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A Manifesto for Cognitive Models of Problem Gambling

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Abstract

Research on problem gambling has identified a wealth of phenomena related to the aetiology and maintenance of pathological gambling, its prevalence and risk factors, and has suggested programs and treatments. Remarkably, techniques of systematic formal modelling have rarely been used in the investigation of problem gambling despite their potential. We summarise and assess the current state of the field and highlight the opportunities and the potential impact of cognitive modelling.

Keywords: Problem gambling; cognitive modelling

Introduction

According to the most recent prevalence survey released by the UK Gambling Commission (Wardle et al., 2011), it can be estimated that 451 000 people in the UK alone are problem gamblers[1]. The authors further note that these figures tend to be underestimated since they exclude homeless people and prisoners, groups which are generally associated with a disproportionally high prevalence of problem gambling.

The adverse effects resulting from pathological gambling are not limited to pathological individuals, but affect their familial and their social context, and even the general public (e.g. via gambling-related crime[2]). Gambling and gambling problems are widespread in many countries around the world, and have become more ubiquitous with the popularity of Internet gambling. In spite of substantial research in psychiatry, genetics, neuroscience, psychology and sociology, recent reviews of the scientific evidence have concluded that the risk factors affecting the development of problem gambling (PG) are still poorly understood (Abbott, Volberg, Bellringer, & Reith, 2004; Blaszczynski & Nower, 2002; Sharpe, 2002).

Effective development of prevention and treatment of pathological gambling necessitates the precise understanding of the causes and related factors. The identification of risk groups and risk factors has been an important direction of previous research. Prevalence studies have also studied the effect of availability of and exposure to gambling activities on the prevalence of pathological gambling. In spite of their merits, prevalence studies are not suited to study the onset of problem gambling, and therefore, longitudinal studies have been called for, some of which are now producing results (e.g. Dussault et al., 2011, which we discuss in this paper).

Various mechanisms have been identified to play a role in the development and maintenance of pathological gambling, including psychopathological and biological vulnerabilities, misleading cues from the gaming environments (e.g. losses framed as wins), the role of emotion, reinforcement mechanisms and irrational beliefs. Recent work suggests that there may be a complex interplay between these different factors, in particular with respect to the question as to why some gamblers develop pathologies while others do not. This calls for the development of well-specified theories of the underlying mechanisms which can be tested against empirical data. Surprisingly, as we shall see later, there are hardly any computational models of PG. The goal of this paper is to review and summarise previous work leading to this direction, and to outline the prospects of developing cognitive models for pathological gambling. Using three levels of analysis (biological, psychological and integrative), we discuss recent work on theories of problem gambling, with a particular focus on the aetiology of this disorder. Based on this, we propose cognitive modelling as an effective methodology for developing and validating theories on problem gambling.

Development and Maintenance of Problem Gambling

Problem gambling has emerged as a topic spanning various academic disciplines. The development of theories of problem gambling is traditionally driven by research in psychiatry, biology and (cognitive) psychology. Since (problem) gambling is also embedded in a wider network of economic interests and socio-cultural contexts, a wealth of interesting cross-disciplinary subtopics has been identified. Not surprisingly, integrative models propose to (re-)establish a holistic view on the phenomenon of problem gambling. As we will discuss later, these theories offer a fertile ground for a cognitive modelling approach, spanning the different levels of analysis mentioned above.

Psychiatric and Biological Theories

The medical model has dominated problem gambling research since pathological gambling was classified as a disorder of impulse control in DSM-III (American Psychiatric Association, 1980). Revised editions use criteria developed

[1] Wardle et al. report the prevalence of problem gamblers in the UK as 0.9% of the entire population aged 16 and over, according to the DSM-IV screen.

[2] Various studies on the relationships between gambling and crime paint a mixed picture. However, a robust relationship between problem gambling and income-generating forms of crime has been found, cf. e.g. Brown (1987), Wheeler et al. (2008).

for diagnosing psychoactive substance dependence. There is good evidence that pathological gamblers show high levels of comorbidity, including disorders such as anxiety, depression, and alcoholism. The medical model has been criticised on methodological and conceptual grounds, in particular the heterogeneity of the problem gambling diagnosis and the fact that the direction of causality is unclear (Abbott et al., 2004; Dickerson & Baron, 2000; Raylu & Oei, 2002). One way to study causality is via longitudinal studies, such as for instance the study by Dussault et al. (2011). The authors examined the interactions between multiple factors and found a pattern of mixed influence between socio-familial circumstances, impulsivity, gambling problems and depression. The study assessed children at different timepoints in their development until adulthood; at age 10, socio-familial risk was assessed, at age 14, impulsivity, and at ages 17 and 23 gambling and depression. Structural equation modelling was used to assess the links among these variables. Impulsivity was found to be linked to both gambling problems and depression at an early age, whereas both of these were found to mutually influence each other over time from late adolescence to early adulthood.

The search for neural and genetic factors has been extensive in recent years, although the results must be seen as tentative (Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2004; Ibanez, Blanco, Perez de Castro, Fernandez-Piqueras, & Saiz-Ruiz, 2003; Raylu & Oei, 2002). There is some evidence that hemispheric disregulation and imbalance in neurotransmitter levels (including dopamine, serotonine, and noradrenaline) are involved in the development of PG. Interestingly, disfunction of the serotonergic system is implicated with impaired impulse control (Mehlman et al., 1994). Regular gamblers show high levels of arousal during gambling, and it has been suggested that arousal plays a key reinforcing role. Some genetic links have been suggested, although further research is needed to establish their validity. Biological theories tend not to be specific to gambling, and are rather imported from the neurosciences and genetics.

Psychological Theories

Learning Theory Skinner (1953) proposed that PG is a function of previous reinforcement history. Support for this comes from the fact that problem gamblers often had enjoyed a big win the first time they gambled. Empirical evidence suggests that the schedule of reinforcement is also a crucial factor. For example, Chóliz (2010) demonstrated that the perseverance of problem gamblers depends on the immediacy of reinforcement. Shead and Hodgins (2009) distinguish between different kinds of regular gamblers according to their expectations towards gambling, whether they expect positive reward, relief from negative affect, or neither, and stipulate that these subgroups should be addressed differently by therapy. Further research (Dickerson, 1984) has suggested that rewards are provided not only by money but also by environmental stimuli producing arousal. Limits of behavioural theories are that they appear to oversimplify PG (Raylu & Oei, 2002; Sharpe & Tarrier, 1993) and do not explain why gamblers come back to gambling after prolonged abstinence (Griffiths, 1995).

Personality The study of personality traits such as sensation seeking, extraversion, locus of control, psychoticism and neuroticism, has produced inconsistent results (Abbott et al., 2004; Griffiths, 1995). Better evidence is available with compulsivity (Blaszczynski, 1999) and impulsivity (Derevensky & Gupta, 2004). There is further empirical evidence that narcissism (when it results in overconfidence) is linked to problem gambling (Lakey, Rose, Campbell, & Goodie, 2007).

Personality research has often been criticised, for example on the grounds that it oversimplifies a complex nexus of causal factors (Allcock, 1986; Walker, 1992) and that problem gamblers form an heterogeneous group (Abbott et al., 2004).

Cognitive Biases It has been repeatedly shown that gamblers' thoughts are far from rational (Griffiths, 1995; Toneatto, 1999; Wagenaar, 1988; Mitrovic & Brown, 2009; Emond & Marmurek, 2010; Myrseth et al., 2010). Examples of cognitive distortions include the illusion of control (overestimation of the amount of contingency between actions and outcomes) and attributional biases (tendency to attribute successful outcomes to internal factors such as skill and unsuccessful outcomes to external factors such as bad luck).

Gamblers are subject to manipulations and misleading cues at several levels, which are thought to be a contributing factor in the formation and maintenance of irrational beliefs. Such manipulations are particularly well-studied for slot machine gambling. Slot machines allow wagers to be placed on combinations of symbols appearing in a row (the "payline"). Often, bets can be placed on several paylines at once, forming horizontal and diagonal patterns across the symbols on the reels, such that multiple bets are made in one game. Symbols are distinguished by how much they "pay" when they occur in a winning combination ("paying symbols"), where non-paying symbols are sometimes represented as blanks.

In a highly revealing article, Harrigan and Dixon (2009) describe how slot machines common in Canada are set up to deceive players. The investigated slot machines are tuned such that the frequency of near misses is increased disproportionally. This is achieved via a deliberately unbalanced mapping of generated random numbers to positions on the reels in electronic gaming machines (so-called *virtual reel mapping*) and a specific arrangement of the symbols on the reels (*clustering*). The weighted mapping results in a higher probability of low- or non-paying symbols at the payline, which violates the naive expectation that the individual positions on a reel should be equiprobable. In addition, high-paying symbols are placed adjacent to non-paying symbols, such that they appear disproportionally often just above or below the payline. This results in an imbalance in favour of near wins. Interestingly, the effect that near wins serve as a conditional reinforcer was supported with rats as subjects in an analogue to a gambling task (Peters et al., 2010).

Furthermore, actual losses or break-even situations are often framed as wins. When wagers can be placed on multiple lines, such a game may result in a net win that is less than the sum of the wagers. However, Dixon et al. (2010) note that the visual and acoustic signals emitted by such slot machines in these cases are categorically the same as for a genuine win. They examined the effect of these "losses disguised as wins" on the arousal of novice slot machine gamblers, as measured by skin resistance. They found that players respond with a similar skin conductance response to both wins and losses disguised as wins, in strong contrast to plain losses. The authors report on the paradoxical situation that players find themselves seemingly on a winning streak where in fact they accumulate losses.

In addition, the reinforcement schedules imposed by many games, with relatively frequent small wins, the seemingly imminent prospect of a big win, and the inherently counterintuitive nature of randomness contribute to biases, superstition and misconceptions among players. Sometimes players are allowed choices that contribute to a false sense of control and skill, even though they often do not improve the odds. Examples are the "stop" button on some slot machines, or choices among chest-like items in the bonus mode of the game "Lobstermania" (cf. Harrigan and Dixon, 2009). Many structural characteristic of gaming machines encourage the illusion of skill (Griffiths, 1995) and their link to problem gambling has recently been corroborated by Mitrovic and Brown (2009). Some of the choices offered to gamblers do in fact make a difference. For example, Harrigan and Dixon found that machines seemingly running the same game can have very different payback percentages (which is permitted in Canada under Ontario law). Not surprisingly, popular guides to slot gambling commonly advise their readers to sample the payout of a slot machine during a few games, and to move on to the next machine if it appears unsatisfactory. It has been proposed that the illusion of skill may act as protection against depression (Delfabbro, 2004). This is consistent with results showing that skill protects against the effects of experimentally induced learned helplessness (Gobet, 1992; Gobet, de Voogt, & Retschitzki, 2004).

Delfabbro (2004) has criticised cognitive theories, arguing that some of the evidence is invalid. In addition, while cognitive theories provide reasonable explanations of why people keep gambling, they do not explain why they started gambling.

Integrative Theories

Recently, several models have aimed to provide a comprehensive explanation of PG, spanning traditional disciplines. In addition to biological and psychological evidence, these models use sociodemographic and cultural data, and include risk factors such as age, gender, income and family environment (Abbott et al., 2004; Orford, Sproston, Erens, White, & Mitchell, 2003; Raylu & Oei, 2002).

Blaszczynski and Nower (2002) propose a pathways model which describes how PG develops in three types of problem gamblers. Behaviourally conditioned problem gamblers follow a pathway characterised by the availability of gambling, acquisition mechanisms based on classical and operant learning, a period of habituation and the presence of chasing (i.e., keeping playing to recoup losses). Emotionally vulnerable problem gamblers follow a similar pathway, but also present emotional and biological pre-morbid vulnerability. Finally, antisocial impulsive problem gamblers also present impulsive traits linked to neurological and neurochemical disfunction.

Revising her earlier model (Sharpe & Tarrier, 1993), Sharpe (2002) proposes a model that integrates biological, psychological, and social factors. The model highlights the role of the early environment in generating psychological vulnerability (e.g., neurotic personality traits, anxiety, difficulty in managing external stress) and of genetic vulnerability in generating biological vulnerability (e.g., biochemical and electrical malfunctions in brain reward systems). These vulnerabilities affect how normal gambling experiences will be perceived and interpreted. This in turn affects the level of arousal and the presence of cognitive distortions. In addition, life circumstances and features specific to each type of gambling activity affect the inclination to gamble, which is moderated by coping strategies. In turn, the outcome of gambling feeds back to the inclination to gamble.

While these models capture some important aspects of PG, they are preliminary and insufficiently detailed – weaknesses that are recognised by their authors. Most of them are illustrated by box-and-arrow diagrams, but the nature of the processes involved is left unspecified. Moreover, some assumptions are disputable. For example, in Sharpe's (2002) model, biological vulnerability affects the development of PG, but not its maintenance, which seems implausible. The models also often conflate several levels of analysis. Additional integrative explanations of PG (Australian Productivity Commission, 1999; Dickerson & Baron, 2000; Walker, 1992) suffer from similar weaknesses.

Towards Cognitive Modelling of Problem Gambling

In general, recent reviews agree that current theories have both strengths and weaknesses. With respect to strengths, current theories have identified some of the key variables and causal links underlying PG. As for weaknesses, the models are often preliminary, they cannot make clear-cut predictions and, therefore, they cannot be tested. There is a consensus that better theories are needed, as these are necessary for advances in the understanding, prevention, and treatment of PG (Abbott et al., 2004; Blaszczynski & Nower, 2002; R. I. Evans, 2003; Shaffer & Gambino, 1989).

However, in comparison with other scientific domains, PG research lacks the conceptual tools necessary to express and understand the complex dynamics involved. There is an urgent need to use tools that enable the multiple constraints present in the literature to be brought together. Informal theories are not precise enough to do this (Gobet, 2000;

Simon & Gobet, 2000). Some PG studies have used statistical modelling, including studies focusing on economic and social aspects (Barr & Standish, 2002; Langhinrichsen-Rohling, Rohde, Seeley, & Rohling, 2004; Marshall & Baker, 2002). However, these studies explain only a small amount of the variance and have limits with the identification of causal structures. Moreover, statistical modelling cannot put together empirical constraints obtained from different studies (Abbott et al., 2004). This limit is not present with computational or mathematical modelling.

In this paper, we argue for the development of formal (mathematical and computer) models explaining the development and maintenance of PG at three levels of analysis; the neural level, the cognitive level and the integrative level. Given the state of the art of PG theorising and the fact that there are robust phenomena to simulate in each of these levels, we believe that it is more efficient to develop these three types of models in parallel rather than to focus on a single level in great detail.

Advantages of Formal Modelling

Formal modelling consists of the development and verification of theories expressed via mathematical formalisms (e.g. systems of equations) and computer programs. These models lead to testable predictions and foster the development of underlying theories. Furthermore, formal models can simulate complex behaviour both qualitatively and quantitatively. They allow for the systematic study of individual parameters within complex interdependent systems. Formal modelling techniques can be used for the exploration of rich and dense datasets (e.g., logs of the actions carried out whilst playing electronic gaming machines). Such data challenge traditional methods of analysis (Dickerson & Baron, 2000). Furthermore, formal models – in particular computer models – often provide explanations that are veridic and 'sufficient', in the sense that they can produce the behaviour under study. Modelling has important implications for basic and applied research. By virtue of generating specific testable predictions, computer models provide guidance for prevention and treatment. As noted above, a better link between theory and practice would be a welcome move in PG research.

Problem Gambling: Three Levels for Formal Modelling

What kind of progress is still required to achieve these benefits? We address this question with respect to the three levels of analysis and modelling.

1. *Neural Level* Biologically-inspired techniques such as neural networks are readily available, and provide a link between theory and its underlying biological substrate. For example, one recent study (Chan, 2010) used neural networks for the modelling of bet amounts in online poker. Even though this line of research appears promising, the models in this particular study do not take into account any individual factors and cognitive biases (factors which are completely dismissed by the author), and seem overly reductionist. Nevertheless, the goal of (successfully) reproducing the behavior in question was obtained.[3] The next step, however, is to align the underlying mechanisms of the artificial models more closely with research on their biological counterparts. Previous and current behavioural, neuroimaging and neurochemical results are instrumental in developing models for studying how – at a functional level – disruptions and imbalances in the emotion and reward system affect gambling behaviour. With respect to reinforcement learning – which, as we have seen in the previous section, is considered a central mechanism in gambling – the TDRL (temporal difference reinforcement learning) model has been proposed (Redish et al., 2007). The basic model assumes that in a particular situation (a state), actions are chosen with respect to an expected reward which is to be maximised. The error between the predicted reward for a particular choice in the given situation and the received reward is employed to update the estimations in the model. The model is implemented using a traditional iterative algorithm known as Q-learning. This technique is further combined with a sophisticated classification mechanism for recognising states from multidimensional cues. In Redish et al's model, extinction may result in either unlearning or fast renewal, which is an important phenomenon in problem gambling. Renewal refers to learned associations which, rather than to be unlearned by a continuous lack of reinforcement, are quickly available (renewed) upon occasional reward. This is thought to be the case with problem gamblers who continue playing in spite of series of losses. The work by Redish et al. exemplifies how existing modelling techniques are combined and extended to account for neural-level phenomena of problem gambling. Accounting for the wealth of phenomena that have been studied (and some of which we discussed in the first section of this paper), there is ample scope for further work in this direction.

2. *Cognitive Level* Cognitive architectures such as ACT-R[4], Soar[5] and CHREST[6] have proven instrumental in the development of models for various cognitive skills, linking phenomena of perception, learning and action. As we mentioned earlier, theories in cognitive psychology provide a comprehensive picture of the stimuli and manipulations that gamblers are exposed to, the patterns of beliefs and behavior that they acquire, and potential explanations. Thus, there is sufficient input and output data available for the de-

[3]Further limitations of the study are the small sample size of players studied (n=6), and that it is not mentioned how the author ascertained that the players were in fact human, and not poker bots or human players assisted by computer tools, which might explain the reported regularities (and absence of "player personality") in the data. Furthermore, it is uncertain whether the results transfer to other modes of gambling.

[4]http://act-r.psy.cmu.edu/

[5]http://sitemaker.umich.edu/soar/home

[6]http://www.chrest.info/

velopment and testing of cognitive models. Questions that still need to be addressed are: (i) can the learning of biases be explained by the systematic manipulations of the inputs, by imbalances and perturbations of perception and learning mechanisms, or an interplay of both? and (ii) in how far irrational behavior can be attributed to implicit processes and/or explicit knowledge (it has been suggested that irrational verbalisations by gamblers may serve only as a rationalisation, see e.g. Evans and Coventry, 2006). Under the assumption that ordinary mental capabilities of learning and decision making are either impaired or misguided in problem gambling, it is of key interest to investigate the parameters that are suspected to lead to biased perception, impaired decision making and impaired control. Thus, it is an interesting prospect to start off with a "healthy" model reflecting the current state of cognitive modelling research, investigate its specific performance in gambling tasks, and then to selectively change inputs and parameters (and combinations thereof), and to check the results and predictions against empirical data.

3. *Integrative Level* Current theories at the integrative level (e.g. pathways models) provide a descriptive account of statistical relationships between problem gambling and various related factors in empirical samples. However, a growing number of such factors are identified (including sociodemographics, family environment, personality traits, arousal, compulsivity, psychological states, mental disorders, and cognitive beliefs) and there is increasing evidence of complex temporal dynamics and interactions that are involved. This calls for a shift in methodology towards more expressive mathematical models (e.g. differential equation systems) and powerful tools of data mining, which are already in routine use in various other fields of research.

In summary, the main observation is that on all three levels, cognitive modelling lends itself as a natural continuation and enhancement of current research on problem gambling.

Conclusion

In view of the wealth of the different psychiatric, biological, psychological and integrative theories on PG that we discussed in this paper, it seems surprising that cognitive modelling (in terms of mathematical models and computer models) has hardly been taken into account. This is particularly remarkable since there is overwhelming evidence that problem gambling is a complex phenomenon on several dimensions, which calls for the use of corresponding modelling techniques. We argued that in comparison to present theories, most of which are of a rather descriptive nature, cognitive models can make (quantitative and/or qualitative) predictions and enable rigorous testing.

Our survey illustrates that whereas cognitive modelling has generally proven its worth as an integral part of the development and verification of psychological theories, its potential has largely been neglected in the study of problem gambling (with some rare exceptions mentioned earlier). However, we consider this as a welcome opportunity for applying proven techniques to serve the better understanding of problem gambling to guide prevention and treatment.

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