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RATS PLAYING A SLOT MACHINE: A PRELIMINARY ATTEMPT AT AN ANIMAL GAMBLING MODEL

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Due to certain ethical and procedural considerations, it is not possible to conduct certain experimental studies on human gambling behavior. Animal models of gambling may hold some utility because they can possibly overcome these considerations. The present experiment was a first attempt to establish an animal model of gambling by having rats play a "slot machine." Rats pressed a lever on a fixed-ratio 5 schedule of reinforcement. In the Cue conditions, a bank of stimulus lights flashed after the completion of the ratio, with the pattern of lights that subsequently remained illuminated signaling what consequence would be received (i.e., a "loss" or small, medium, or large "win"). In the No-Cue conditions, the stimulus display was not used and the consequences were not signaled. Results showed that, in terms of preratio pausing, the rats displayed a similar pattern of behavior as shown by humans playing an actual slot machine. However, this pattern of behavior did not vary as a function of the presence or absence of the "slot" stimuli as one might expect to observe with human gamblers. Thus, the procedure shows some promise as an animal model of gambling, but additional modifications are necessary before it can be considered an adequate model.

Keywords: Gambling, Post-reinforcement Pause, Fixed-ratio Schedule, Lever Press, Rats.

Gambling occurs when one risks a valued commodity, such as money, on a probabilistic outcome over which the gambler has little or no control. Many people will gamble at least some point in their lives and, on most occasions, the behavior is not especially harmful. Of special concern, however, is a minority of individuals suffering from pathological gambling. According to Petry (2005), the prevalence of pathological gamblers likely ranges from 1-3% of the world population.

Although thousands of articles have been published to date on the topic of pathological gambling, the origins of the problem are not yet well understood. We believe that for significant progress to be made in addressing the problem, it is necessary that more investigations be experimental in nature[1]. One reason, perhaps, why more experimental investigations are not performed is that it is illegal in many parts of the United States to possess gaming equipment, even if only for research purposes. Also, while sound experimentation requires control over the situation, such as the outcome of individual gambles, such control is inconsistent with the goal of establishing external and/or face validity (but see MacLin, Dixon, & Hayes, 1999). Finally, certain aspects of a gambling situation cannot be replicated in the laboratory. Researchers, for example, cannot ethically allow participants to

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[1] A literature search using the search engine SCOPUS, conducted on January 22, 2007, yielded 1,660 articles when using a keyword search with the term "gambling." However, only 29 articles were obtained when the term "experiment" was cross-referenced with "gambling."

risk their own money or to go into debt due to their participation. Likewise, the researcher has no control over the participants' pre-experimental learning histories that might contribute to gambling behavior (see Weatherly & Phelps, 2006, for a more detailed discussion). Although changes in the law and advances in technology can help address some shortcomings of conducting laboratory gambling research, other shortcomings, such as the inability to recreate actual financial risk, are intractable. As with other fields of study, when ethical considerations preclude the use of human participants, nonhuman animal models may be of use (e.g., see Madden, Ewan, & Lagorio, 2007, for a recent review).

In one of the first attempts to model gambling in animals, Kendall (1987) gave two food-deprived pigeons repeated opportunities to choose between two food-reinforced alternatives. One alternative was a "sure thing" that, if chosen, provided food on a fixed-ratio (FR) 30 schedule of reinforcement. The other choice was a "gamble" that led to either a FR 10 schedule of reinforcement for a period of time or a 60-s timeout. In other words, under the gambling option, subjects could potentially "win" or "lose" a greater or lesser, respectively, rate of reinforcement. Results indicated that the gambling option was preferred and that preference was determined principally by the probability of the FR 10 schedule rather than the length of time the FR 10 schedule remained in effect (i.e., the probability of a "win" was more critical than its size). In a later study, Kendall (1989) manipulated the length of the timeout period. Once again, the probability of the FR 10 schedule was found to be the critical variable and the size of the "loss" had little impact on behavior.

In a similar investigation, Christopher (1988), gave pigeons concurrent access to FR and variable-ratio (VR) schedules of food reinforcement in a closed economy. The FR schedule provided 3-s access to food reinforcement, and the VR schedule provided reinforcers of variable durations (i.e., 3 s to 15 s). Early in training, the duration of reinforcement on the VR schedule was typically long. Under these conditions, the subjects tended to choose the VR option and gained weight as a result. Later, however, the average duration of reinforcement was reduced until it was less than that offered by the FR alternative. Nevertheless, subjects continued to choose the VR alternative and lost weight as a result. Ultimately, Christopher had to discontinue the VR alternative because subjects reached dangerously low body weights. This tendency for the subjects to persistently gamble despite "losing" is analogous to the problems suffered by pathological gamblers.

In addition to research featuring variable consequences for completion of the ratio, there is a large literature comparing responding on FR and VR schedules of reinforcement (i.e., a schedule in which the reinforcer is delivered at predictable times with one in which it is not). Although research of this kind is not intended explicitly to model gambling, it nevertheless reveals mechanisms likely affecting gambling choices. For example, Madden, Dake, Mauel, and Rowe (2005) had pigeons respond on FR or random-ratio (RR) schedules (a variant of VR schedules) for food reinforcement within a closed economy. When the ratio was relatively small, both schedules maintained similar levels of operant behavior. However, at large ratios (e.g., 3 food pellets per 384 responses), the RR schedule maintained much greater levels of responding. In fact, pigeons made over 35,000 more responses per day on the RR schedule than on the equivalent FR schedule at the largest response requirement. Results such as this suggest that reinforcers delivered by RR or VR schedules are more valuable than those delivered by FR schedules (see Madden et al., 2007, for a discussion which attributes preference for VR reinforcement to the manner in which organisms discount delayed rewards).

Unlike previous studies of gambling-like behavior in nonhumans, the present study used a procedure that was an attempt to more closely mimic the basic features of slot-machine gambling on the human level than these previous attempts at animal models. For humans, slot-machine gambling entails the deposit of a number of tokens into the machine, pushing a button (or pulling a handle) to initiate the gamble, the appearance of spinning symbols on multiple reels, and the final display of a symbol array that indicates whether the person lost or how many tokens the person won. By comparison, in the present study a rat was required to press a lever a certain number of times (a small FR schedule was in effect). Once the response requirement was complete, a 3 X 3 grid of lights located above the lever began to flash. After the flashing ceased, three lights remained illuminated and the arrangement of these lights indicated the outcome. If the lights appeared in a diagonal fashion, the subject "lost" and no reinforcer was delivered. If the first, second, or third columns of lights were illuminated, then a "small," "medium," or "large" amount of the reinforcer, respectively, was delivered.

Unlike the research of Kendall or Christopher, the procedure was not designed to determine whether subjects would choose to gamble despite losses. Instead, all subjects were required to "gamble" throughout the procedure and the variables of interest concerned the specific patterning of behavior during the session. Observations of gambling in humans suggest that the latency from one gamble to the next is short when the outcome of the gamble is a loss. The latency increases when the result is a win, and the longest latencies tend to follow the largest wins (Delfabbro & Winefield, 1999; Schreiber & Dixon, 2001). To determine whether rats would show an analogous response pattern, we measured the preratio pause before each gamble (i.e., the latency from the end of the previous consequence to the first response on the following ratio). Furthermore, we observed the rate at which each ratio was completed to determine whether the speed of a gamble would be affected by the consequences delivered on the previous ratio.

The FR task described above for rats captures many of the aspects found in human slot machine gambling; however, some features are also absent. For instance, the rat does not deposit tokens nor does it "lose" anything beyond the effort expended to press the lever. However, the goal of the present study was not to perfectly mimic the human situation. Rather, the goal was to determine whether the behavior of a rat faced with this situation would resemble that of a person playing a slot machine. We predicted it would (i.e., shorter pauses after losses and longer pauses after wins). Of secondary interest was also whether the rats' behavior would come under the control of the "slot" stimuli, as these stimuli arguably contribute to human gambling behavior (e.g., see Ghezzi, Wilson, & Porter, 2006). In this regard, we predicted that the rats' behavior would differ between conditions in which the procedure presented or did not present the "slot" stimuli. If these goals are not met, then further pursuit of this paradigm can be dropped. If they are met, then further intricacies could be built into the procedure so as to better model the actual situation faced by a person who is gambling.

METHOD

Subjects

The subjects were seven experimentally experienced male Sprague-Dawley rats originally obtained from the Center for Biomedical Research on the campus of the University of North Dakota. Subjects were approximately 14 months of age at the beginning of the study. All had experience pressing a lever for liquid sucrose and food pellets delivered by a random-interval schedule of reinforcement. Subjects were maintained at approximately 85% of their free-feeding weights via postsession feedings or daily feedings on days that sessions were not conducted. Because the subjects were experienced, their food-restricted weights had been established prior to the present study. Those weights were continuously maintained. The rats were housed individually with water available only in the home cage. They experienced a 12/12 hr light/dark cycle. Experimental sessions were conducted during the light portion of the cycle. All care and maintenance of the rats conformed to the guidelines published by the National Research Council (1996).

Apparatus

Subjects responded in an experimental chamber for rats (Coulbourn Instruments) that measured 30.5 (L) by 25.0 (W) by 28.5 cm (H). The chamber was equipped with one response lever that was located on the left side of the front panel, 2.5 cm from the left wall and 6.5 cm above the grid floor. The lever was 3.5-cm-wide by 0.1-cm-thick and extended 2 cm into the chamber. The lever required a force of approximately 0.25 N to depress. Five cm above the lever was a panel of three stimulus lights (red, yellow, and green from left to right). Each light was 0.6 cm in diameter. The yellow light was centered on the panel, with the red and green lights 0.6 cm to the left and right, respectively. A second panel of stimulus lights was located 5 cm above the first, and a third panel was located 5 cm above the second. Together, these panels formed a grid of nine stimulus lights. Centered on the front panel, 2 cm above the grid floor, was a 3.3-cm-wide by 3.8-cm-high by 2.5-cm-deep opening that allowed access to a trough into which reinforcers were delivered. Liquid sucrose was delivered to the trough by a syringe pump that was located outside of the chamber and attenuating cubicle. Food pellets were delivered to the trough by a dispenser that was located behind the front panel. A 1.5-cm-diameter houselight provided general illumination during the session. The houselight was centered on the back wall of the chamber, 2.5 cm below the ceiling.

The chamber was located inside a sound-attenuating cubicle equipped with a ventilation fan to mask outside noise. The experimental events were programmed, and data were recorded, by a desktop computer that was connected to a Coulbourn Instruments Universal Linc and that ran Graphic State software (Coulbourn Instruments). The control equipment was located in a room adjacent to the one housing the experimental chamber.

Procedure

Subjects were experimentally experienced and were therefore immediately placed on the procedure. Subjects responded in two types of sessions, Cue and No Cue. The Cue sessions were those in which the “slot” stimuli were presented. A FR 5 schedule was in effect at the beginning of each of these sessions. Once the subject completed the response requirement, the nine stimulus lights above the lever flashed. The lights simultaneously alternated between on and off every 0.2 s for a total of 5 s. After 5 s, the lights stopped flashing and three lights remained illuminated in one of four combinations. Specifically, the left, center, or right column of lights was illuminated or three lights in a downward diagonal pattern were illuminated. These patterns were displayed for 1 s (in an attempt to enhance their salience), after which one of four consequences occurred. One consequence was a “small” win. This outcome occurred when the left column of (red) lights was illuminated and consisted of 0.05 ml of 5% liquid sucrose (v/v mixed with tap water) being delivered to the trough. The second was a “medium” win, which occurred when the center column of (yellow) lights was illuminated and consisted of 0.2 ml of 5% sucrose. The third was a “large” win, which occurred when the right column of (green) lights was illuminated. The large win was a

45-mg food pellet (Research Diets, Formula A/I). These three types of "wins" were chosen based on previous work, both published (e.g., Weatherly, Stout, Rue, & Melville, 2000) and unpublished, from our laboratory that indicated that rats respond at higher rates for food pellet reinforcers than for 5% sucrose reinforcers and for 0.2 ml of 5% sucrose than 0.05 ml of 5% sucrose. The final outcome was a "loss." The loss occurred when the diagonal pattern was displayed and resulted in no reinforcement.

After the occurrence (or non occurrence in the case of a loss) of the programmed consequence, the FR 5 schedule was again in effect. The stimulus display from the prior trial continued to be illuminated until the FR 5 was completed. Once completed, the lights again flashed for 5 s, etc. The session progressed in this fashion until the subject completed 101 ratios. For data analysis purposes, the first ratio was discarded because it did not allow for the calculation of a post-reinforcement pause. The final trial ended after completion of the FR 5 (i.e., the consequence was that the session ended). Thus, subjects experienced 100 outcomes per session. The start of the session was signaled by the illumination of the houselight, which was continuously illuminated throughout the session. The end of the session was signaled by extinguishing the houselight.

The No-Cue sessions were identical to the Cue sessions with the exception that the "slot" stimuli were not presented. Specifically, when the subject completed the FR 5, only the left/red light on the lowest stimulus panel flashed for 5 s. That light was continually illuminated when the consequence was delivered regardless of whether the consequence was non-reinforcement or a small, medium, or large reinforcer (identical to those described above). As in the Cue conditions, reinforcers were delivered 1 s after the light ceased flashing. No-Cue sessions were conducted to determine whether the behavior of the subjects came under the control of the "slot" stimuli in the Cue condition or was controlled by the different outcomes. Subjects responded in a total of four conditions. In the initial two conditions, the probability of each type of "win" was 20%, and the probability of a loss was 40%. In the final two conditions, the probability of each type of "win" was decreased to 15%, and the probability of a loss was increased to 55%. These different probabilities were chosen so that part of the time the probability of winning exceeded that of losing (i.e., the 20% conditions) and part of the time the probability of losing exceeded that of winning (i.e., the 15% conditions). Four subjects completed these four conditions in the sequence Cue, No-Cue, Cue, No-Cue. The remaining three subjects experienced conditions in the sequence No-Cue, Cue, No-Cue, Cue. All conditions were conducted for 23 consecutive sessions, with sessions conducted daily, five to six days per week.

RESULTS

Figure 1 shows the mean preratio pause duration as a function of type of consequence experienced following the previous ratio during each condition. The data were derived from the final five sessions of each condition. The error bars represent one standard error of the mean across subjects for that particular consequence in that particular condition. The figure shows that pause durations were shorter following non-reinforcement than following reinforcement. When reinforcement was delivered, the duration of the pause increased across the small, medium, and large "wins."

Results from statistical analyses supported this description. A three-way (Cue condition by Win percentage by Outcome type) repeated measures ANOVA, conducted on the pause durations of individual subjects, produced a significant main effect of outcome type, F (3, 18) = 20.32, $p < 0.001$. The linear-polynomial contrast for the effect of outcome type was also significant, indicating that

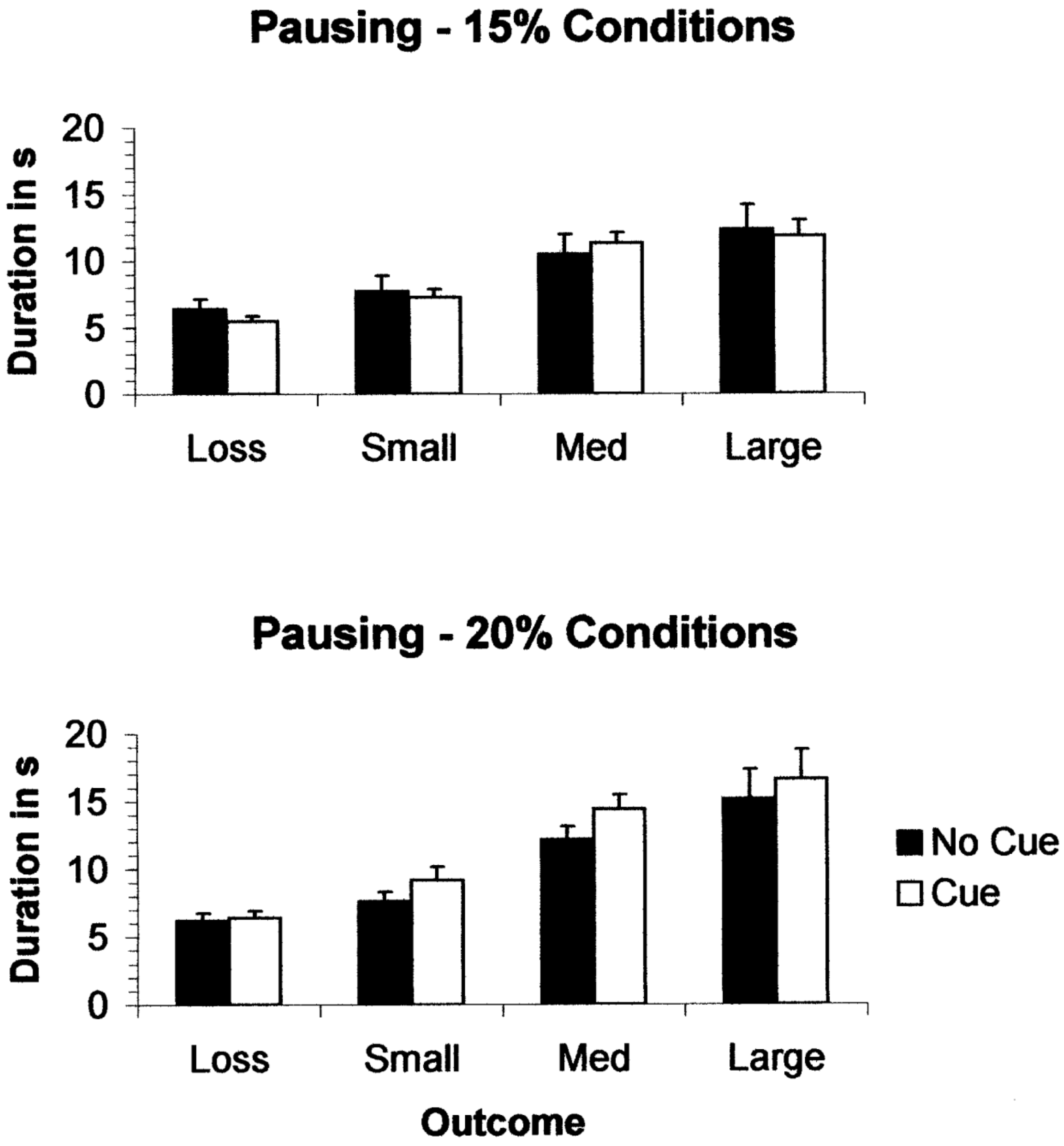

Figure 1. Presented are the post-consequence pauses for the mean of all subjects for each type of outcome in each of the conditions.

pausing increased linearly across the four outcomes, F (1, 6) = 44.20, p= 0.001. The main effect of cue condition was not significant (i.e., $p < 0.05$), but significant differences were obtained for the main effect of win percentage, F (1, 6) = 7.64, p = 0.033, and the interaction between win percentage and outcome type, F (3, 18) = 7.03, p= 0.003. As can be seen in Figure 1, pause durations in the 20% conditions, especially following the medium and large "wins," were longer than in the 15% conditions. None of the interactions

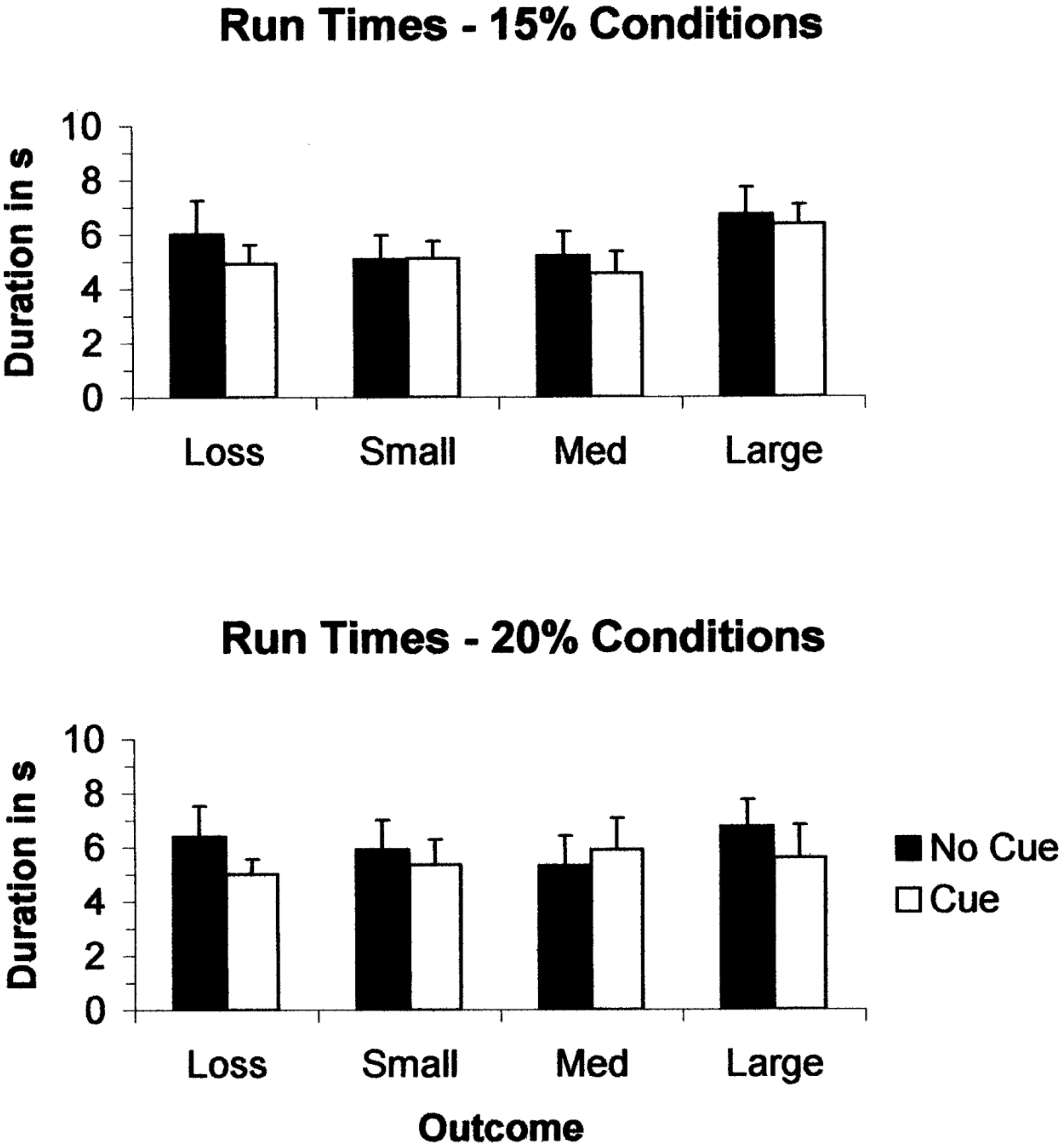

Figure 2. Presented are the run rates for the mean of all subjects for each type of outcome in each of the conditions.

involving cue condition were significant.

Figure 2 shows run rates observed under the various conditions and types of consequences. It was constructed similarly to Figure 1. The data in Figure 2 offer little to suggest that there were systematical differences in behavior across conditions. A three-way (Cue condition by Win percentage by Outcome type) repeated measures ANOVA did yield a significant main effect of outcome type, *F* (3, 18) = 3.28, *p*= 0.045. For this effect, the cubic polynomial contrast was significant, *F* (1, 6) = 6.31, *p*=0.046. As can be seen in Figure 2, this outcome was largely driven by longer run rates after large "wins" than after the other consequences. None of the other main effects or interactions was statistically significant.

DISCUSSION

The present experiment was an attempt to establish whether the procedure was a legitimate potential animal model of gambling. To this end, the results were mixed. On the positive side, the observed pattern of behavior did resemble that of people who play slot machines. On the negative side, this pattern of behavior did not appear to be controlled by the presence of the "slot" stimuli, as documented by the similar pattern of behavior observed between the Cue and No-Cue conditions.

As previously reported for people playing slot machines (e.g., Delfabbro & Winefield, 1999; Schreiber & Dixon, 2001), the pause durations of the rats was shortest following "losses" and longest following large "wins." The exact ramification of this outcome can be debated because both outcomes would be considered consistent with the broader literature on ratio schedules of reinforcement. For example, finding shorter pauses following non-reinforcement than following reinforcement is not surprising, if only because there is no reinforcer for the subject to stop and consume. Previous studies using percentile schedules of reinforcement have found that the preratio pause following non-reinforcement is only a small fraction of that following reinforcement, including at small ratios (Baron & Derenne, 2000). This finding would suggest that the factors responsible for pausing are mostly absent following non-reinforcement. In fact, the differences in pausing after non-reinforcement and reinforcement in the present study were not extremely large relative to those previously reported. The reasons for this outcome are not immediately clear, and it is possible that the present procedure played a role in that outcome.

On its face, the finding that pause durations increased as a function of the size of the previous win is also consistent with findings from basic research on ratio schedule performance (e.g., Lowe, Davey, & Harzem, 1974), at least when the size of the upcoming reinforcer is not signaled (Perone & Courtney, 1992). A somewhat longer pause may be expected after large reinforcers because a larger reinforcer requires more time for consumption than a small one. However, the terms small, medium, and large "wins" in the present study do not necessarily correspond linearly to the amount of time subjects needed to consume them. For instance, it would seem reasonable to conclude that the subjects needed more time to consume the medium (i.e., 0.2 ml) than the small (i.e., 0.05 ml) "win." However, it is possible that the time needed to consume the 45-mg food-pellet large "win" was actually less than that for either the small or medium "wins" because the pellet could be placed completely in the rat's mouth, allowing it to be eaten while the rat oriented back toward the lever. The liquid reinforcers had to be licked from the trough. Thus, the present differences in pausing are not the obvious outcome of differences in reinforcer size.

It is also the case that previous studies point to factors other than the amount of reinforcement *per se* as being responsible for the change in preratio pausing. Pausing may partially be the result of conditioned inhibition elicited by the previous reinforcer. That is, the previous reinforcer signals the beginning of a period of time in which subsequent reinforcement is unavailable. Large previous reinforcers may act as particularly salient stimuli prompting longer-than-average pauses. Also possible is that once subjects receive the largest possible win, the probability that the subsequent response requirement will yield a less favorable outcome is very high. Therefore, pausing may be longer because the subject is transition from a more-to-a-less favorable situation (cf. Galuska, Wade-Galuska, Woods, & Winger, 2007, for specific examples of this kind).

As was the case with comparison of reinforcement and non-reinforcement, the difference in pausing following the different win amounts was small compared to findings from analogous studies designed to examine ratio schedule performance. It is possible that this outcome was mitigated by some features of the present procedure. For example, the small response requirement may have minimized the contribution of conditioned inhibition to pausing, and the cue stimuli may have overshadowed the signal provided by the reinforcer. In other words, while gambling may entail elements similar to ratio schedules of reinforcement, those elements may not be of the kind that evokes long pauses in responding. Regardless, the present results on pausing are a novel contribution to the basic literature. We are not aware of previous work on ratio schedule pausing that has manipulated both quality and quantity of reinforcement within the same procedure.

The present procedure also failed to produce easily interpreted changes in run rates (see Figure 2). Run rates after "large" wins exceeded those after other outcomes. Although systematic, these differences were not large (i.e., 1 s at the greatest discrepancy). Overall, run rates are less sensitive to schedule parameters than pause durations (e.g., Baron & Derenne, 2000), so this outcome was not necessarily unexpected. Indeed, once the pause has been terminated, the most efficient possible response pattern is to complete the response requirement in the shortest possible time.

Despite the present results being consistent with the overall literature on pausing, we believe the present procedure still retains potential utility as an animal model for gambling. For instance, one topic that has received considerable interest in the gambling literature is the effect of "near misses" on a slot machine (e.g., Ghezzi et al., 2006; Kassinove & Schare, 2001). A near miss occurs when all but one winning symbols appear on the win line of the slot machine, with the remaining winning symbol just off the win line (e.g., one spot above or below where it would need to be for a win to occur). Much of the research in this area has focused on what function the near miss plays in maintaining gambling behavior (e.g., a conditioned reinforcer), but a universally accepted conclusion has yet to emerge. The present procedure could aid this research process. That is, it should be possible using the stimulus array to present the animal with a "near miss." One can then design an experimental procedure to assess the function of the "near miss" stimuli. If, for instance, the near miss is serving as a conditioned reinforcer, then it should be possible to teach the animal a new operant response using the presentation of the "near miss" stimulus as the reinforcer.

Before such research takes place, however, another deficit in the present procedure must be addressed. Although the rats displayed a pattern of behavior similar to that observed when humans play a slot machine, the rats' behavior did not vary as a function of the presence of the slot stimuli. This outcome may have occurred for a number of different reasons. One possibility is that the rats simply did not attend to the stimuli and, instead, oriented toward the food trough once the stimulus light(s) started flashing (i.e., goal tracking; e.g., see Farwell & Ayres, 1979). A second, and potentially related, possibility is that the present procedure induced certain behaviors between the completion of the FR schedule and the delivery of the consequence (i.e., adjunctive behaviors; Staddon & Simmelhag, 1971). Adjunctive behaviors would have competed with the rats' ability to attend to the stimuli. This possibility is an interesting one given that people have been shown to display adjunctive behaviors when gambling (e.g., Clarke, 1977).

Alternatively, the failure of the stimuli to control behavior may have simply been related to our choice of subject: the Sprague-Dawley rat. We had these rats available in our colony prior to the experiment and therefore they were subjects of convenience. However, Sprague-Dawley rats are albino rats that are not visually oriented. At best, the rats would have attended to the location and arrangement of the lights in the slot array, not to their color. It is possible that stimulus control by the "slot" stimuli would have emerged if a visually adept subject had been used (e.g., a different strain of rat or a different species altogether, such as pigeons). Regardless of which of the above possibilities may be correct, demonstrating such stimulus control would be a necessary step before the present procedure could be used to pursue other research questions such as the near-miss effect.

As noted above, the present procedure lacks many of the variables that one would find in the human gambling scenario. However, many of these variables could be added on to the procedure. Humans are given myriad choices (e.g., gamble vs. not gamble; slot machine X vs. slot machine Y) whereas the present procedure did not incorporate choice. This difference could be rectified by providing access to a second lever that produced a fixed reinforcer for a fixed price and no "slot" stimuli. Human gamblers lose money and can possibly go into debt. The rats in the present procedure expended only effort and were maintained at a constant body weight regardless of the outcomes experienced during data collection. Both, however, could be changed. One could arrange a "bank account" of responses (e.g., the rat can only respond 100 times per session) or train the animals to use tokens. Likewise, one could mimic "debt" by allowing the subjects to lose weight if they "gambled" and "lost," much as did Christopher (1988; and see Madden et al., 2007, for a discussion of "closed economies" in animal models of gambling).

Thus, although the present attempt at an animal model of gambling was not wholly successful, the procedure shows some promise. It generates behavior patterns similar to those observed when people play slot machines. Complexities can be added that make it even more similar to the human gambling situation than just the presentation of "slot" stimuli. Finally, because the experimental can control both the environment and the history of the subject, developing a successful animal model may lead to answering questions about gambling that may not be possible or ethical when studying humans (and see Madden et al., 2007, for additional arguments in favor of animal models). Additional research with the present model is certainly necessary. It would also seem warranted.

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