins ($R_{sig,\ t} > 0$ and $R_{obj,\ t} < 0$) yield a net-negative outcome that is nonetheless celebrated with feedback similar to a regular win [17–19].
(3) Near misses are a specific type of regular loss where a winning symbol falls just above or below a payline [17].
(4) Regular losses yield a loss of the full amount wagered and are usually accompanied by the complete absence of audio-visual feedback.

This design leads to a high event frequency and a nested anticipation-feedback structure within a single spin: The reels stop sequentially, such that anticipation and outcome processing occur for each individual reel (Figure 1B). Anticipation and outcome phases also occur with respect to the overall spin outcome, which is revealed following the stopping of the final reel (Figure 1C). High event frequencies likely contribute to the risk profile of EGMs [10,20].

EGMs operate via **intermittent reinforcement** (see Glossary) [21,22], specifically via random ratio schedules, where frequent losses are randomly interspersed with fewer, but potentially much larger, wins (Figure 1D,E). Because spin outcomes are determined in advance by a random number generator [22], outcomes are independent, unpredictable, and depend only on the mathematics of the product (although manufacturers can manipulate the relative frequencies of specific outcomes such as near misses [23] or losses-disguised-as-wins). Primary aspects that can affect product preferences [24–26] are return-to-player and volatility. Return-to-player is the average percentage of payback per wager. Typical values for EGMs range around 89–96%, substantially lower than, for example, European Roulette, which has a return-to-player of 97.3%. Volatility, however, refers to payout variance. An EGM with low volatility pays out smaller wins with higher frequency, whereas high-volatility EGMs are associated with very infrequent but potentially very large wins (see Figure 1D,E for an example of actual gambling transaction data from high-volatility EGMs).

DA and EGM gambling

The addictive properties of psychoactive substances are directly linked to their ability to elicit phasic release of the neurotransmitter DA [27]. It is therefore not surprising that the potential role of DA in gambling and gambling disorder has been extensively discussed [28–33]. Recent findings indicate that exposure to gambling-like reward uncertainty (intermittent reinforcement) can elicit behavioral and dopaminergic effects similar to drugs of abuse (see later), which is likely a major initial driving factor of the addictive process in gambling. At least three related DA responses likely factor into gambling in general, and EGMs more specifically.

Salience

Two aspects of dopaminergic salience processing may contribute to EGM gambling: perceptual and incentive (motivational) salience. The perceptual salience of a stimulus depends on the degree to which its features differ from the surroundings [34], and DA release is greater for stimuli with greater perceptual salience [35–40]. Perceptual salience is masterfully leveraged in EGM design (see earlier and Box 1). The perceived salience and the motivational properties of cues (**incentive salience** [41]) are directly related to their association with states of high DA release, which, in the case of substance-use, is elicited by drug effects [41]. In gambling, this likely occurs via uncertainty exposure [42–44] (see section on uncertainty later). Notably, such effects may be modulated by genetic factors [45] and may depend on cue characteristics [46].

Prediction errors

DA neurons in the ventral tegmental area (VTA) encode **reward prediction errors** [47] – they increase their firing rate for better-than-expected outcomes (positive prediction errors) and reduce their firing rate below baseline for worse-than-expected outcomes (negative prediction errors). In formal learning models [39,47,48], prediction errors update a model of the environment to enable a better reward prediction in the future. Phasic activity of DA neurons thus associates stimuli and/or actions with reinforcement [49,50]. DA neurons also signal **sensory prediction errors** [51] where outcomes deviate from expectation in terms of their sensory features [52–56]. Due to their nested anticipation-feedback structure, EGMs likely elicit several reward and sensory prediction error responses during a single spin, with respect to individual reels (Figure 1B) and with respect to the overall spin outcome (Figure 1C). Given the random reinforcement scheme of EGMs, prediction error signaling will be permanently elevated.

Uncertainty

VTA DA neurons also signal reward uncertainty [30,57,58] and exhibit greater anticipatory activity for cues that signal higher reward uncertainty [58]. This resonates with human neuroimaging work showing the greatest responses in regions of the DA system when uncertainty is highest [59]. Again, due to the nested anticipation-feedback structure of EGMs, several such anticipatory effects may occur per spin – for each reel and the overall spin outcome. In line with the importance of anticipatory effects, reinforcement-related neural circuits respond to the anticipatory reel spin phase [60], and anticipatory responses in dopaminergic regions are upregulated in individuals suffering from disordered gambling [61,62]. Exposure to intermittent reinforcement elicits behavioral and neural effects highly similar to those of drugs of abuse: DA release in the nucleus accumbens increases during intermittent reinforcement [63] and repeated exposure to reward uncertainty increases the attribution of incentive salience (i.e., motivational properties, see earlier) to conditioned stimuli [42–44]. This likely reflects neuroadaptation processes (incentive sensitization) in the DA system, similar to those that are elicited by drugs of abuse [63–67]. Uncertainty exposure,

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rather than winning *per se*, might therefore be an important reinforcing component of EGM gambling. This dovetails with field observations that individuals engaging in machine gambling often spend their winnings to increase the time spent gambling rather than cash out [68].

A latent state perspective on EGM gambling

Gambling shares structural similarities with conditioning paradigms, where agents learn to predict reinforcement based on experienced cues and outcomes. Conditioning likely involves the inference of **latent states** that underlie cues and outcomes [69–71]. For example, an animal may learn during acquisition that cues predict reinforcement, and later learn during extinction that this association no longer holds (Figure 2A). Latent state models conceptualize extinction as the learning of a new latent state where the conditioned stimulus is no longer reinforced, rather than the unlearning of the initial association [69–71]. This can explain renewal, where a conditioned response rapidly re-emerges in a new context following extinction, suggesting that the original association was not unlearned.

In contrast to conditioning paradigms, where acquisition and extinction are statistically distinct (i.e., reinforcement occurs during acquisition, but not during extinction), EGMs only have a single machine state [22,69], which is defined, for example, by return-to-player and volatility (see earlier). Nonetheless, gambling often involves seemingly erroneous inferences about latent states. For example, common misconceptions include the idea that EGMs cycle through ‘hot’ and ‘cold’ machine states, where wins are likely and less likely, respectively (Figure 2B), that situational cues or outcome sequences predict that bonus games or jackpots are ‘due’ (Box 1), or that outcomes may in some situations be controllable or predictable [4–9]. The idea that such gambling-related beliefs may be linked to maladaptive state inferences was first put forth by Redish *et al*. [69]. Such latent state inference accounts also resonate with active inference accounts of behavior and cognition [72] that are centered around the idea that the brain continuously attempts to update an internal model of the environment.

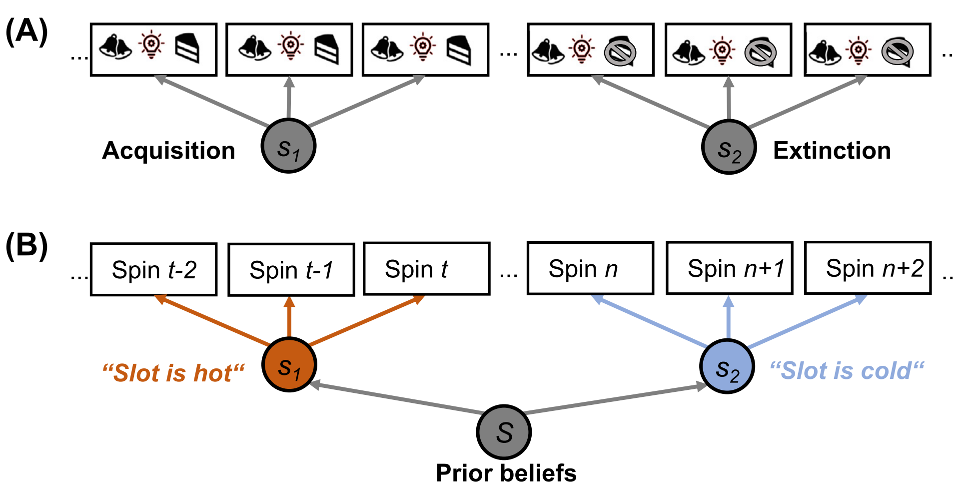
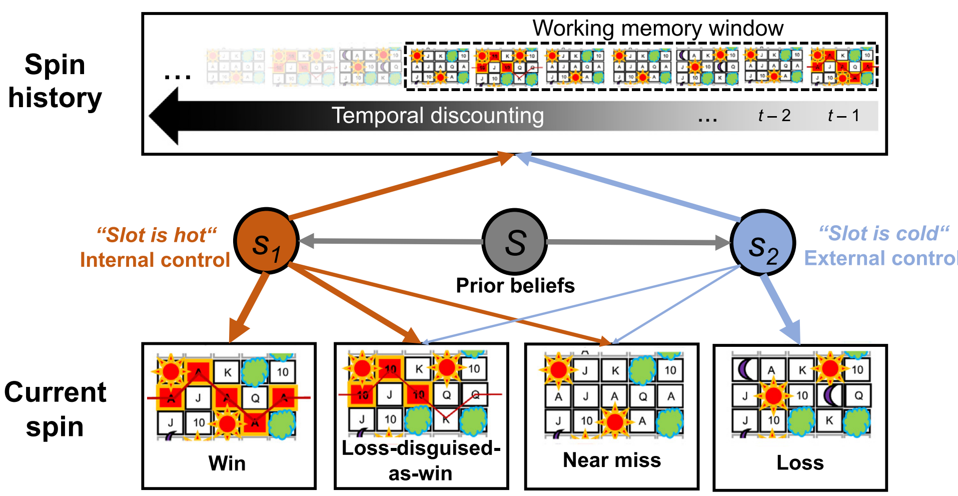


Figure 2. Latent states in conditioning and machine gambling. (A) Latent state perspective on acquisition and extinction in Pavlovian conditioning. During acquisition, cues are consistently paired with reinforcement. During extinction, reinforcement is omitted. An animal might therefore attribute trials during acquisition to the presence of a common latent state s_1, where cues predict reinforcement. From the absence of reinforcement during extinction, the animal might infer that the environment has transitioned to a different latent state, s_2. (B) Latent state perspective on electronic gambling machine (EGM) gambling. Based on experienced sequences of spin outcomes, individuals might (erroneously) infer that an EGM cycles through ‘hot’ (s_1) and ‘cold’ (s_2) states, where wins are likely and less likely, respectively. Prior beliefs (S) may influence these erroneous latent state inferences.

EGM design features and underlying dopaminergic mechanisms may foster erroneous latent state inferences in several ways. First, latent state inference is thought to depend in part on the similarity of observed cues to learned representations [69–71,73]. Given their perceptual similarity to actual wins, losses-disguised-as-wins [17–19] (and potentially also near misses) might erroneously be attributed to a 'hot' machine state (Figure 3). In line with this account, despite their net negative value, losses-disguised-as-wins tend to be miscategorized as wins [17] and elicit similar neural effects [74]. Dopaminergic prediction errors support the updating of an agent's beliefs about the current state of the environment [48]. In several recent models, belief updating depends on cue salience [75–79] such that highly salient events coupled with positive prediction errors (such as an EGM big win) may exert disproportional effects on state updating. This might specifically foster the stabilization of erroneously inferred latent states linked to conditions of high positive prediction errors and high salience. DA release associated with salient big wins may also facilitate episodic memory encoding via interactions of the DA system with the hippocampus [80–82]. This resonates with the availability heuristic [83], where the ease of memory access to past events influences probability estimates, and with the idea that (early) big wins may play an important role in driving excessive gambling [69,84,85]. Such effects may also contribute to the observation that individuals often continue to gamble following big wins rather than cash out [68]. Big wins may be interpreted as particularly salient indicators for the transition into a 'hot' machine state (Figure 3), where more wins are expected to follow. Within the skewed belief system of an individual who regularly participates in gambling [86], quitting in such a situation may appear irrational.

Second, latent state inference in gambling likely depends on erroneous interpretations of event sequences [4,5,9,87]. Prominent examples include the **gambler's fallacy** and the **hot hand**



Trends in Cognitive Sciences

Figure 3. Factors that may contribute to latent state inference during machine gambling. Latent state inference during electronic gambling machine (EGM) gambling is likely affected by the experienced spin history, the outcome of the current spin, and an individual's priors over gambling latent states. The perceptual similarity of spin outcomes (see main text) may lead to an attribution of outcomes to different latent states (e.g., s_1, s_2). These states might, for example, correspond to erroneously inferred 'hot' or 'cold' machine states, or more generally, to perceived internal versus external control over outcomes. In reality, there are no latent states, and all outcomes result from a single statistical machine state. Spin outcomes are associated with a combination of audio-visual cues, a signaled reward, and the objective reward corresponding to the signaled reward minus the wager. Due to their perceptual similarity to actual wins, losses-disguised-as-wins and near misses may both be preferentially attributed to s_1, despite their net negative values. Latent state inference may be additionally affected by the experienced spin history, subject to additional processing constraints (e.g., limited working memory capacity, temporal discounting, see main text) and an individual's prior beliefs over states (S).

fallacy [5] and beliefs about the cyclical nature of luck [4]. Processing of sequences is subject to additional cognitive constraints and biases (Figure 3): a limited working memory capacity and attentional constraints imply that individuals only process a 'sliding window' of outcomes – small samples that often deviate from the true long-run statistics of the environment [88]. Further, the salience of wins and losses-disguised-as-wins implies that these events may be prioritized in working memory [89], thereby further skewing sequence-based inference. In some models, the probability that a new latent state is inferred increases with decreasing average reward prediction error [69], and this may contribute to the erroneous attribution of wins and losses to different latent states [69]. Gambling episodes may also be subjectively structured into sequences of 'losses culminating in a win' [90]. If sequence values are only tallied up following wins, discounting of temporally more distant losses in the sequence (Figure 3) may inflate the subjective value of net negative sequences, thereby skewing an individual's perception of actual wins [90].

While 'hot' and 'cold' machine states are examples of erroneous latent state inferences that exhibit a clear analogy to conditioning, a latent state perspective may accommodate other gambling-related cognitive distortions and beliefs [4–8,69]. For example, wins may be taken at 'face value', or interpreted as related to skill, ability, or expertise, whereas losses are 'explained away', or related to circumstances [6,69,91]. Gambling is also linked to control illusions (e.g., erroneous beliefs that chance outcomes can, in some situations, be controlled [8,9,92] or predicted [6,9]; sometimes referred to as primary and secondary control [93]). At the most fundamental level, gambling latent states may fall into two broad categories: states linked to perceived internal versus perceived external control [94,95]. Under real-world conditions, latent state inferences contributing to gambling behavior are likely to be idiosyncratic and individual latent state priors (Figure 3) may depend on experience, contextual factors, and situational cues [86].

This account suggests two levels at which gambling-related cognitive distortions may affect gambling behavior. The first level involves state inferences on the level of an ongoing gambling episode. The second level involves an individual's prior beliefs, which may bias episode-level inferences [8,96] (note that current self-report scales do not clearly dissociate these levels [5–7]). Over time, erroneous latent state inferences may then foster the formation and stabilization of maladaptive state priors, which clinically manifest as gambling-related beliefs and expectancies (Figure 4). This account makes several predictions. First, erroneous beliefs should primarily arise from exposure to gambling, rather than preceding gambling. Indeed, problematic gambling tends to increase maladaptive beliefs rather than vice versa [97], and non-gambling individuals also exhibit erroneous cognitions when exposed to a simulated slot machine [87]. Second, early in EGM gambling, the number of previously inferred latent states is likely limited (Figure 4A), and prior beliefs may often be relatively vague and restricted to more general beliefs, such as the gambler's fallacy [88]. However, skill-based features in EGMs [98,99], and gambling formats with

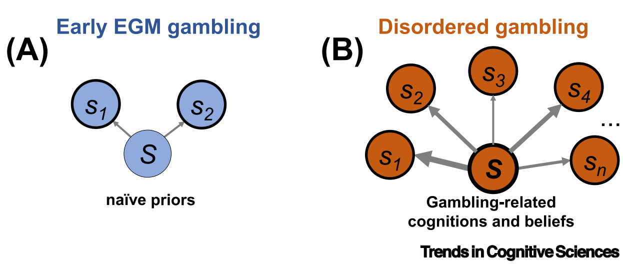


Figure 4. Gambling beliefs and latent state inference over the course of problem gambling. (A) During the early phases of electronic gambling machine (EGM) gambling, individuals may only have naïve and vague prior beliefs (e.g., reflecting more general beliefs such as the gambler's fallacy), and a limited portfolio of latent state representations (s_1, s_2). (B) Over the course of extended exposure to gambling, the size of the portfolio of erroneously inferred latent states is predicted to increase (s_1 to s_n), fostering the development of maladaptive state priors that clinically manifest as gambling-related cognitions, beliefs, and expectancies. States in (B) then reflect an individual's belief portfolio.

some role of expertise (e.g., sports betting [100]), may skew initial priors towards internal (vs. external) control states. This has direct implications for policy and regulation (Box 2). Over time, participation in EGM gambling should then increase the number of previously inferred erroneous latent states in a gambler's 'state portfolio' (Figure 4B). This would not only increase the likelihood of erroneous state inferences occurring during future gambling episodes, but an increasing size of the state portfolio should also increase the likelihood of latent state switches occurring during a gambling episode. The reason is that a larger state portfolio increases the likelihood of a match with a stored state representation, thereby evoking a state switch. Third, to the extent to which current clinical scales accurately measure these processes, state portfolio size should be a direct function of the degree to which gambling-related beliefs and expectancies are endorsed.

Maladaptive beliefs, gambling, and the model-based system

Conditions of uncertainty have long been linked to the formation of superstitious, magical, and conspiratorial beliefs [101–105], which exhibit substantial conceptual links to gambling-related cognitive distortions [4–7] that arise under reward uncertainty. Generally, decision-making may be driven by model-based predictions that are based on a model of the environment and model-free predictions that are based on the past reinforcement history [106]. In this view, erroneous latent state inferences correspond to the formation of an incorrect model of the environment. Gambling disorder has repeatedly been linked to impaired model-based control in multistep reinforcement learning tasks [107–109], consistent with the idea of erroneous latent state inference. Despite this general impairment in case-control studies, when individuals suffering from problem gambling are exposed to gambling-related environments, model-based control is markedly improved [110]. This is consistent with the idea that gambling may lead to the formation of state priors facilitating latent state inference in those settings in which gambling regularly takes place. Such priors may be maladaptive under the unpredictable reinforcement scheme of EGMs, where they facilitate erroneous latent state inference. However, when there are regularities that can be exploited by the model-based system, as in standard tasks used to measure model-based control, such priors may result in performance improvements [110].

Concluding remarks

By drawing an analogy between EGM gambling and latent state inference accounts of conditioning [69–71], the present account casts maladaptive gambling-related cognitions, beliefs, and expectancies as erroneous latent state inferences arising during exposure to random reinforcement. This process may be facilitated by dopaminergic processes associated with salience, prediction error, and uncertainty, which can be linked to specific EGM design features (see Outstanding questions). Over repeated exposure to gambling, an individual's portfolio of erroneously inferred latent states increases, contributing to the formation of maladaptive latent state priors over

Box 2. Implications for policy and regulation

Gambling regulation and harm prevention should be informed by the consideration of structural design features of products, as argued previously [15,18,26,113,116–118]. Regulation differs between jurisdictions, but some approaches focus on mechanisms highlighted here. These include, for example, imposing minimum spin durations or mandatory breaks (targeting event frequency) and maximum bet- or win-sizes (targeting outcome variance and limiting losses per unit time). However, such measures can only serve harm reduction if no regulatory loopholes are exploited [119]. EGM design features that may drive erroneous latent state inferences may constitute potential further targets for prevention and regulation [18,86]. Furthermore, many of the considerations outlined here might also apply to other gambling formats. Sports betting products, for example, have a similar risk profile as EGM gambling [10,12] and share several design features with EGMs, including high event frequencies, multiplier potentials and near-miss outcomes [100]. These mechanisms should therefore be taken into account in future approaches to the regulation of these products. In the present framework, maladaptive or erroneous latent state priors might facilitate the development of erroneous gambling-related beliefs and cognitions. Therefore, the role of gambling advertising also warrants further investigation [120], as advertising content may be a route towards the induction of erroneous priors (e.g., priors related to internal control states).

Outstanding questions

How do experimental manipulations targeting the dopamine system affect erroneous latent state inference during gambling?

How are latent state priors affected by contextual and situational cues in gambling?

What new experimental approaches are required to map an individual's 'latent state portfolio'?

How do different EGM design features interact in driving maladaptive belief emergence in EGM gambling?

Which individual risk and resilience factors may explain individual differences in gambling-related beliefs and cognitions?

gambling episodes, which in turn clinically manifest as gambling-related cognitions, beliefs, and expectancies. EGMs, by virtue of their structural design, may foster such erroneous latent state inferences, thereby facilitating persistent gambling despite negative consequences.

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Declaration of interests

No interests are declared.

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