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A Rat Model of Gambling Behavior and its Extinction: Effects of "Win" Probability on Choice in a Concurrent-Chains Procedure

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A RAT MODEL OF GAMBLING BEHAVIOR AND ITS EXTINCTION: EFFECTS OF "WIN" PROBABILITY ON CHOICE IN A CONCURRENT-CHAINS PROCEDURE

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Two experiments examined the effects of varying the probability of "wins" within a rat model of gambling. On a concurrent-chains procedure, rats could choose between a "work" lever on which a fixed 20 responses produced a food pellet or a "gamble" lever, where on some trials ("wins") only one response was required for reinforcement while on other trials 40 responses were required. Despite the fact that the work lever was always associated with the higher overall reinforcement rate, rats frequently chose to respond on the gamble lever. The frequency with which rats chose the gamble lever varied as a function of win probability. Extinction of the gamble choice (i.e., gamble-lever choices no longer resulted in wins) resulted in consistent choice of the work lever. The behavioral baselines reported in the present study may prove useful for investigators interested in employing a rat model of gambling.
Keywords: gambling, choice, concurrent chains, impulsivity, rats

There has been growing interest in the development of animal models that capture essential features of human pathological gambling (Johnson, Madden, Brewer, Pinkston, & Fowler, 2011; Madden, Ewan, & Lagorio, 2007; Peters, Hunt, & Harper, 2010; Weatherly & Derenne, 2007; Winstanley, Cocker, & Rogers, 2011; Zeeb, Robbins, & Winstanley, 2009; Zeeb & Winstanley, 2011). As Madden et al. (2007) note, there are a number of practical difficulties with human models of gambling and animal models can permit investigators to manipulate neuropharmacological variables and to take measures of brain functioning. Animal models might also be used in the development of a treatment for pathological gambling, which is estimated to occur in 1-3% of the population (Petry, 2005; Welte, Barnes, Tidwell, & Hoffman, 2008).

An early effort to develop an animal model of gambling used a concurrent-chains schedule in pigeons. Boeving and Randolph (1975) trained pigeons on a procedure where two white keys were simultaneously illuminated during the initial link. Once a pigeon made 10 responses on a particular key, the second (terminal) link of that chain was entered (and

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the other key went dark). For one key, the second-link schedule was fixed-ratio (FR) 30, while for the other key it was multiple FR-5 FR-80. On the multiple schedule key, the ratio in effect was either FR-5 or FR-80 and each ratio was associated with a different stimulus (a triangle or parallel lines) projected on the key. Food was delivered when the second-link ratio requirement was completed. Then, a new trial commenced.

Initially, FR-5 and FR-80 were equally likely to be the effective ratio when the multiple schedule alternative was chosen. Pigeons chose this "gamble" key 100% of the time under these conditions, even though they had to make 42.5 responses per reinforcer on average (the mean of 5 and 80) as opposed to only 30 responses on the FR-30 key. Boeving and Randolph then decreased the probability of a "win" (an FR-5) occurring on the gamble key in steps from 0.5 to 0.4 to 0.25 to 0.05 and finally to 0. All pigeons continued to exclusively choose the gamble key when the probability of a small ratio (win) was 0.25 and two of three pigeons continued to exclusively choose the gamble key when this probability was as low as 0.05. Such choice is remarkable because at a 0.05 probability of the small ratio, pigeons would have to make on average 76 responses per reinforcer on the gamble key as compared to only 30 on the FR-30 key. Thus, by choosing to gamble, pigeons risked the opportunity to earn reinforcement at an overall much higher rate. Only when there was no chance of a "win" (i.e., when the probability of FR 5 was 0) did pigeons prefer the FR-30 key.

The goal of the present study was to further explore the concurrent-chains model of gambling in rat subjects. A method similar to that used by Boeving and Randolph (1975) was used to investigate the effects of varying the probability of "wins" on choice of the gambling-like option in rats. The effects of extinction of the choice to gamble (i.e., removing the consequence maintaining gambling) were also investigated. Adapting the concurrent-chains model of gambling for use with rats would expand its usefulness to a species that has been used in much recent behavioral neuroscience research. Though rats and pigeons perform similarly on many learning tasks, previous research using the delay discounting procedure has demonstrated species differences in impulsive choice (Green, Myerson, Holt, Slevin, & Estle, 2004). Experiment 1 used a within-subjects design and Experiment 2 used a between-groups design.

EXPERIMENT 1

In Experiment 1, rats chose between two retractable levers that were inserted into the chamber. The initial-link schedule was FR-1 for both alternatives. When a lever-touch response was made on one lever, the other lever retracted and the rat was required to complete the terminal-link schedule requirement associated with the chosen lever (that remained inserted) to receive a food pellet. The terminal links were FR-20 on one alternative (the "work" lever) and multiple FR-1 FR-40 on the other alternative (the "gamble" lever). Initially, the FR-1 ("win") and FR-40 ratios were equiprobable on the gamble lever. That is, if a rat chose this alternative, there was a 50% chance that it would only have to emit one response (FR-1) to earn food on that trial (i.e., on a win trial). A tone signaled when these FR-1 trials occurred. On the remaining 50% of trials, 40 responses (FR-40) were required for reinforcement. On the work lever, 20 responses (FR-20) were always required for reinforcement on every trial that it was chosen. Over phases, the probability of an FR-1 (i.e., a win) occurring on the gamble lever was changed in steps from 0.5 to 0 and then back to 0.5.

These contingencies were arranged so that the gamble lever was always associated with the lower overall rate of reinforcement throughout all phases of the experiment. That is, choosing to gamble was never the rational choice in terms of maximizing reinforcement rate. In some phases, the difference in overall reinforcement rates between the alternatives was relatively small. For example, when the probability of a win was 0.5, on average 20.5 responses (the mean of 1 and 40) were required for reinforcement on the gamble lever as compared to 20 on the work lever. With the 0.5 win probability, the difference in reinforcement rates between levers may not have been discriminable. However, in other phases, the difference in reinforcement rates was much greater. For example, when the probability of a win was 0.125 (1 out of 8 ratios were FR-1), on average 35 responses were required for reinforcement on the gamble lever as compared to only 20 responses on the work lever. Under these circumstances, rats risked having to make many more responses per reinforcer by choosing to gamble.

METHOD

Subjects

Subjects were 4 adult male Long-Evans rats maintained at approximately 80% of their free-feeding bodyweights (~350-450 g). Rats were individually housed in stainless-steel hanging cages where they had unlimited access to water and were fed approximately 12–15 g of laboratory rat chow following training sessions. The colony room where subjects were housed was on a 12:12 h light:dark cycle, with lights on at 08:00 h. Throughout the experiment, rats were treated in accordance with the Guide for the Care and Use of Laboratory Animals (National Academy of Sciences, 1996) as well as the guidelines of the Institutional Animal Care and Use Committee (IACUC) of American University.

Apparatus

Training took place in a Coulbourn Instruments test chamber (28.5 cm×25.5 cm×39.5 cm) enclosed in a Coulbourn Instruments sound attenuation shell that was equipped with an exhaust fan. The two sidewalls of the chamber were made of Plexiglas and the front and rear walls were made of aluminum. The grid floor consisted of 0.7-cm diameter steel rods spaced 1.3 cm apart. The chamber was continuously illuminated by a 100-mA houselight mounted on the rear wall of the sound attenuation shell. Two retractable levers (Scientific Prototype; 3.2 cm×1.0 cm) were located on the front wall approximately 2 cm from the left or the right side walls and approximately 2.5 cm from the floor. When fully inserted, each lever extended 1.2 cm into the chamber. When retracted, a guillotine door descended to cover the aperture through which the lever moved. Each lever, as well as the grid floor, was connected to a Med-Associates lickometer circuit so that lever contacts (touches) could be measured. The lever-contact response was the operant used in this study. The food trough was located on the front wall directly between the levers. Food pellets (P.J. Noyes Co., 45-mg Formula 1-A pellets) were delivered by a Coulbourn Instruments Model E14-12 food dispenser. All experimental events were controlled by a computer located in an adjacent room that was running Med-PC (Med-Associates) software.

Procedure

Lever-touch response acquisition. Rats were first trained to respond on both levers with the same schedule in effect on both. On the first session, one of the levers (randomly selected) was inserted into the chamber for 10 seconds and a food pellet was delivered upon retraction. In addition to this contingency of response-independent food pellet presentation, an FR-1 contingency operated such that the lever immediately retracted and the food pellet was delivered if the subject touched the inserted lever. Only one lever was inserted at a time. After an inter-trial interval lasting 60 seconds on average (range: 40-105 s), the next trial commenced with the insertion of one of the levers, selected at random with the restriction that no more than 2 consecutive trials were of the same lever. There were 50 trials per session (25 of each lever). Rats were trained on this procedure until a lever-contact response was made on at least 80% of trials. On subsequent sessions, the response-independent contingency of food delivery/lever retraction was discontinued. The response requirement was gradually increased over sessions until rats regularly responded on both levers on an FR-40 schedule of lever-touching.

Forced-choice sessions. Rats were then exposed to both levers on an alternating, forced-choice procedure to ensure that they had equivalent exposure to the reinforcement schedules associated with each lever prior to the start of free-choice (concurrent chains) training. For half the rats, the left lever was designated the work lever and the right lever was the gamble lever. For the other half of the subjects, these designations were reversed. The position of the work and gamble lever remained constant for each rat throughout the experiment. Rats did not choose which lever to respond on during these sessions. Each lever was presented 50 times over the course of a session in a random order with the restriction that no more than 2 consecutive trials were of the same type. There was an inter-trial interval lasting 7 s on average (range: 5-12 s) between lever insertions. For both levers, the initial-link schedule was an FR-1. Touching the lever once advanced the subject to the terminal-link schedule. For the work lever, this was FR-20. Completion of 20 lever touches resulted in delivery of a food pellet and lever retraction. For the gamble lever, the terminal link was multiple FR-1 FR-40. On half of the gamble-lever trials, an FR-1 (one lever touch) had to be completed for food pellet delivery (and lever retraction). These trials were signaled by the tone stimulus, which was activated when the initial-link FR-1 response was made and was turned off when the terminal-link FR-1 response was made. On the other half of the gamble-lever trials, the subject was required to make 40 lever touches to complete the trial and earn a food pellet. The sequence of FR-1 and FR-40 ratios on the gamble lever was randomized with the restriction that the same ratio did not occur on more than 2 consecutive gamble-lever trials. Rats were trained on this procedure for 4 sessions.

Free-choice sessions. Each free-choice session began with 32 forced-choice trials (16 of each lever) just like those described above. This was done to ensure that subjects remained familiar with the terminal-link contingencies available on both of the levers. Then there were 100 free-choice trials. On these trials, both levers inserted simultaneously. A lever-touch response on one of the levers resulted in retraction of the opposite lever. The subject was then required to complete the terminal-link schedule requirement associated with that lever in order to obtain a food pellet. For example, if the work lever was chosen, the gamble lever immediately retracted and the rat was required to emit 20 lever touches on the work lever. Then, a food pellet was delivered, the work lever retracted, and the inter-trial interval (mean: 6 s; range: 4-9 s) began. This interval was not an adjusting inter-trial interval, but instead its length was randomly selected from a list of values independently of how long it took the rat to complete the previous trial. If the gamble lever was chosen, the work lever retracted and then either an FR-1 (signaled by the tone) or FR-40 schedule was in effect on the gamble lever. Completion of the ratio resulted in food pellet delivery, lever retraction, and initiation of the next inter-trial interval.

The probability of the FR-1 ratio (i.e., a win) occurring when subjects chose the gamble lever was manipulated over phases lasting generally 8 sessions each. (This win probability also applied to the 16 forced-choice gamble-lever trials at the start of each session.) The win probabilities were varied over phases in the following order: 0.5, 0.25, 0.125, 0, 0.125, 0.25, 0.5. The sequence of wins and losses that occurred on gamble-lever trials was randomized within blocks of 16 trials. For example, when the probability of a win was 0.25, each block of 16 gamble trials included 4 wins and 12 losses, with the order of wins and losses randomized within this sequence of 16 trials. The same process was used with the other probabilities, adjusting the number of wins and losses per block of 16 to achieve the desired win probability.

Data Analysis

The primary measure of interest was percentage of free-choice trials on which the gamble lever was chosen. For all statistical tests, α was set to 0.05. To determine if there was an effect of win probability on choice, the non-parametric Page's L test for ordered alternatives (Page, 1963) was performed on percentage of free choices on the gamble lever averaged over the last 3 sessions of each phase. Separate Page's tests were performed on the first 4 phases (where win probability decreased from 0.5 to 0) and on the last 4 phases (where win probability increased from 0 to 0.5).

RESULTS AND DISCUSSION

Rats required a mean of 8.8 (± 0.8 SEM) sessions to learn to regularly respond on both levers on an FR-40 schedule. Thus, including the 4 forced-choice sessions that followed response acquisition, rats had a mean of 12.8 (± 0.8) total sessions prior to the start of free-choice training. Figure 1 presents for individual subjects the percentage of free-choice trials on which the gamble lever was chosen during each free-choice session. Figure 2 presents the mean (± SEM) gamble-lever choice percentage averaged over the final 3 sessions of each phase.

As Figure 1 illustrates, 3 out of 4 subjects displayed near exclusive choice of the gamble lever by the end of the first phase where the probability of a win was 0.5. The fourth subject chose the gamble lever on approximately 40% of the trials. When the probability of a win on the gamble lever was reduced to 0.25, 3 out of 4 subjects continued to choose the gamble lever, despite the fact that 50% more responses on average (FR-20 vs. the mean of 1, 40, 40, 40 = 30.3 responses) were required to earn a food pellet on that lever. When the probability of a win was reduced to 0.125, 2 out of 4 rats continued to regularly choose the gamble lever and the group mean percentage of trials where the gamble lever was chosen remained above 50% (see Figure 2). This result occurred despite the fact that on average rats had to make 35 responses per food pellet (mean of seven FR-40 ratios and one FR-1

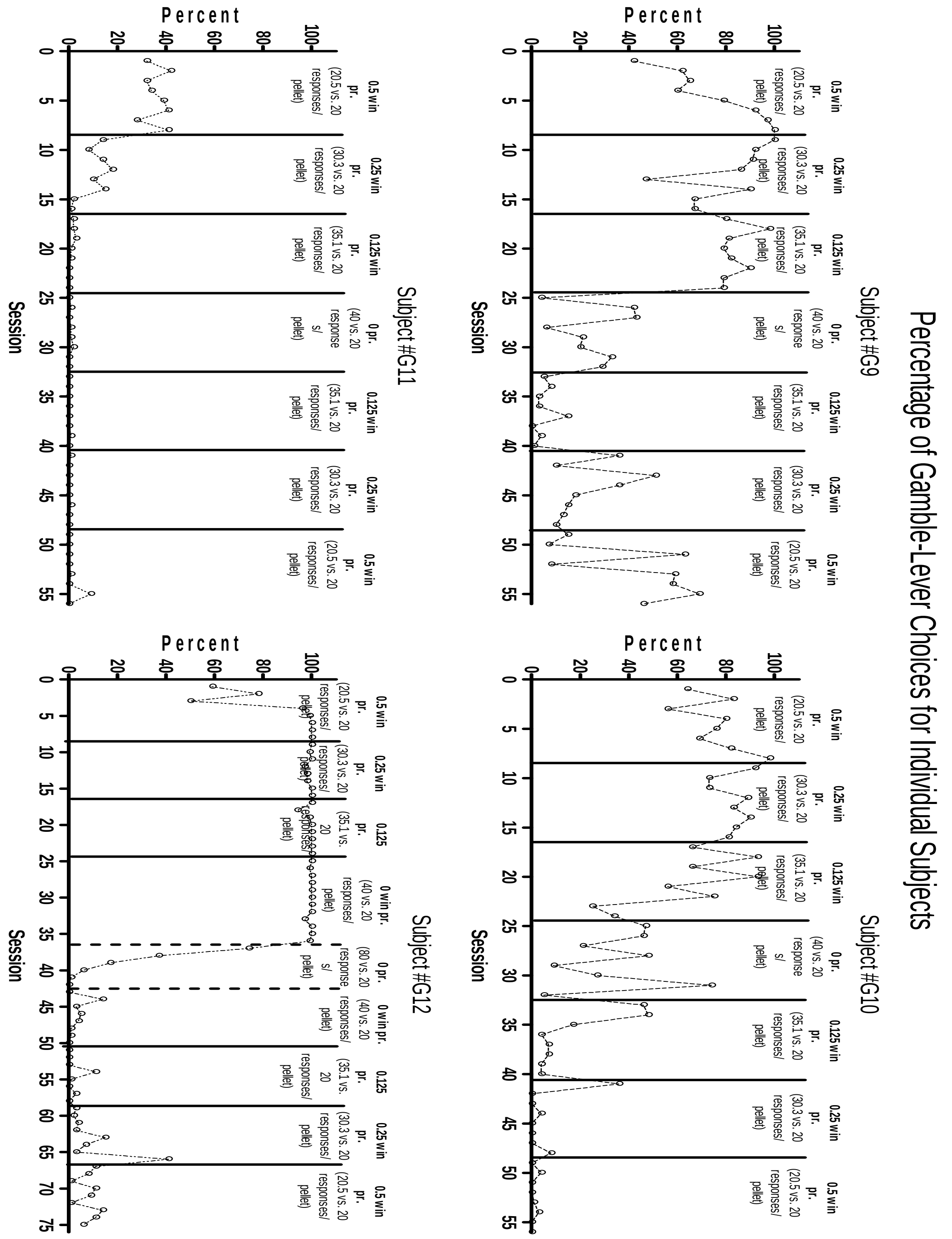

Figure 1. Individual subjects' data from Experiment 1. Data presented are the percentage of free-choice trials made on the gamble lever in each session. Phases are demarcated by solid vertical lines. The win probability (i.e., probability of an FR-1 on the gamble lever) operative in each phase is indicated above the data points. The numbers in parentheses represent the mean number of responses required per reinforcer on the gamble lever vs. the work lever.

ratio) on the gamble lever versus only 20 responses on the work lever. It should be noted that the pigeons trained by Boeving and Randolph (1975) on a similar procedure generally chose the gamble alternative more frequently than the rats did in the present experiment. This result is consistent with the finding by Green et al. (2004) that pigeons respond more impulsively than rats on choice tasks.

When the probability of a win was 0 (i.e., when the choice was simply between FR-20 and FR-40 terminal links), 3 out of 4 rats now more frequently chose the work lever. The fourth subject – G12 – continued to exclusively choose the gamble lever even after 4 extra sessions (12 total) on this choice contingency. Therefore, this subject was trained for 6 additional sessions where the FR associated with the gamble lever was increased from FR-40 to FR-80 (see Figure 1, lower right panel). On this contingency, the subject finally came to choose the work lever. Subject G12 was then run for 8 sessions with win probability 0 and FR-40 on the work lever so that this subject's training experience was similar to that of the other subjects before progressing to the next phase. (For subject G10, there were 4 occasions between sessions 31 and 45 where the gamble lever was found to have malfunctioned and was stuck in the inserted position at the end of the session. Data were discarded from each of these sessions and a replacement session was run in its place the following training day.)

A Page's L test performed on the choice percentages averaged over the final 3 sessions (see Figure 2) of each of the first 4 phases (where the win probability was deceased from 0.5 to 0) confirmed that choice of the gamble lever significantly decreased over phases ($L[4] = 115$, $p < 0.01$).

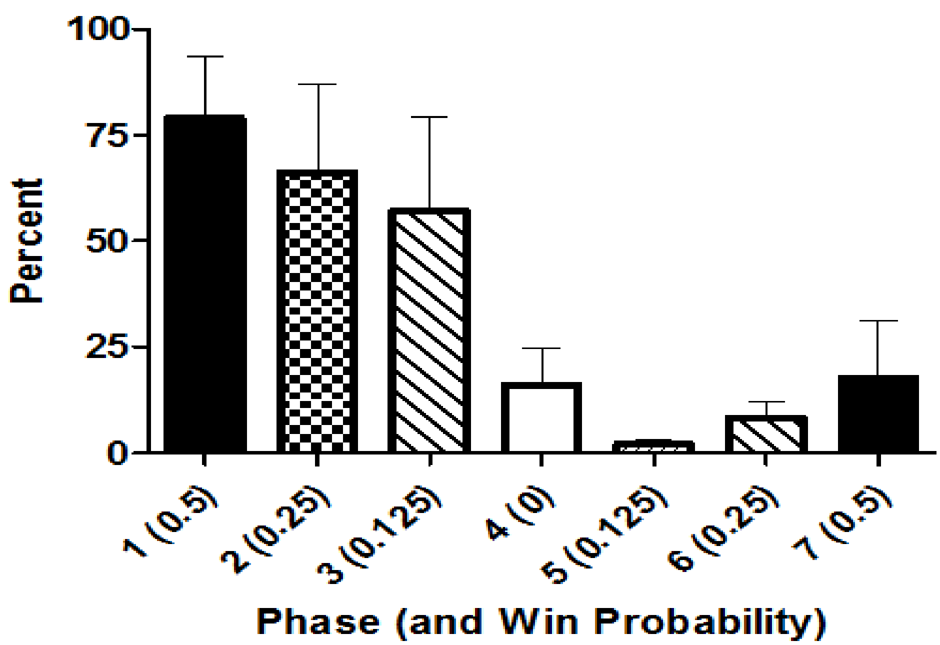

Figure 2. Mean (± SEM) percentage of free-choice trial choices on the gamble lever averaged over the last 3 sessions of each phase in Experiment 1. The numbers in parentheses on the X-axis indicate the win probability that was in effect on the gamble lever during each phase.

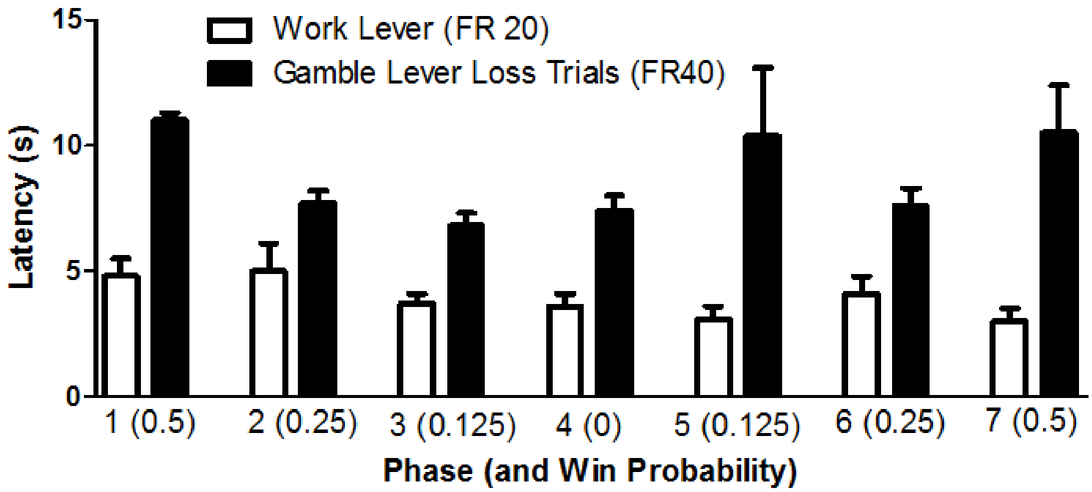

Figure 3. Mean (± SEM) latencies (in seconds) to complete the FR-20 and FR-40 ratios on the work and gamble levers, respectively, averaged over the final 3 sessions of each phase in Experiment 1.

After the 0 win probability phase, subjects were trained for 8-session phases with the 0.125, 0.25, and 0.5 win probabilities (now in ascending order). As Figure 1 shows, the effects of the 0 win probability contingency were persistent. Animals continued to generally choose the work lever, even when the probability of a win on the gamble lever was increased to 0.5. Even subject G12, who previously displayed exclusive choice of the gamble lever during the initial 3 phases and only came to choose the work lever when the FR-40 ratio was increased to FR-80, now showed near exclusive choice of the work lever even as the win probability was increased to 0.5.

A Page's L test performed on the percent choices for the gamble lever averaged over the last 3 sessions (see Figure 2) of the final 4 phases (where win probability increased from 0 to 0.5) indicated that there was no significant effect of phase ($L[4] = 103$, $p > 0.05$).

Rats' behavior after the 0 win probability phase suggests that the effects of extinction of gambling behavior (i.e., removal of the outcome maintaining the choice to gamble) persist even in situations that previously engendered high rates of gambling behavior. It is unlikely that this effect was due to rats not learning that FR-1 ratios were again available on the gamble lever because each free-choice session began with 32 forced-choice trials where the subject was made to experience the contingencies operating on each lever.

Figure 3 presents mean (± SEM) latencies to complete the terminal-link ratio on free-choice work-lever (FR-20) trials and on gamble-lever loss (FR-40) trials averaged over the final 3 sessions of each phase. If, due to exclusive choice of one or the other lever, there were no work-lever or gamble-lever loss trials during the last 3 sessions, then earlier session(s) from the phase were used in calculating the average. As Figure 3 illustrates, work-lever FR-20 ratios were generally completed in 3-5 s and gamble-lever FR-40 ratios were generally completed in 7-11 s. Latencies are not presented for the gamble win (FR-

1) trials because the computer program resolution was set to 1 s. This caused most of the gamble-lever win trial latencies to be recorded as 0 since these FR-1 ratios were usually completed in less than 1 s. Extrapolating from the approximate 4-s latency to complete the FR-20 ratios it may be estimated that gamble-lever win FR-1 ratios were completed in approximately 0.2 s (4 s/20 = 0.2 s).

EXPERIMENT 2

Experiment 1 used a within-subjects design with multiple phases to investigate the effect of various win probabilities on choice of the gamble lever. As was especially evident after the 0 win probability phase, results suggested that exposure to one probability influenced choice behavior in subsequent phases. To investigate the effect of different win probabilities without the influence of potential order effects, Experiment 2 used a between-groups design. Separate groups of rats (different from those used in Experiment 1) were trained on only one of the win probabilities used in Experiment 1.

METHOD

Subjects & Apparatus

Subjects were 20 adult Long-Evans rats maintained at approximately 80% of their free-feeding bodyweights (~350-450 g). Rats were housed under the same conditions described in Experiment 1. Throughout the experiment, rats were treated in accordance with the Guide for the Care and Use of Laboratory Animals (National Academy of Sciences, 1996) as well as the guidelines of American University's IACUC. The apparatus was the same as that described in Experiment 1.

Procedure

Lever-touch response acquisition. Rats were first trained on the same lever-touch acquisition procedure as that described in Experiment 1 until they responded on an FR-40 schedule on both levers.

Forced-choice sessions. Rats were then assigned to one of four groups, based on the win probability that they would experience: 0 probability (n=4), 0.125 probability (n=6), 0.25 probability (n=6), and 0.5 probability (n=4). The gamble-lever and work-lever designations were counterbalanced over left and right levers within each group. The position of the gamble and work levers remained constant for individual subjects throughout the experiment. Forced-choice training proceeded just as described in Experiment 1, except the probability of a win on gamble-lever trials was 0.5 only for the 0.5 group. For the 0, 0.125, and 0.25 groups, the probability of a win on gamble-lever trials was 0, 0.125, and 0.25, respectively. There were 5 forced-choice sessions (instead of 4 sessions as in Experiment 1). All other aspects of the procedure were the same as those described in Experiment 1.

Free-choice sessions. Rats were then trained for 8 sessions on the same free-choice training procedure as that described in Experiment 1. The probabilities of a win on trials when the gamble lever was chosen remained at 0, 0.125, 0.25, and 0.5 for the 0, 0.125, 0.25, and 0.5 groups, respectively, throughout this experiment.

Data Analysis

The primary measure of interest was percentage of free-choice trials on which the gamble lever was chosen. For all statistical tests, α was set to 0.05. A Kruskal-Wallis test, followed by the associated multiple comparison procedure (Siegel & Castellan, 1988), was performed on the percentage of gamble-lever choices averaged over the last 3 sessions.

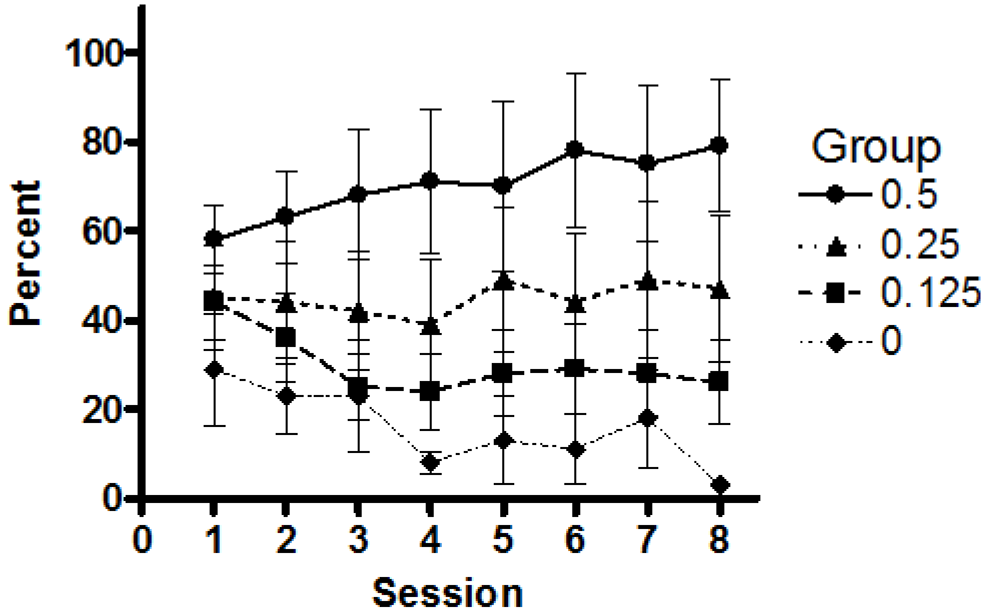

Figure 4. Mean (± SEM) percentage of free-choice trials on which the gamble lever was chosen over sessions for each of the 4 groups in Experiment 2.

RESULTS AND DISCUSSION

Rats required a mean of 7.1 (± 0.1 SEM) sessions to learn to respond on the FR-40 schedule on both levers. With the 5 forced-choice sessions that followed acquisition, rats had a mean of 12.1 (± 0.1 SEM) total sessions prior to the start of free-choice training.

Figure 4 presents for each group the mean (± SEM) percentage of trials on which the gamble lever was chosen on each of the 8 free-choice sessions. By the end of training, rats in the 0.5 win probability group chose the gamble lever on almost 80% of trials. This outcome replicates the result of the first phase of Experiment 1, where the mean percentage of gamble-lever choices was also approximately 80% at the end of the first phase where the win probability was 0.5. Rats in the 0.125 and 0.25 win probability groups chose the gamble lever on approximately 25% and 45% of trials, respectively, by the end of training. By the end of training, rats in the 0 win probability group of Experiment 2 almost never chose to gamble, which is not surprising since for this group the choice was simply between FR-20 vs. FR-40 terminal links.

A Kruskal-Wallis test performed on the percentage of gamble-lever choices averaged over the last 3 sessions indicated that the groups significantly differed ($\chi2[3] = 7.93$, $p < 0.05$). Subsequent group comparisons, using the Kruskal-Wallis post-hoc procedure described by Siegel and Castellan (1988), indicated that the 0.5 and 0 groups significantly differed from each other ($p < 0.05$), while the 0.25 and 0.125 groups were intermediate to and did not significantly differ from either of these extremes ($p > 0.05$).

Figure 5 presents mean latencies to complete the free-choice work-lever FR-20 ratios and the gamble-lever FR-40 ratios averaged over the final 3 sessions

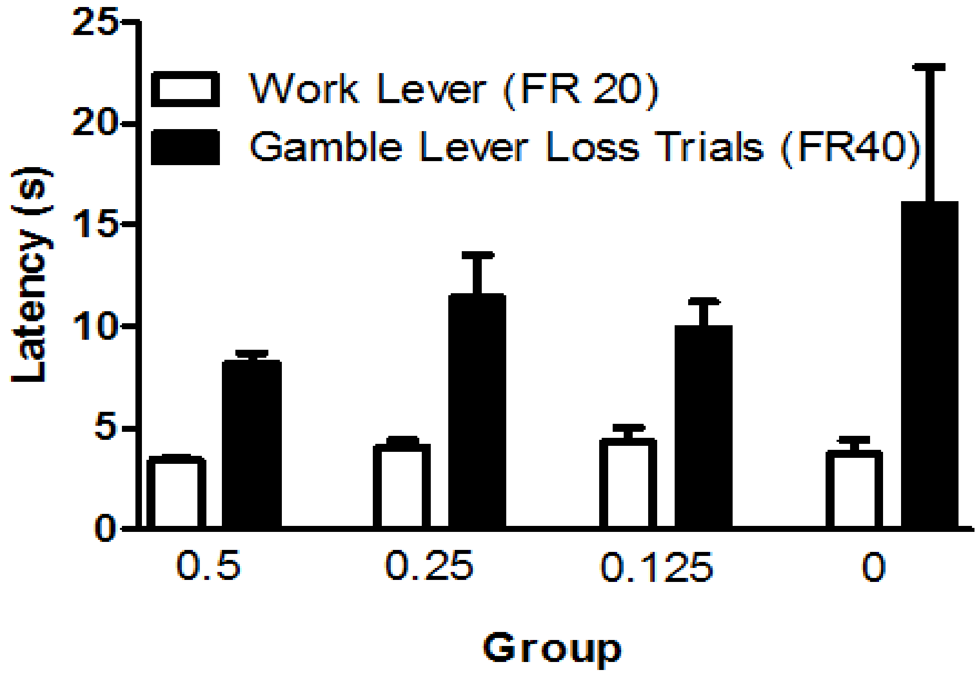

Figure 5. Mean (± SEM) latencies (in seconds) to complete the FR-20 and FR-40 ratios on the work and gamble levers, respectively, averaged over the final 3 sessions for each group in Experiment 2.

(again, data from earlier sessions were used if there was exclusive choice for one lever during the final 3 sessions). Similar to the results from Experiment 1 presented in Figure 3, rats generally required approximately 4 s to complete the FR-20 ratio and slightly more than double that to complete the FR-40 ratios.

GENERAL DISCUSSION

Experiments 1 and 2 demonstrated that rats would frequently choose an alternative associated with a lower overall reinforcement rate over one associated with a higher rate if the former provided occasional and unpredictable opportunities to receive food on an FR-1 schedule. The work lever was the rational (overall reinforcement rate maximizing) choice throughout both experiments (even when the win probability was 0.5), yet rats frequently (and sometimes exclusively) chose the gamble lever. By choosing the gamble lever, rats risked the opportunity to receive food for a fixed and relatively modest amount of work (FR-20) for the chance to collect a food pellet for very little effort (FR-1). Rats continued to frequently take this risk when the cost in the long run was having to make almost double the number of responses per reinforcer (i.e., on the 0.125 win probability contingency). These results fit with much previous research showing that animals often prefer probabilistic schedules of reinforcement over fixed schedules, even when the probabilistic schedule is associated with a lower reinforcement rate (e.g., Davison, 1969; Fantino, 1967; Herrnstein, 1964; Kendall, 1987, 1989; Rider, 1979, 1983; Sherman & Thomas, 1968)

Results of Experiment 1 also suggest that removal of the consequence (i.e., wins) that maintains gambling behavior has an effect that persists even in situations that previously engendered high rates of gambling behavior. After exposure to the 0 win probability contingency for a number of sessions, rats only infrequently chose the gamble lever even when the frequency of wins was increased to 0.5, a win rate that normally results consistent choice of the gamble lever (see Figure 2, first 0.5 probability phase and Figure 3, 0.5 group). This outcome suggests that an extinction-based treatment where gambling behavior never results in wins may decrease the likelihood of future gambling behavior. This outcome also suggests that very long losing streaks that sometimes naturally occur in human gambling activities may have persistent suppressive effects on subsequent gambling behavior.

An application of delay discounting to gambling behavior (Madden et al., 2007; Rachlin, 1990) appears to account well for the apparently irrational gambling behavior of rats in the current study. According to a hyperbolic delay discounting model (e.g., Mazur, 1987), the subjective value of the FR-1 reinforcers, delivered essentially immediately, would have been substantially higher than that of either FR-20 or FR-40 reinforcers, which were discounted in value since they were delivered after delays of several seconds. This model helps explain why rats frequently chose the gamble lever despite the fact that it was always associated the lower (sometimes substantially lower) overall reinforcement rate. Similar delay discounting dynamics may explain the apparently irrational behavior of human compulsive gamblers. A number of studies have shown that compulsive gamblers discount delayed rewards to a greater extent than do control subjects (Dixon, Marley, & Jacobs, 2003; Petry, 2001; Petry & Casarella, 1999).

The present study endeavored to further develop an animal model of gambling using a concurrent-chains procedure. Use of this model may permit many potential avenues of research that may provide important insights into factors related to pathological gambling. For example, Johnson et al. (2011) recently showed, using a procedure similar to that used here, that administration of a D2/D3 dopamine agonist increases percent gambling choices under conditions where there is a low baseline of gambling choice. Future animal studies might investigate the association between substance abuse and gambling (Hodgins, Peden, & Cassidy, 2005). Due to the limitations of research with human subjects, it would be difficult or impossible to determine whether substance abuse plays a causal role in pathological gambling or whether the correlation might be due to a third variable. A study employing the rat model used here could shed light on this question by investigating the effects of prolonged drug self-administration on the choice to gamble. Future studies might also investigate potential treatments for pathological gambling. Results of the present study suggest that extinction-based treatments might be effective in substantially decreasing the motivation to gamble.

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