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An Animal Model of Slot Machine Gambling: The Effect of Structural Characteristics on Response Latency and Persistence

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Abstract Despite the prevalence of problem gamblers and the ethical issues involved in studying gambling behavior with humans, few animal models of gambling have been developed. When designing an animal model it is necessary to determine if behavior in the paradigm is similar to human gambling. In human studies, response latencies following winning trials and near win trials are greater than those following clear losses. Weatherly and Derenne (Anal Gambl Behav 1:79–89, 2007) investigated whether this pattern was found with rats working in an animal analogue of slot machine gambling. They found a similar pattern of response latencies but the subjects' behavior did not come under control of the visual stimuli signalling the different outcomes. The animal model of slot machine gambling we used addressed procedural issues in Weatherly and Derenne's model and examined whether reinforcer magnitude and the presence of near win trials influenced response latency and resistance to extinction. Response latencies of the six female Norway Hooded rats varied as a function of reinforcer magnitude and the presence of near-win trials. These results are consistent with prior research and with the idea that near win trials serve as conditional reinforcers.

Keywords Gambling · Near-win · Reinforcer magnitude · Animal analogue

Problematic gambling causes significant social problems (Abbott et al. 2004) and is most likely to occur with slot machine gambling (Abbott 2001). Understanding the role this type of gambling plays in the development of problematic gambling would enable us to design more effective interventions to reduce or eliminate problem gambling. There are, however, ethical difficulties associated with conducting experimental research with humans such as the possibility of creating more problem gamblers and the implications of asking people to

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risk their own money within an experimental context (Weatherly and Derenne 2007). As Madden et al. (2007) suggest, an alternative possibility is to develop an animal model to examine the influence of environmental (structural) characteristics of slot machine gambling on behavior.

The first step towards developing an animal model is to determine if animals respond to variations in an experimental analogue in a similar manner that humans do when they gamble. Few studies have examined human responses to structural characteristics of gambling machines. However, one response pattern that has been reported in human participants in experiments using slot machine is that response latencies (the time from the outcome of one wager to the beginning of the next) following a winning trial are longer than those following clear loss trials (Schreiber and Dixon 2001; Dixon and Schreiber 2004). This has also been found in video poker machines (Dixon and Schreiber 2002). A second finding is that response latencies increase as the magnitude of the win increases (Delfabbro and Winefield 1999). In these studies the direction of differences in response latencies was found in all or the majority of participants, but the magnitude of the effect was variable. For example, in Dixon and Schreiber (2004) latencies for 8 of 12 participants increased with the proportional increase in latency for wins compared to clear losses ranging from 10 to 300% (estimated from figure provided).

A third characteristic of slot machines that has been studied with humans is the pattern of behaviour when near win trials are included. In a slot machine there are a minimum number of symbols required for a winning gamble and a near win occurs when the number of symbols is close to but does not quite reach that minimum. For example, two pineapples and an apple would be a near win on a machine requiring three pineapples for a win. In addition to examining wins versus clear losses Dixon and Schreiber (2004) included near win trials in their study. They found that latencies following near wins were more similar to those following true wins than clear losses and argued that near wins were therefore "somewhat reinforcing". This is consistent with the finding that the inclusion of near wins increases persistence in the absence of reinforcement (Strickland and Grote 1967; Kassinove and Schare 2001; MacLin et al. 2007; Cote et al. 2003).

Weatherly and Derenne (2007) report a first attempt to design a rat model of slot machine gambling. They examined whether the pattern of response latencies after losses and wins of different magnitude in their model was similar to those found in the human studies described above. They also argued that human gambling is, in part, controlled by structural cues (e.g., the symbols indicating wins and losses) and behavior in an animal model needs to be under the control of those cues. To test this, they also looked at whether behavior was sensitive to the visual stimuli that signalled the different gambling outcomes. In their analogue a three by three light array was used. Each row of the array had from left to right a red, yellow and green light. There were four possible consequences. If the first column of lights was eliminated there was a small win (0.05 ml of sucrose), if the second column was illuminated it was a medium win (0.2 ml of sucrose), if the third column was illuminated it was a large win (a 45 mg food pellet) while if a diagonal was lit it was a loss. They found that, similarly to humans, the rats' response latencies differed as a function of the reinforcer magnitude and they made longer pauses after winning larger reinforcers. The differential latencies were, however, not controlled by the discriminative stimuli that signalled the outcomes. That is, when in a second condition the array was not used to signal the consequences, response latencies were also sensitive to the outcomes obtained. The lack of control by the visual cues limits the usefulness of that model. It is possible that the rats' behavior in Weatherly and Derenne's study did not come under stimulus control because they did not need to attend to the visual cues for their behaviour to be reinforced.

Additionally, trial duration was not controlled so the differential response latencies may have been due to the eating times associated with the different magnitude reinforcers. Despite the procedural limitations of this preliminary study, animal models of gambling are still potentially useful way to look for the mechanisms that control human gambling behavior.

The aim of the current study was to develop an animal model of slot machine gambling that was similar to Weatherly and Derenne's (2007) model but incorporated additional features designed to further mimic slot machine gambling and to address the limitations identified above. In assessing the validity of their model, Weatherly and Derenne (2007) manipulated only reinforcer magnitude. As well as replicating that manipulation, across experimental conditions we included near win trials. Additionally, to looking at response latencies we examined whether the presence of near wins influenced persistence of behaviour in extinction.

The visual stimuli in our procedure were a single row of five lights and the gambling response in our procedure was an FR schedule. After the FR was completed the lever was retracted and between one and five lights were sequentially illuminated from left to right. This is consistent with the sequential presentation of slot machine symbols and with research that indicates that this may be an important structural characteristic (Ladouceur and Sevigny 2002). If four or five lights turned on it was a winning gamble. Four lights signalled a small win and five lights a big win. Losing trials were signalled by illumination of one, two, or three lights and the wager resulted in no reinforcement. Three light trials most closely resembled winning trials and were defined as near wins. Following presentation of the cue lights a 'collect' lever was inserted into the chamber for a fixed period of time. On winning trials a single response on this lever was required to obtain the scheduled reinforcer. A response to the collect lever on losing trial had no effect and was considered an error. This additional contingency increases the probability of the rats attending to the visual cues and is consistent with the presence of a collect button on slot machines. A 20-s adjusting ITI between each opportunity to gamble was used to minimise the impact of time taken to consume the reinforcer on response latencies (the time from the reinsertion of the response lever and the first FR response).

Method

Subjects

Subjects in this study were eight female Norway hooded rats bred in the Psychology Animal Facility at Victoria University of Wellington. During the course of the experiment two of the subjects died, hence data are reported for the remaining six subjects. Throughout the duration of training and experimentation, the rats were maintained at approximately 85% of their free-feeding weight and water was available ad libitum in their home cages.

Apparatus

Training and experimental sessions were carried out in ENV-202M modular test chambers, equipped with two ENV-112CM retractable response levers and an ENV-202M liquid dipper (Med Associates Inc.). The dipper was positioned between the levers in the centre of the front wall of the chamber 2 cm above the floor. The levers were positioned 8 cm away from each side of the dipper. The left lever was designated the 'spin' lever and the right lever was the collect lever. A single row of five stimulus lights (red light-emitting diodes) was centred on the front wall 8 cm above the levers. The lights were 4 cm apart. Diluted sweetened condensed milk was used as the reinforcer. Three dips of reinforcer were delivered for each ‘big win’ (five lights illuminated) and one dip for each ‘small win’ (four lights illuminated).

Procedure

Pretraining

Subjects were initially trained to respond on the spin lever using a forward chaining procedure. Once subjects were responding on the spin lever the go/no-go discrimination task was introduced on the collect lever. For this task, both levers were inserted in the chamber at the start of each trial and a CRF schedule operated on the spin lever. A response on the spin lever resulted in that lever being retracted. After the lever was retracted either one (no-go) or five (go) lights were illuminated with a 0.5 probability of either trial type. After the lights for the trial type had been lit, the stimulus light(s) remained illuminated and the collect lever was available until either the rat made a ‘go’ response or the 5 s delay had elapsed. On go trials responses to the collect lever were immediately reinforced. If they did not make a response during the 5 s delay the collect lever was retracted and no reinforcer was delivered. On no-go trials subjects were required to abstain from responding on the collect lever for 5 s, the lever was then retracted and the reinforcer was delivered. If they did respond on a no-go trial the lever was retracted and a 15 s time out commenced. When rats were responding with 80% or better accuracy on this task all consequences for responses to the no-go trial were removed (i.e., they were no longer reinforced for not responding or punished for responding), the no-go period was decreased to 3 s and the proportion of go trials was reduced to 33%.

Experimental Conditions

All rats were exposed to the conditions described below in the following order: Condition 1, Extinction, Condition 2, Extinction, Condition 1R (a replication of Condition 1) followed by Extinction. Conditions 1, 2 and 1R were continued until visual analysis revealed no increasing or decreasing trend in mean overall response latency. The extinction conditions were in effect for 5 days.

Condition 1 In Condition 1 there were five potential outcomes for each trial. Outcomes were either wins or losses and each type of outcome was signalled by illuminating the appropriate number of cue lights after completion of an FR10 on the spin lever. Five lights signalled a big win and four lights a small win. One, two and three lights were losses with three lights representing a near win. Reinforcement was only delivered on win trials. In Condition 1 the percentage of winning trials was 33% and increased to 40% in Condition 1R to match the percentage of wins in Condition 2. The remaining trials were divided equally between the three types of losing trial.

At the beginning of each trial all lights were off and the spin lever was inserted into the chamber. After the completion of the FR10 the spin lever was retracted, the correct lights for the trial type were sequentially illuminated 1 s apart from left to right and then the collect lever was inserted into the chamber. On all trials these lights remained illuminated and the collect lever remained available until the subject made a response or 3 s had elapsed. Responses to this lever were immediately reinforced on win trials. On losing trials there were no scheduled reinforcers. The interval between trials was adjusted so that the time from the completion of the FR (spin responses) until the next trial was constant at 20 s regardless of the number of dips obtained. Sessions continued for 90 min. The average number of trials completed in this time was 56 for Condition 1 and 65 for Condition 1R.

Condition 2 Only three of the five trial types were used in Condition 2 (the two winning trials the one light losing trial). The proportion of winning trials was 40% with half of these being large wins. This condition more closely resembled the conditions used in Weatherly and Derenne's (2007) and served as a comparison condition for Condition 1. Sessions lasted for 90 min. The average number of trials completed in this time was 66.

Extinction In extinction conditions the same procedure used in the immediately preceding condition continued with the exception that no reinforcers were delivered for winning trials.

Data Analyses

Response latency analyses were conducted using the data from the last 5 days of each experimental condition. Response latency was the time between the presentation of the spin lever at the beginning of a trial to the first response on that lever. Initial examination revealed high measures of variability in response latencies, across trials for all subjects in all conditions. This variability was driven by the presence of occasional extreme values. That is, on occasional trials the rats would pause for several minutes before resuming responding on the spin lever. These very long pauses were not associated with particular trial types but tended to be among the last few trials of a session. To limit the influence of these unusually long pauses a 10 min response latency cut-off criterion was selected after examining the distribution of latencies. Removing those greater than 10 min removed the majority of extreme values from all rats without excluding a substantial portion of the data. The percentage of the individual rats data in any one conditions that was excluded from the analyses when response latencies were greater than 10 min ranged from 0 to 7.78%. The median percentage of data excluded across individual rats and conditions was 1.87%. There were a few further trials with latencies under 10 min but still well over the median for an individual rat so to minimise the impact of these the data for the last 5 days of each experimental condition were pooled and the medians of these response latencies for each rat were used in the analyses. The subsequent group data analyses used the means of these median values.

Accuracy was defined as making a collect response following win trials or not responding on the collect lever following losing trial types. Data for used for this analysis were also taken from the last 5 days of each experimental condition.

Results

Response Latencies

Condition 1 (near wins presented) was replicated and initial analysis looked at whether there were any significant differences in the response latencies across the replications. A two-way repeated measures ANOVA revealed no significant differences, thus data from both of the near wins conditions were combined for remaining analysis of response latencies.

Figure 1 displays mean response latencies (s) for big wins, small wins and single light trials (losses) for Condition 1 and 2. As expected, for both conditions the shortest response latencies followed losses; and latencies after small wins were shorter than those following big wins. The difference between the small and big wins was more pronounced in Condition 1 than in Condition 2. Statistical analyses confirmed these observations. A 2 (condition: near win, no near win condition) × 3 (trial type: loss, small win, big win) repeated measures ANOVA revealed a significant interaction between condition and trial type ($F(2,4) = 13.06$, $P < 0.02$, $\eta_p^2 = 0.87$). Univariate ANOVAs indicated a significant effect for trial type ($F(2,5) = 12.93$, $P < 0.01$, $\eta_p^2 = 0.72$) but this effect was moderated by condition. The difference between the response latencies for Condition 1 and Condition 2 were significantly greater for the big win versus the small win ($F(1,5) = 27.59$, $P < 0.01$, $\eta_p^2 = 0.86$) and for the big win versus the loss ($F(1,5) = 13.18$, $P < 0.02$, $\eta_p^2 = 0.73$). These results are consistent with Weatherly and Derenne (2007) and human studies (e.g., Delfabbro and Winefield 1999).

Condition 1 included near win trials (three light trials) as another way of examining the validity of this animal model. It was expected that, consistent with the human literature, response latencies following near win trials would be similar to winning trials and different from the two other types of losing trials (one and two light trials). Figure 1 shows mean response latencies for each trial type in Condition 1. Response latencies increased as the number of lights illuminated for losing trials increased. That is, as the losing-trial stimuli became more similar to winning trials the more closely the response latencies were to those following winning trials. Statistical analyses confirmed a main effect for trial type ($F(5,20) = 20.55$, $P < 0.01$, $\eta_p^2 = 0.80$) and response latencies on near win trials were significantly different than the other types of loss trials ($F(1,5) = 6.69$, $P < 0.05$, $\eta_p^2 = 0.57$). Contrary to expectations, response latencies on near win trials also were significantly different from win trials ($F(1,5) = 34.00$, $P < 0.01$, $\eta_p^2 = 0.87$). However,

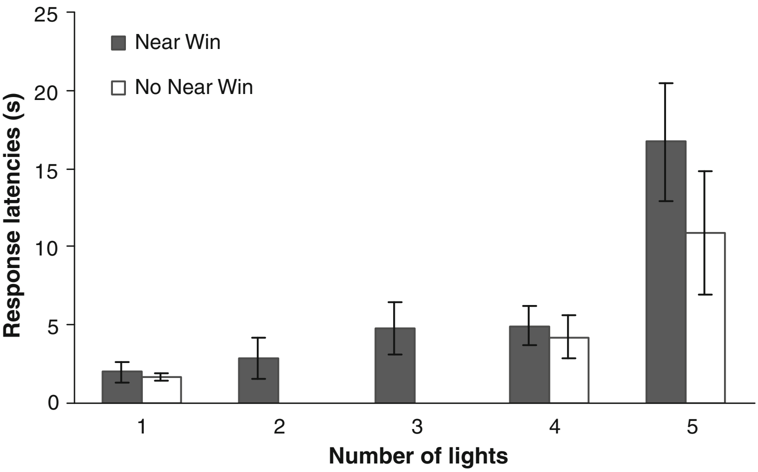

Fig. 1 Mean response latencies (s) for Condition 1 (near wins present) and 2 (no near wins) for each trial type. Trials signalled by *1*, *2* and *3* lights were not reinforced, trials signalled by *4* and *5* lights were reinforced

further analysis indicated that response latencies on near win trials were not significantly different than small win latencies ($F(1,5) = 0.69$, n.s., $\eta_p^2 = 0.01$). This finding is consistent with the hypothesis that near wins are perceived somewhat like wins.

Stimulus Control

The collect lever provided a measure of stimulus control as reinforcement was only delivered on winning trials. If behavior was under stimulus control, responding on winning trials (4 or 5 lights) should be different than on losing trials (1, 2, or 3 lights). We would expect a low proportion of collect responses on 1, 2, or 3 light trials and a high proportion on 4 and 5 light trials. Initial analysis of the proportion data found no significant differences between the two replications of Condition 1. As done with latency data subsequent analyses were based on the mean of these conditions. Figure 2 shows proportion go responses as a function of trial type for Condition 1. A one-way repeated measures ANOVA confirmed a main effect for trial type ($F(4,20) = 105.26$, $P < 0.001$, $\eta_p^2 = 0.96$). Post hoc contrasts (see Table 1) indicated that the proportion of collect responses on winning trials were significantly different from all three types of losing trials. Additionally, three light trials (near win trials) were significantly different than those for both the winning trial types and the remaining losing trial types. No significant differences were found between proportions of collect responses for Condition 1 versus Condition 2. These data demonstrate that the rats' responding was under control of the stimuli signalling the different trial types. Responding to near win trials was the least consistent suggesting some generalisation of stimuli that signal winning trials (Fig. 2).

Persistence in Extinction

Greater persistence of gambling behavior when near wins were present has been treated as further evidence that near wins may be perceived as similar to winning trials. To assess this we examined the mean number of trials completed in the 5 days of extinction as a proportion of mean number of trials completed across the last 5 days of each experimental

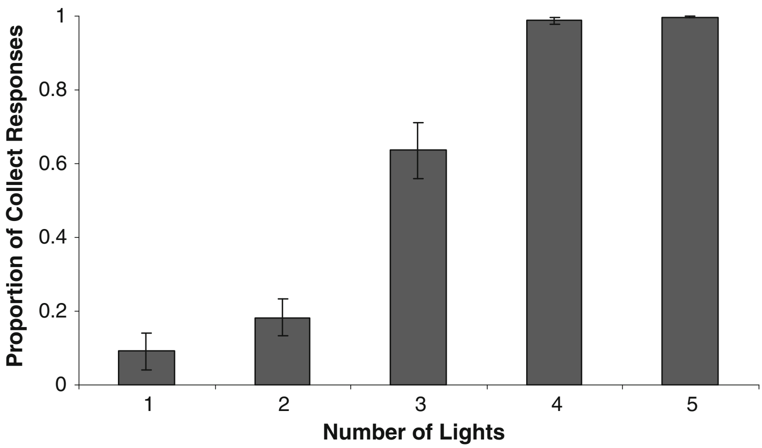

Fig. 2 The mean proportion of collect responses for each trial type in Condition 1. Losing trials were signalled by *1*, *2* or *3* lights and winning trials by *4* or *5* lights

Table 1 Summary of contrasts comparing proportion of collect responses by trial type

Comparison	F	P value	η_p^2
5 lights vs. 3 lights	22.32	0.005	0.82
5 lights vs. 2 lights	286.45	0.000	0.98
5 lights vs. 1 light	350.31	0.000	0.99
4 lights vs. 3 lights	20.63	0.006	0.81
4 lights vs. 2 lights	285.52	0.000	0.98
4 lights vs. 1 light	382.40	0.000	0.99
3 lights vs. 2 lights	75.06	0.000	0.94
3 lights vs. 1 light	33.59	0.002	0.87

5 Lights = big win; 4 lights = little win; 3 lights = near win; 2 lights = loss; 1 light = clear loss

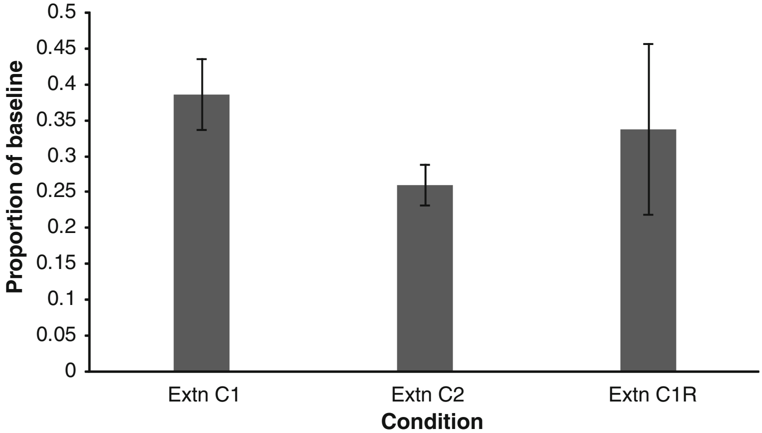

Fig. 3 Mean number of trials completed in extinction as a proportion of the mean number of trials completed in the last 5 days of each preceding experimental condition (Extn C1 = near win first extinction; Extn C2 = no near win extinction; Extn C1R = near win second extinction)

condition. As seen in Fig. 3, there was a general order effect where proportionately fewer trials were completed in the replication of Condition 1 than in the initial condition. This is an expected effect of repeated exposure to extinction conditions. Taking into account the order effect there was, however, no consistent evidence of greater persistence in extinction following near win conditions as compared to no near win conditions.

Discussion

The primary aim of this study was to develop and test an animal analogue of human slot machine gambling. The analogue was successful in that some aspects of the rats' behavior were similar to gambling behavior seen in human studies. Like Weatherly and Derenne (2007), we found that for rats, as with humans, the pause between the outcome of one gamble and initiation of the next was a function of reinforcer magnitude. However, unlike the Weatherly and Derenne study, the ITI in the current study was adjusted so this effect can not be dismissed as an artefact of differences in the time taken to consume reinforcers

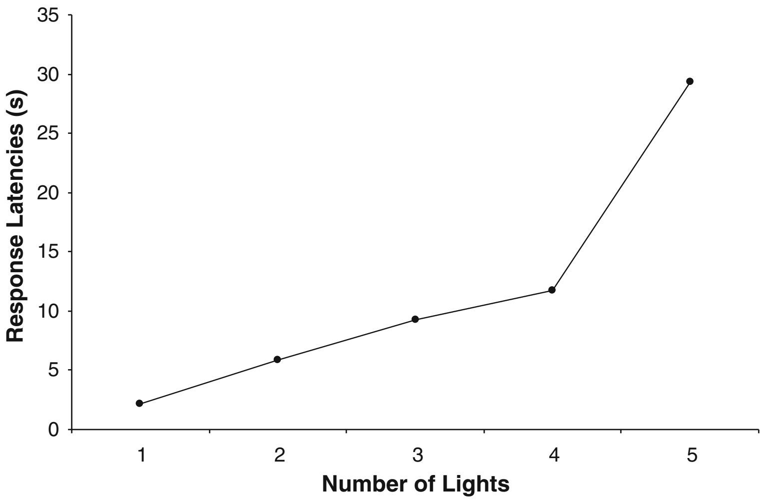

Fig. 4 Response latencies following each trial type on the first day of extinction for Condition 1

of different magnitudes. Inclusion of the extinction condition also provided further evidence that the different response latencies following winning trials were not due to consummatory responses. Figure 4 clearly shows that on the first day of extinction there was a continuation of the response latency trends seen in the immediately prior conditions.

It was important to replicate the response latency effect with regard to reinforcer magnitude as previously reported in human studies and by Weatherly and Derenne (2007). However the similarity of the rats' responding in this study, to human behaviour following near wins trials may be of more significance when considering the applicability of animal analogues to human gambling behaviour. Near wins are structural characteristic found in all slot machines and evidence found in both laboratory and ecologically valid settings clearly indicate that presence of near wins does influence gambling behaviour (Abbott 2001; Cote et al. 2003; Giroux and Ladouceur 2006; Kassinove and Schare 2001; MacLin et al. 2007; Strickland and Grote 1967 and others). The use of an animal analogue may enable us to identify how the near wins have their effect.

One explanation of the near win effect found in the human literature is that near wins change perceptions of luck (e.g., Wohl and Enzle 2003). The appearance of similar response latency patterns between the rats in this study and those found with humans suggests there may be alternative explanations for the near win effect. Other researchers (e.g., Griffiths 1999; Griffiths and Wood 2001; Dixon and Schreiber 2004) suggest that near wins are reinforcers in their own right. An operant conditioning explanation found in the literature is that near wins obtain these reinforcing properties because of the past history (Griffiths 1999; Reid 1986; Skinner 1953). In many domains (e.g. sporting) behaviour resulting in outcomes close to those that are reinforced are indicative of increases in skills and are closely followed by behaviors that are reinforced. That is, outcomes that are close to the desired outcome are discriminative stimuli signalling reinforcement is likely in the near future. In the current study, the rats prior history in the animal colony would seem to have presented few opportunities to acquire an extensive history of 'near wins' being correlated with 'wins'. This explanation of the near win phenomenon seems unlikely in this study. Further experiments where prior history is directly manipulated would be needed to confirm this suggestion.

Another possibility is that near win stimuli obtain reinforcing properties via Pavlovian processes. Stimuli associated with winning trials are likely to become conditional reinforcers because of temporal association with the gambling reinforcer (food in the animal analogue; credits in human slot machine gambling). It follows that near-win stimuli which are perceptually similar to win stimuli may also obtain reinforcing properties through Pavlovian generalisation. The occurrence of responses on the collect lever following near win trials provides some evidence of generalisation.

The lack of a consistent effect of the inclusion of near win trials on the rats' resistance to extinction may indicate a functional difference between the current animal analogue and human gambling. This could limit the usefulness of the model as a means of investigating the mechanisms underlying problematic slot machine gambling. However, it is important to note that the influence of near win trials on extinction data in the human gambling literature is unreliable. In humans, resistance to extinction appears to vary as a function of the density, not simply the presence, of near win trials. Two studies reported the effect only when there was a high percentage of near win trials (i.e., 30%, Kassinove and Schare 2001; and 45%, MacLin et al. 2007). These percentages are considerably greater than those obtained by the rats in the current study and it is possible that increasing the near win trial density would influence persistence.

Overall, the model presented in this paper produced behavior in animals that shares important characteristics with human slot-machine gambling. The procedure is thus a promising model that can be used to help identify the mechanisms by which structural features of slot machines contribute to persistence of human gambling behaviour.

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