An Analysis of Behaviour on Near-miss Feedback in Slot-machine-like Contexts

by

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Abstract

A *near miss* is considered a special type of failure that approximates a goal. In skillful activities, near misses are indeed contingent on behaviour. Therefore, they can suggest how behaviour ought to be modified to achieve a desired end. However, near misses in games of chance do not share this function. Despite the independence of near-miss feedback and behaviour, near misses are presumed to enhance the gambling response. In slot machine gambling, a near miss occurs when all but the last reel line up with the same image (e.g., cherry-cherry-lemon on a three-reel slot machine). Behavioural research has been inconsistent and there is a lack of consensus on whether or not the near-miss effect in slot machine gambling is a real phenomenon. Furthermore, the behavioural studies that claimed to find a near-miss effect are disputable. In the present work, Experiments 1A, 1B, and 2 examined the putative conditionally reinforcing function of near misses in pigeons and humans through an extinction procedure using highly simplified slot-machine-like tasks. Experiment 3 further simplified the task to assess the procedural validity of the extinction procedure. The results from Experiments 1A, 1B, and 2 did not find evidence that near-miss feedback causes greater persistence. Although Experiment 3 provided evidence for conditional reinforcement, the effect did not apply to persistence. Using a different approach, Experiment 4 showed that people were indifferent to the presence or lack of near-miss feedback. The results from the present work and the existing literature suggest that the near-miss effect is unlikely to be a real behavioural phenomenon.

Preface

This thesis is the original work of Joshua J.H. Yong. The research in this thesis that involved human participation received research ethical approval from the University of Alberta Research Ethics Board: project name "Decision making and gambling", No. Pro00058367, protocol expiring on May 8, 2019. The pigeon research received ethical approval from the Bioscience Animal Care and Use Committee: project name "Cognitive Processes in Pigeons", No. AUP00002018, protocol expiring on November 16, 2018.

I dedicate this to the ones who may wish to go unnamed but deserve recognition:

To the Community: Thank you for keeping me going and helping me find a purpose in addition to all of this. I am honored to be a part of something much larger than myself.

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Recently, gambling has garnered more attention from behaviour analysts and psychologists alike (see Witts, 2013; Raylu & Oei, 2002). Although most people gamble for entertainment, some people's engagement can become "pathological" in ways that resemble substance abuse (Potenza, 2008). The causes of pathological or problem gambling have been speculated by cognitive psychologists who propose that distorted beliefs underlie gambling addiction (see Ladoucer, Gaboury, Dumont, & Rochette, 1988) whereas behaviour analysts suggest that schedules of reinforcement are responsible for gambling addiction (Skinner, 1953). The present work examined one factor that has been suggested to increase people's tendency to gamble (Skinner, 1953): The presence of *near-miss feedback* in games of chance.

The near miss is considered a special type of failure that approximates a goal (Reid, 1986). They might be more accurately termed near wins or near hits rather than near misses, but convention favours the latter. In games of skill, near misses can indeed function as useful approximations towards a goal. For instance, a competitor in the shooting sports either hits the target or misses, but on a miss, their shot can go wide or it can come very close. By modifying their technique based on the characteristics of the near-miss event, a competitor can bring themselves closer to the target on subsequent shots. However, in games of chance, the role of the near miss is different: Unlike in games of skill, near misses in games of chance (e.g., slot machine, lottery, roulette, etc.) cannot be used by players to meaningfully impact the game. Since the outcomes are purely probabilistic, the near miss occurs randomly and not because of the player's behaviour.

However, as Reid (1986) commented, this does not necessarily mean that people will be immune to near-miss feedback in games of chance. Indeed, gamblers tend to engage in superstitious behaviours such as having "lucky" objects and their subjective reports indicate that they have distorted and biased views regarding the otherwise probabilistic nature of gambling (Toneatto, Blitz-Miller, Calderwood, Dragonetti, & Tsanos, 1997). The notion that near misses may impact behaviour has even received attention by governmental organizations: The *U.S. Commission on the Review of the National Policy Toward Gambling* (1976) was critical of the overuse of near misses by scratch card instant lotteries because of their potential to increase the addictiveness of these games (as cited in Moran, 1979, p. 7) and the *Report of the Royal Commission on Gambling* (1978) reached a similar conclusion (as cited in Reid, 1986, p. 34). The fact that near misses do not actually provide any feedback on behaviour is perhaps what makes them worthy of scientific inquiry: Despite the lack of a true contingency between near misses and behaviour, it has been taken for granted that they can still affect people. The notion that near misses may enhance people's propensity to gamble is perhaps intuitive: since people have learned the correlation between near misses and their behaviour in skillful pursuits, this learning might generalize to contexts that involve only chance. But have there been any demonstrable near-miss effects? An overview and discussion on some of the literature on near misses is outlined below.

Human Near-Miss Studies

What is considered a *near-miss effect* varies depending on the nature of the research. Earlier studies tended to focus on how near misses affected *gambling persistence* (e.g., Côté, Caron, Aubert, Desrochers, & Ladouceur, 2003; Kassinove & Schare, 2001; Strickland & Grote, 1967). Most research today has taken a more eclectic approach to examine what might be considered *psychological factors* of the near miss (e.g., Billieux, Van der Linden, Khazaal, Zullino, & Clark, 2012; Clark, Lawrence, Astley-Jones, & Gray, 2009; Clark, Liu, McKavanagh, Garret, Dunn, & Aitken, 2013).

Psychological Near-Miss Studies

Recent studies on near-miss effects have focused on psychophysiology and cognition. For instance, these studies have examined how near misses relate to motivation (Clark et al., 2009; Clark et al., 2013; Billieux et al., 2012), brain activity (Clark et al, 2009; Dymond et al., 2014), and gambling cognitions (Billieux et al., 2012). However, there are fundamental limitations that underlie psychological approaches to studying the effects of near-miss feedback on gambling behaviour. The above studies assumed that if near misses have a differential relationship between wins and other losses according to measures such as changes in the BOLD signal and subjective responses, then a near-miss effect has occurred. If taken strictly on their own terms and assuming that their experiments are procedurally valid, findings from these studies could be construed as near-miss effects.

However, assuming that these factors can explain why people gamble is problematic (see Clark et al., 2009; Dixon, MacLaren, Jarick, Fugelsang, & Harrigan, 2013). Gambling is, after all, behaviour, and whether or not the psychological perspective contributes to understanding behaviour has been debated. Skinner (1977) and Baum (2005) noted that both cognitive psychologists and behaviour analysts use the same core methodology: something in the environment in which the participant is situated in is altered, and then something about the person – which is presumably under the influence of the environmental change – is recorded. Due to this, Baum (2005) argued that using cognitive psychology to explain behaviour is merely methodological behaviourism with extra steps. Whereas behavioural researchers are inclined to attribute the change in the measured response to the environmental contingencies, cognitive psychologists insist that there is some inferred and unobserved intermediate phenomenon that causes the observed change in behaviour. However, the cognitive approach relies more on inference rather than a functional explanation.

Take for instance a study by Dymond et al. (2014) where they found a correlation between win-related brain regions following near misses and a trait measure of gambling propensity. They claimed that they had found "convincing evidence of a role for reward-related brain responses to near-miss outcomes, particularly in the insula, in maintaining PG [problem gambling]" (p. 216). Here, inferring that near misses enhanced activity in win-related brain regions is justified assuming that the study was procedurally valid. However, inferring that the brain activity associated with near misses contributes to problem gambling cannot be substantiated by the experimental evidence here – problem gambling was merely inferred based on a questionnaire and there was no direct assessment on the relationship between the near misses and behaviour. Granted, there are practical limitations that prevent brain imaging studies from examining multiple dependent variables, but this problem exists in other studies that measured other factors as substitutes for the gambling response (e.g., Clark et al., 2009; Clark et al., 2013; Billieux et al., 2012; Dixon et al., 2013). However, even if one takes for granted that cognitive processes related to near misses share some contingency with gambling behaviour, the cognitive processes necessarily originated from the same putative causes of the behaviour – namely, the near misses in the environment (see Skinner, 1977). The findings from psychological research may be interesting and informative on their own terms, but if the objective is to explain behaviour, practicality and parsimony dictates that these "extra steps" are not required. Since near-miss research is predicated on its proposed effect on the gambling response, an analysis of behaviour offers the most direct means to understanding how near misses may contribute to persistent play on the slot machine.

Behavioural Near-Miss Studies

In behavioural research, the near-miss effect is typically described as increased persistence (i.e., an enhanced gambling response; Skinner, 1953; Kassinove & Schare, 2001). Near misses have also been proposed to bias choices or preferences (Győző & Körmendi, 2012; MacLin, Dixon, Daugherty, & Small, 2007; Witts, Ghezzi, & Manson, 2015). These behavioural near-miss effects have been presumed to occur via *conditional reinforcement*. This is the process by which an initially neutral stimulus acquires a reinforcing function through learning based on its relationship with primary reinforcers or other already conditioned reinforcers (Bell & McDevitt, 2014). Exactly what this relationship is will be explored and returned to later in this paper. Conditional reinforcement can be easily observed in dog training: Here, verbal praise or an audible "click" from a device is repeatedly paired with food when the dog executes the correct behaviour. Eventually, praise or the click alone can be used to reinforce the dog's behaviour, thus they are said to be *conditionally reinforcing.* B.F. Skinner was one of the first to propose that conditional reinforcement could account for the near-miss effect. He commented that

> Gambling devices make an effective use of conditioned reinforcers which are set up by pairing certain stimuli with the economic reinforcers which occasionally appear. For example, the standard slot machine reinforces the player when certain arrangements of three pictures appear in a window on the front of the machine. By paying off very generously – with the jackpot – for "three bars", the device eventually makes two bars plus any other figure strongly reinforcing. "Almost hitting the jack pot" increases the probability that the individual will play the machine, although this reinforcer costs the owner of the device nothing. (Skinner, 1953, p. 397)

Skinner's proposal draws from the *pairing hypothesis* of conditional reinforcement which simply considers the contiguity or correlation between a putative conditional reinforcer and a primary reinforcer or a previously conditioned reinforcer (Fantino, 1977). In other words, Skinner (1953) proposed that "bar" itself becomes paired with getting "bar-bar-bar" (which is paired with the jackpot) due to the contiguous nature of each reel presentation. Therefore, getting two consecutive bars can presumably acquire a conditionally reinforcing function because two of the same stimuli are paired at the start. Some of the experimental studies that attempted to demonstrate enhanced persistence from near-miss feedback are outlined below.

Strickland and Grote (1967) conducted one of the earliest behavioural studies related to the subject by manipulating the temporal presentation of winning stimuli on a three-reel slot machine. Half of the participants experienced the "win" stimulus more often on the first reel (i.e., they saw the winning stimulus 70% of the time on the first reel, 50% of the time on the middle reel, and 30% of the time on the last reel) and the other half saw it more often on the last reel (i.e., proportions of winning stimuli shown on each reel was in the reversed order of the other group). Although their study was not strictly a near-miss experiment, Strickland and Grote's manipulation did in fact alter the proportions of near-miss feedback experienced by the two groups.

The authors found that participants who saw more winning stimuli earlier were more likely to continue playing past a mandatory phase compared to participants that saw more of the winning stimuli later in the reels. However, the groups did not differ in terms of how many trials they played (i.e., no difference in persistence). Reid (1986) conducted a replication study that also manipulated early versus late winning stimuli. In contrast to Strickland and Grote's (1967) results, Reid's (1986) groups did not differ in terms of their decision to continue gambling – in fact, nearly all of them continued to gamble after the mandatory trials. Although participants that saw more winning stimuli on the early reels seemed to play longer on average, this was not statistically significant.

One possible reason that the above two studies did not demonstrate a difference in gambling persistence is that their constant response-cost procedure was not sensitive to detecting differences in persistence. A few decades later, Kassinove and Schare (2001) assessed the effects of slot machine near misses with an *extinction* phase. In other words, they implemented a period of nonreinforcement to measure persistence of the gambling response. Here, participants experienced near misses 15%, 30%, or 45% of the time during the training trials. After training, the slot machine stopped providing wins and near misses. The participants were not told that this change had occurred, although they were required to play through all of the training trials. They were instructed that they could stop whenever they wanted after the first 50 trials and then leave with whatever amount of money that they had left.

Kassinove and Schare (2001) found that participants who had experienced near misses 30% of the time in training persisted longer during extinction which suggested that an “intermediate” percentage of near misses was optimally reinforcing for the betting response. They reasoned that if near misses are infrequent, the occasions in which they can be followed by (i.e., paired with) wins are too few to establish a reinforcing function. Likewise, if near misses occur too often, there would be far more unpaired instances of the near miss, so the near-miss effect would be weakened. Although their interpretation is logical according to the mechanisms of conditional reinforcement (see Bell & McDevitt, 2014), this interpretation is not necessarily applicable to Kassinove and Schare’s (2001) results because they did not manipulate the contingencies between near misses and wins, so whatever pairings between near misses and wins – if they occurred at all – would have been purely accidental and not necessarily systematically different across the near miss densities.

However, there were two methodological problems in this study: First, the authors conducted parametric statistics on their extinction data although their data was almost certainly skewed. In extinction, the probability of each response decreases as the subject’s behaviour is continuously unreinforced, hence the data becomes skewed to the right (see results by Davis & Smith, 1976 for examples). Therefore, Kassinove and Schare’s (2001) statistical inferences may not be representative of the population. Second, their extinction phase removed not only wins but also near misses across all groups. However, to assess for a proposed reinforcing function, the putative conditional reinforcer ought to be present in one treatment. The putative conditional reinforcer would be omitted in another treatment group during extinction, and then the respective extinction rates from each treatment can be compared. This is a standard procedure used to assess for conditional reinforcement in drug studies (see Davis & Smith, 1976). Without the near misses during extinction, persistence ought to have been similar across all of the groups. The fact that a difference was observed by Kassinove and Schare (2001) is peculiar, but this could be influenced by the statistical issue discussed above. Despite these problems, this study is frequently cited as positive evidence for the near-miss effect (Côté et al., 2003; Dymond et al., 2014; Fortes, Case, & Zentall, 2017; Scarf et al., 2011; Winstanley, Cocker, & Rogers, 2011).

Another resistance-to-extinction study was also published by Côté et al. (2003). In this experiment, the first 48 trials contained nine wins and 12 near-miss trials and near misses preceded every win (the remaining three near misses were randomly interspersed among the rest of the trials). After these 48 trials, no wins occurred for both groups. Control participants also no longer saw any near misses, but near misses still occurred 25% of the time for participants in the experimental group. According to a nonparametric analysis, the authors found that participants who saw near misses during extinction persisted longer. However, this result is not necessarily representative of what might be observed in true slot machines. Unlike this experiment, the outcomes on true slot machines are randomly determined, so the near misses do not actually share a contingency with the wins. However, Côté et al. (2003) did not consider that their results may have been confounded by their contrived contingency.

In addition to the specific issues outlined above, these studies contained a few general issues (e.g., Côté et al., 2003, Kassinove & Schare, 2001; Strickland & Grote, 1967). For instance, they often used complex apparatus and stimuli such as real slot machines and spinning reels. Understandably, these factors were likely included to improve the external validity of the experiments and to make the tasks relevant to the experiences of human participants. However, these extraneous factors can have unknown influences on behaviour. Arguably, the emphasis on ecological validity in these studies has undermined internal validity which must be firmly established in the first place (see Branch & Pennypacker, 2013). Even the number of stimuli presented on each reel can influence variability in the data, let alone the number of reels presented at a time, and the methodological variations between these studies has made comparisons difficult. Due to practical limitations of collecting human data, these studies also had low numbers of participants who completed a low number of trials. This lowers statistical power which could account for the lack of consensus on the near-miss effect on the gambling response. Many of these issues can be alleviated through a *comparative approach*: For instance, by using pigeons as an animal model to study the near-miss effect.

Animal Models of Gambling

Using other animals to study what seems to be a uniquely human behaviour may appear to have limited utility or may even seem preposterous. However, gambling is merely behaviour and there are no inherent qualities about the schedules of reinforcement involved in gambling that ought to restrict it to humans – it just so happens that the tasks are constructed for use by humans. Gambling can be conceived of as a form of risky behaviour, and risk is indeed a factor when nonhuman animals forage for food (see Kacelnik & Bateson, 1996 for a review on risk-sensitive foraging). Also, pigeons can behave suboptimally given particular contexts and this is reminiscent of gambling behaviour (Zentall, 2014, 2016). Additionally, pigeons' behaviour shows steep rates of delay discounting in that they prefer smaller but more immediate reinforcers over larger but more delayed reinforcers (Rachlin & Green, 1972) and other research has shown that problem gamblers display steeper delay discounting compared to non-gamblers (Dixon, Marley, & Jacobs, 2003; Reynolds, 2006). Therefore, studying pigeons in gambling contexts may actually be more relevant to understanding problem gambling than recruiting human participants from subject pools which are mostly comprised of non-gamblers.

There are also practical reasons to study animals such as the pigeon in conjunction with human research. Indeed, pigeons have been used for decades to study conditional reinforcement and learning in general (Logue, 2002). They are also easy subjects to work with and can be cheaper to use than recruiting human participants who may require monetary incentives to induce motivation. Pigeons also possess sharp visual acuity (Catania, 1964) so they can easily see simulated reel patterns on a slot-machine-like task. Also, their motivation levels are easily controlled and their histories are known. However, controlling for motivation is practically impossible with human participants and their learning histories are unknown. Finally, it is also unfeasible to collect data from the same participants over a lengthy period of time, and this prevents analyzing human behaviour at the individual level. Conducting repeated-measures experiments are far more feasible with animal subjects. Due to enhanced experimental control, the behavioural data obtained through animal models are often more reliable than studying humans directly. However, the results from animal studies should be verified in human participants where it is practicable.

Animal Near-Miss Studies

Despite the practical benefits of nonhuman animal research, the existing near-miss literature involving other animals is scarce. In one pigeon study, Scarf et al. (2011) found that in addition to specific neurons that fired differentially for wins and losses, there were also "near-miss neurons" that fired more vigorously when pigeons saw the first non-matching stimulus after a series of matches. However, whether or not these neurons contribute to persistence could not be determined from this study because the authors only examined post-reinforcement pausing. Winstanley, Cocker, and Rogers (2011) conducted a behavioural study with rats that assessed extinction rates with respect to near misses. One group of rats experienced near misses, and the other group did not. Here, rats initiated the trials by first pressing a *roll* lever. After the reel stimuli (also accompanied with auditory stimuli) were presented, the subjects could then press a separate *collect* lever to have access to food if all of the three reels were lit up (i.e., signaled a win). However, pressing the collect lever when at least one of the reels did not light up incurred a timeout penalty. The authors found that although there was no difference in persistence on the roll lever, the rats' tendencies to press the collect lever during extinction increased linearly with the number of lights that lit up. Winstanley et al. (2011) suggested that this is similar to a near-miss effect, but Stagner, Case, Sticklen, Duncan, and Zentall (2015) have argued that the result by Winstanley et al. (2011) appears to be due to a lack of discriminative control of the reel patterns rather than an effect specific to the near miss.

Later, Fortes, Case, and Zentall (2017) conducted a follow-up study on the work by Stagner et al. (2015). Whereas the prior study presented pigeons with two-reel slot-machine-like options, Fortes et al. (2017) used three-reel slot machines. This ensured that the reel stimuli would better approximate true slot machines such that the outcomes were determined by how the reel's colours were arranged (i.e., three reds or three greens could be a win) rather than what colour occurred (i.e., two reds lead to wins but two greens lead to losses). In this study, pigeons were put on a concurrent operant schedule using two slot-machine-like options with equal rates of reinforcement. On the near-miss option, wins were always signaled by getting three of the same colour, and all losses were signaled by "red-red-green" or "green-green-red". On the clear-loss option, wins were signaled as before, but all losses were signaled by "blue-yellow-blue" or "yellow-blue-yellow". Counter to the near-miss effect hypothesis, the authors found that the pigeons reliably preferred the clear-loss option over the near-miss option.

This result can be understood in terms of suboptimal choice (McDevitt, Dunn, Spetch, & Ludvig, 2016; Pisklak, McDevitt, Dunn, & Spetch, 2015; Spetch, Mondloch, Belke, & Dunn, 1994; Zentall, 2014) and delay discounting (Mazur, 1995, 1996, 1997). According to suboptimal choice literature, *negative discriminative stimuli* (i.e., the S-) only signal nonreinforcement so they cannot acquire conditionally reinforcing properties. Therefore, the subjects in Fortes et al. (2017) only valued the *positive discriminative stimuli* (i.e., the S+ which signals reinforcement) which could acquire a conditionally reinforcing status due to its contingency with primary reinforcement. Next, delay discounting could clarify the nature in which the subjects valued the S+. According to the hyperbolic decay function, the strength of a conditional reinforcer is inversely proportional to the amount of time that the subject spends in its presence (Mazur, 1995, 1996, 1997). In Fortes et al. (2017), the absolute amount of time that the subjects could spend observing S+ and S- stimuli were equal across the two options, but they differed according to contiguity of the S+ stimuli. In the clear loss option, the S+ appeared once and then it was cut off by the S- in the second reel during the loss trials. However, the S+ in the near miss option continued for two reels during losses. Therefore, the pigeons remained in the presence of the S+ (the putative conditional reinforcer) longer in the near miss option. Delay discounting would predict that the near-miss option will be discounted and that the clear-loss option will be preferred, and this is how the subjects in Fortes et al.'s study behaved.

Although there are few animal near-miss studies, they already appear to share the same issues with the literature on human research: there is a lack of procedural consistency, and what is considered a near-miss effect already varies from study to study.

Rationale and Overview of Experiments

Given that animal research affords higher experimental control, the present work analyzed pigeon behaviour and then the experiments were replicated with human participants. Behavioural persistence was studied in the first four experiments because it most closely corresponded with the gambling response and addiction. The final experiment used a choice procedure to corroborate the findings from the persistence studies. Also, given the broad procedural variations in the literature, the following experiments were designed to be highly simplified tasks that could serve as a basis for future research.

The procedures in this work adhered to the ethical standards of the University of Alberta and the Canadian Council on Animal Care. All pigeon studies were approved by the Bioscience Animal Care and Use Committee and the human studies were approved by the Research Ethics Board. All experiments were programmed using E-Prime® 2.0 Professional software and all statistical analyses were performed with R 3.4.4 (R Core Team, 2018). The first three of five experiments tested for persistence with respect to near-miss feedback. Pigeon behaviour was examined in Experiments 1A and 1B and Experiment 2 was the human analogue of those two experiments. These three studies used an extinction procedure to determine if near-miss feedback would cause greater persistence. The rationale for these studies was as follows: If near misses enhance the gambling response, then near misses should produce greater resistance to extinction relative to different kinds of loss feedback. In other words, if near misses have a conditionally reinforcing function on the gambling response, then increasing their presence in extinction should cause subjects and participants to continue responding longer compared to increasing the presence of some other miss in extinction. Due to practical limitations, near misses were only compared against the *far miss* (e.g., lemon-cherry-cherry). Experiment 3 was conducted as a “proof-of-concept”. It was designed to first produce a conditional reinforcement effect, and then test whether or not conditional reinforcement could be detected during extinction. In light of the results from the extinction experiments which measured persistence, Experiment 4 used a choice procedure to provide a second approach to studying the near-miss effect.

Experiment 1A

Pigeons pecked at a central response circle for a chance to receive food. Feedback regarding the outcome was signaled by three circles above the response circle. When all three circles were red (i.e., a win), the subject was given access to food. Otherwise, if any of the circles did not turn red, the bird did not receive food. In the treatment phase, pecks on the response circle were put on extinction: All wins were removed and replaced by either near misses or far misses. Perseveration was measured by comparing the number of trials completed during extinction between the near-miss and far-miss treatments.

Method

Subjects and apparatus. Eight homing pigeons (*Columba livia*) were randomly selected for the experiment. Subjects were housed in 65”x27”x70” flight cages in a colony room maintained at 20ºC. The colony room operated on a 12-hour daylight cycle from 6:00 A.M. to 6:00 P.M. MST. All birds had free access to vitamin-enriched water and crushed oyster shell grit in the colony room. Subjects were maintained at 80% of their free-feeding weight by adjusting their post-experiment feeding of Mazuri Gamebird food pellets (PMI Nutrition International).

Six custom-built operant boxes were equipped with Carrol Touch infrared touchscreens (Elo Touch Systems, Inc., Menlo Park, CA) to detect pecking responses. Stimuli were presented on a centrally-mounted 17” Viewsonic LCD monitor located at the back wall of each chamber. Speakers in the operant boxes continuously played white noise to mask sounds from outside the experimental room. The sound pressure levels were equalized in each operant box at 65 dB via A-weighting filter with a Brüel & Kjær Type 2239 Integrating Sound Level Meter. Two 2” × 2” feeding ports flanked the monitor and each port was equipped with a food hopper. Access to food was controlled by Colbourne H20-94 photocell sensors that detected entry into the ports. A 1/8” thick white Plexiglass barrier was mounted in front of the screen to prevent errant behaviours (e.g., subject’s wings, bodies, and feet contacting the screen) from interfering with the touch screen’s ability to record pecking responses. The barrier had four holes cut in it: three horizontal circles were cut to 1.5” in diameter near the top to allow for visual identification of the stimuli and a 1” diameter hole was cut beneath the middle of the three circles to allow for pecking responses. Stimuli were presented on a black background and they were aligned behind the holes cut in the barrier.

Procedure. This experiment was a repeated-measures design with two treatments: the near-miss and far-miss treatments. The order of these treatments for each subject was randomly determined by a Latin square (i.e., subject × treatment). All subjects began on a three-component pre-exposure phase before moving on to a treatment phase. Upon completion of the first treatment, the subjects repeated the entire pre-exposure phase and then they were subjected to the second treatment. Each experimental session took 90 min or less to complete, and each subject completed one session per day. Only one handler (J.P.) conducted the experimental sessions to further reduce sources of systematic and unsystematic error.

Pre-exposure phase. The subjects began on a basic autoshaping procedure (see Schwartz & Gamzu, 1977) with a fixed-ratio 1 (FR1) contingency. Here, a white circle was presented at the lower response hole for 10 s or until the bird pecked it. After 10 s or after a peck on the white circle, the circle disappeared and then one of the feeding port lights illuminated and its associated hopper raised. The subject had 1 s to eat from the hopper upon entry. Then, the port light extinguished, the hopper lowered, and a 240 s interval began. This process was repeated over a 90 min session. All subjects remained on this component for three consecutive sessions.

Following autoshaping, the subjects were put on a FR1 schedule. Responses were made on the lower response hole as before. Following one peck, the white pecking circle disappeared and then the subject had to wait 2400 ms until they were given access to food from either the left or right hopper. The FR1 schedule lasted for one 90 min session. On the next session, the schedule was extended to a FR3 (i.e., three pecks were required to gain access to food). The 2400 ms interval was still implemented after every response. Following one session of FR3, the schedule was extended to a FR6 for one more session.

In the final pre-exposure component, subjects were put on a random-ratio 5 (RR5) schedule. Similar to a variable-ratio (VR) schedule, a RR schedule is also characterized by an average response requirement, but unlike a VR schedule, an RR schedule is constructed by random number generation rather than a predetermined list of reinforced and nonreinforced trials (Zeiler, 1977). In this pre-exposure component, each peck was separated by at least a 2400 ms interval but during this interval, the reel stimuli were now presented at the upper three circles. A *win* occurred when all three circles were red. All loss feedback was presented as such: A *near miss* occurred when only the left and middle circles were red. A *flanked miss* occurred when only the left and right circles were red. A *far miss* occurred when only the middle and right circles were red. Finally, a *single miss* occurred when only one of the three circles was red. On single misses, each of the three locations had an equal chance of turning red.

The reels were always presented sequentially from left to right with a 600 ms interval in between each presentation. For instance, this was the sequence of events on a win: Following a peck to the white circle, the white circle disappeared. After 600 ms, the left reel appeared. Then, the middle and right reel each appeared in sequence with a 600 ms interval between each presentation. All three reels remained onscreen for another 600 ms. In total, the sequence was 2.4

s long. Then, the right or left hopper would rise to give the bird 1 s access to food pellets (i.e., primary reinforcement). Finally, the white pecking circle returned to occasion the start of the next trial. On all loss trials, each of the intervals still occurred whether or not a red circle appeared so that the total sequence was always 2.4 s long. The reels then reset back to black and the white pecking circle reappeared following the last 600 ms interval.

Birds only gained access to food following wins. The probabilities of all outcomes were equated across every 30 trials (i.e., within one string of 30 trials, 20% of the outcomes were *wins,* 20% were *near misses*, 20% were *far misses*, and so on). This component lasted 15 sessions.

Treatment phase. After the pre-exposure phase, all subjects were put on either the near-miss or far-miss treatment for five sessions. Both treatments put pecking responses on the white key on extinction. Specifically, all wins and primary reinforcement were removed and either the near-miss or far-miss reel patterns were presented in their place. For instance, a subject in the near-miss treatment experienced near misses 40% of the time, and all other loss feedback was experienced 20% of the time as before. The subjects were not presented with any additional cues to signal this change in the schedule. After the treatment phase, the subjects repeated the pre-exposure phase and then they were subjected to the next treatment condition (i.e., a pigeon that did the near-miss treatment first would do the far-miss treatment next and vice versa).

Results

The mean difference in the number of responses made to the response circle during extinction between the near-miss and far-miss treatment phases was assessed using a paired t-test. An effect size was calculated using Hedges' *g* for paired samples (Torchiano, 2017). The fit of the data was compared under the alternative hypothesis (i.e., the mean responses in the near-miss treatment will be greater than the far-miss treatment) over the null hypothesis (i.e., there is no statistical difference between the treatments) through a JZS Bayes Factor (*BF*) using a medium prior (Morey & Rouder, 2015; Jarosz & Wiley, 2014). The *BF* represents a ratio of the likelihood of the data according to the alternative hypothesis over the null hypothesis. In general, a *BF* of 1-3 suggests weak or anecdotal support for the alternative hypothesis, 3-10 suggests positive or substantial evidence for the alternative, and a *BF* of 150 or above suggests very strong or decisive evidence for the alternative hypothesis (see Jarosz & Wiley, 2014).

The results are depicted in Figure 1. Resistance to extinction was greater overall during the far-miss treatment (M = 784.125, SD = 294.73) compared to the near-miss treatment (M = 613.25, SD = 246.39) but this difference was not statistically significant, $t(7) = 1.68$, $p = .136$, [-69.00, 410.75], $g = 0.56$, $BF = 0.92$.

Discussion

In contrast with the hypothesis, near misses did not cause greater resistance to extinction. Additionally, the estimated Bayes Factor (alternative/ null) indicated that the obtained results were only 0.92:1 in favour of the alternative hypothesis – the data was marginally more likely to occur according to the null hypothesis.

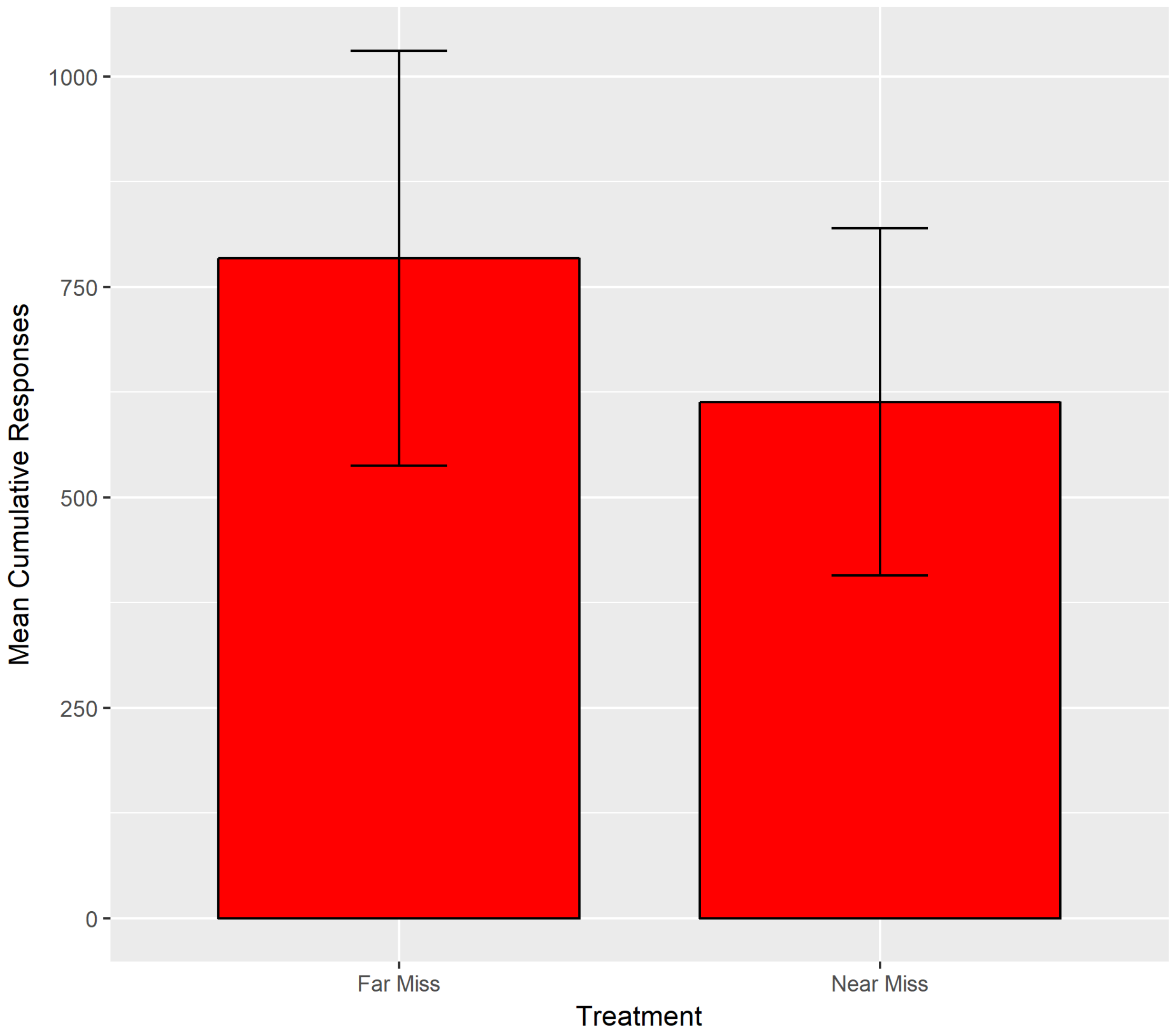

Figure 1. Average number of responses made during extinction in Experiment 1A. Here, only red circles comprised the reel patterns. During pre-exposure phase, losses occurred when at least one of the three circles did not turn red. In extinction, either the far miss or near miss replaced the wins. The results from the far-miss treatment are shown the left; near-miss treatment results are on the right. Error bars show 95% confidence intervals.

Experiment 1B

Experiment 1A was designed to be as simple as possible, but slot machines do not typically issue feedback with only one kind of stimulus. This experiment was functionally identical to the previous one but included S- stimuli on loss trials.

Method

An additional 8 homing pigeons that were not used in Experiment 1A were used in this study. The procedure was identical to Experiment 1A with one alteration: Whereas Experiment 1A produced the reel stimuli using only red circles and losses occurred whenever there was at least one blank circle, Experiment 1B presented blue circles (i.e., S- stimuli) in place of the blank circles in Experiment 1A. Otherwise, the apparatus and procedure were the same as before.

Results

Statistical analyses were the same as in Experiment 1A. The results are shown in Figure 2. Persistence was less overall during the far-miss treatment (*M* = 573.13, *SD* = 262.82) compared to the near-miss treatment (*M* = 677.88, *SD* = 288.19). However, this difference was not statistically significant, *t*(7) = -1.44, *p* = .193, [-276.81, 67.31], *g* = -0.48, *BF* = 0.73.

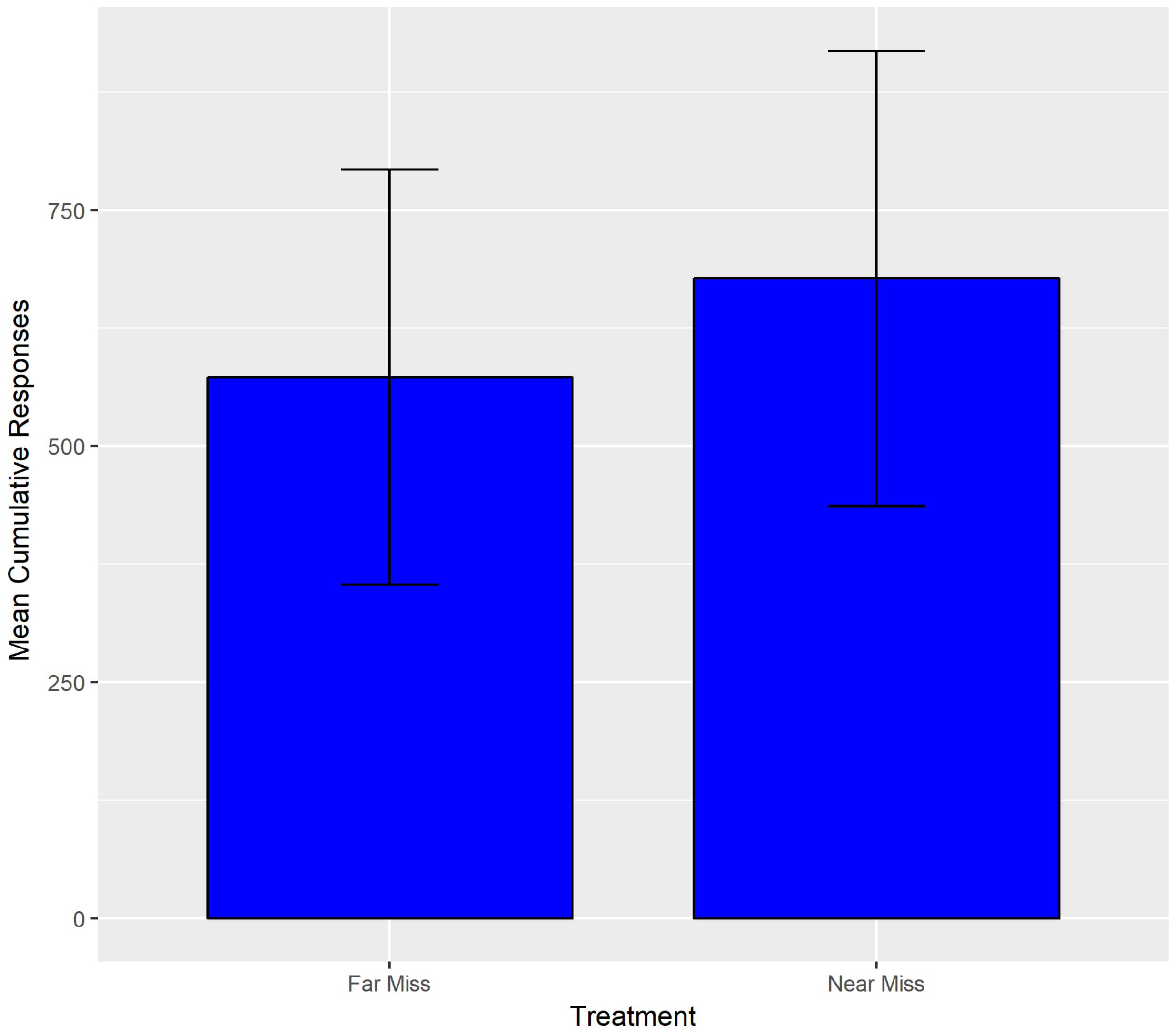

Figure 2. Average number of responses made during extinction in Experiment 1B where red and blue circles comprised the reel patterns. During the pre-exposure phase, losses occurred when at least one of the circles were blue. As in Experiment 1A, either the far miss or near miss replaced the wins during extinction. The results from the near-miss treatment results are shown on the right. Error bars indicate 95% confidence intervals.

Discussion

Unlike the results from the previous experiment, the mean number of responses during extinction was greater during the near-miss treatment, but as before, resistance to extinction was not significantly different between the near-miss and far-miss treatments. Additionally, the estimated Bayes Factor suggested that the data was only 0.73:1 in favour of the alternative hypothesis. Inversely, this means that the results were 1.37 times more likely to occur under a model that assumes no effect of treatment.

Experiment 2

The above pigeon experiments were redesigned for use by human participants. As before, perseveration was measured by comparing the number of trials completed during the near-miss and far-miss extinction phases.

Method

Participants and Apparatus. This experiment had 296 participants that were recruited from the subject pool of introductory psychology courses at the University of Alberta. They were compensated with partial course credit and a small monetary bonus up to $9.50 CAD depending on their performance. Data was collected from up to 14 participants at a time at each experimental session. Each session was conducted in a large room that contained fifteen individual testing rooms that were located around the perimeter of the room. The task was completed using a computer equipped with a keyboard and mouse. E-Prime® 2.0 Professional software was used to present stimuli and record responses.

The structure of this experiment was adapted from Experiments 1A and 1B. The stimuli were presented on a black background. Three 2.125" circles comprising the reel patterns were oriented at the top of the screen and their locations were outlined by a grey border. The reel patterns were presented in the same manner as in Experiments 1A and 1B. Also similar to the previous studies, a 1.5" white circle with a grey border served as the response key and it was located just below the middle reel stimulus. Black text within the response key read "Click Me!".

Procedure. Participants first read and signed a form to provide their consent for participation. Then, the participants were assigned to the individual testing rooms and they were instructed to begin. The computer screen first prompted them to enter their age, and then a brief set of instructions was presented to them for 1 min. Participants were instructed to try and earn as much money as they could and that they could choose to stop playing at any moment. After 1 min, the instructions prompted them to press the Enter key to begin the experiment. Participants were randomly assigned to one of two groups and experienced one of two treatments. The groups were analogous to Experiments 1A and 1B: Participants in the S^D *only* (i.e., positive stimulus only) group only saw red circles in the reel patterns, and participants in the $S^D S^\Delta$ (i.e., positive and negative stimulus) group saw both red and blue circles where only red circles functioned as signals for wins. The treatments were the same as in the previous two experiments: wins were replaced by either near misses or far misses.

Pre-exposure phase. The initial phase proceeded similarly to the third component of the pre-exposure phases of Experiments 1A and 1B. The first 15 trials were contrived so that the first, fifth, and eleventh trials were wins. This was implemented to prevent participants from experiencing an early long string of losses that could occur due to the RR schedule. Then, the rest of the 285 trials proceeded on a RR5 schedule. The probabilities of all outcomes were equated across every 15 trials. Participants started with $0.50 which was represented at the bottom of the computer screen. Each play on the response key cost $0.05 which was immediately subtracted from the participant’s score. Wins awarded $0.40 and they were signaled by “Win! +40¢” in large bright yellow text.

Treatment phase. After 300 trials, plays on the response key were put on extinction. Specifically, clicking on the response key still cost $0.05 but doing so no longer awarded wins. Participants in the near-miss treatment had the wins replaced by near misses and participants in the far-miss treatment had wins replaced by far misses. Participants were not presented with any cues to signal this change. If participants had not already stopped playing, they could continue until 50 minutes had elapsed. When participants were ready to leave, they were paid in cash ranging from \$0 to \$5 depending on to the number of points they had left. They were also given a debriefing form about the experiment.

Results

Since the participants were free to leave at any point during the experiment, some participants chose to leave before entering the extinction phase. Out of 296 participants sampled, 118 participants left prior to extinction and 178 remained. Of the participants that left, 57 (about 48%) participants were assigned to the S^D only group and 61 (about 52%) participants were assigned to the S^DS^Δ group.

Data was analyzed from participants that entered the extinction phase. As in the previous experiments, the mean cumulative responses during extinction was compared between the near-miss and far-miss treatments. Visual inspection of the data revealed heavy right skew (see Figure 3), so a base-10 logarithmic transformation was done to permit parametric analysis via a 2 × 2 Factorial ANOVA. Partial omega-squared estimates (ω_p^2) were calculated for the effect sizes of the main effects and the interaction. A JZS Bayes Factor was calculated to show the relative odds of the main effects and the interaction against the model's intercept. The main effect of group (S^D only versus S^DS^Δ) was nonsignificant, $F(1, 174) = 0.01$, $p = .920$, $\omega_p^2 = -0.01$, $BF = 0.16$, and the main effect of treatment (far-miss versus near-miss treatment) was also nonsignificant, $F(1, 174) = 2.12$, $p = .148$, $\omega_p^2 = 0.01$, $BF = 0.42$. Finally, the interaction between group and treatment was also nonsignificant, $F(1, 174) = 1.49$, $p = .224$, $\omega_p^2 = 0.003$, $BF = 0.03$.

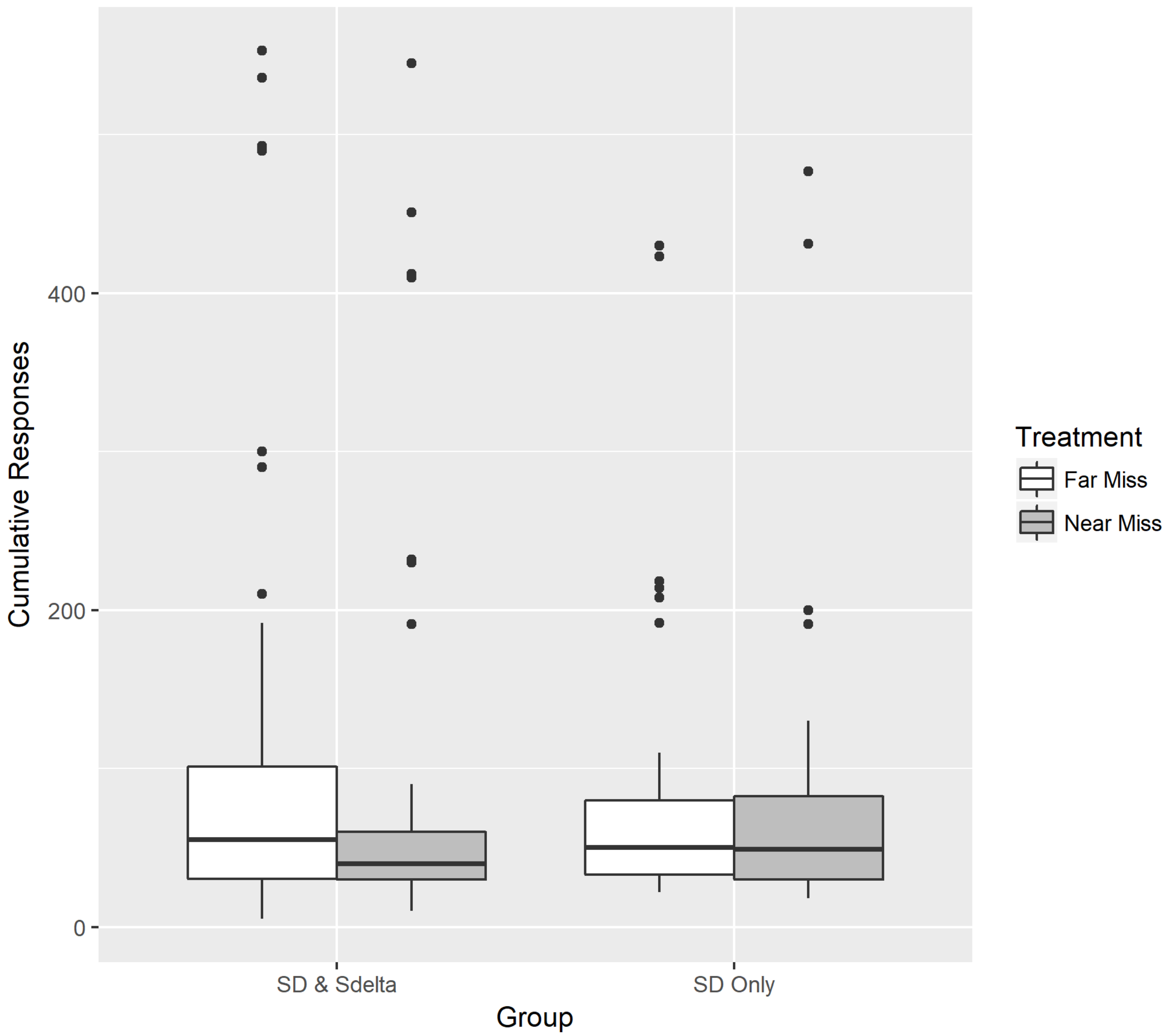

Figure 3. Boxplots of untransformed cumulative responses during extinction from Experiment 2. The groups were analogous to Experiments 1A and 1B. The results from the participants that saw red and blue circles in the reels are shown on the left. Results from participants that only saw red circles in the reels are shown on the right. Data from the near-miss treatment are indicated by the gray plots.

Discussion

Similar to Experiments 1A and 1B, the participants did not show greater persistence when the near misses were presented more during extinction. Also, the data indicates that the monetary bonus was not sufficiently reinforcing given that nearly 40% of the participants left prior to extinction. The group manipulation did not appear affect participants' decisions to leave as indicated by the roughly equal proportions of participants who had been assigned to both groups.

Experiment 3

The studies above did not find evidence for conditional reinforcement in terms of enhanced persistence. The following experiment was conducted to assess the validity of the procedure used in the previous experiments. In Experiment 3, the feedback stimuli were simplified and the pre-exposure phase was structured such that conditional reinforcement of the feedback stimuli could be verified independently of the extinction procedure. In other words, this experiment was designed to see if a conditional reinforcement effect could be established in the first place, and then the effect was tested to see if that same reinforcer could be used to increase persistence during extinction.

Method

Subjects and apparatus. An additional 8 homing pigeons that were not used in the above experiments were randomly selected for this study. The apparatus was the same as before.

Procedure. This experiment was also a repeated-measures design with two treatments. The order of these treatments was randomly determined by a Latin square (i.e., subject × treatment). Subjects began on a three-component pre-exposure phase followed by a treatment phase. Only one handler (J.P.) conducted the experimental sessions during the treatment phase to reduce unsystematic variation.

Pre-exposure phase. The first component of the pre-exposure phase was identical to the autoshaping procedure used in Experiment 1A. In the next component, the pigeons were put on a 200-trial FR1 schedule for one session that reinforced responses to the white pecking circle at the lower hole in the barrier. The interval between each peck and reinforcement was 2.4 s. where the pecking circle was removed during this interval. In the third component, the pigeons were put on a pure RR2 schedule (i.e., probabilities were not equalized over a set number of trials). Similar to the previous component, there were only 200 reinforced trials, but a feedback stimulus was now presented at the middle hole of the upper three circles in the Plexiglass barrier. On reinforced trials, pecking once on the white response circle caused the response circle to disappear and then a yellow circle with a thin horizontal black line (i.e., the S^D) appeared in the upper circle for 2.4 s. The bird then had 1 s to access food, and then the response circle reappeared. On nonreinforced trials, a blue circle with a thin black vertical line (i.e., the S^Δ) appeared at the upper middle hole for 2.4 s and then the white response circle returned to occasion a response for the next trial. The S^D and S^Δ stimuli were counterbalanced across subjects.

Treatment phase. After five days on the RR2 schedule, subjects were put on a three-day treatment phase that put responses towards the white pecking circle on extinction. Here, all primary reinforcement was eliminated and the proportions of stimulus presentations were modified: Subjects in the S^D 80% treatment saw the S^D 80% of the time and they saw the S^Δ 20% of the time. Likewise, birds in the S^D 20% treatment saw the S^D 20% of the time and the S^Δ 80% of the time. After three days on the first extinction phase, subjects repeated the pre-exposure phase and then they completed the next treatment condition.

Results

Assessing conditional reinforcement via discrimination index. The putative conditionally reinforcing effect of the S^D and S^Δ was assessed by calculating a discrimination index (I) for each subject with the equation $I = S^D / [S^D + S^\Delta]$ where S^D and S^Δ represented each subject's cumulative responses towards the respective feedback stimulus during the pre-exposure phase. This was tested against $I = 0.5$ which would indicate no discrimination. An unbiased estimate of Cohen's *d* (see equation 11.13 in Cumming, 2012) was calculated for the effect size.

Data was collapsed across both pre-exposure phases for each subject. There was a mean discrimination index of *M* = 0.99, *SD* = 0.01. Subjects responded significantly more towards the S^D relative to the S^Δ, *t*(7) = 187.73, *p* < .000, [0.99, 1.00], *d* = 119.33, *BF* > 150.

Assessing conditional reinforcement via extinction. Data analysis for extinction in Experiment 3 was conducted similar to Experiments 1A and 1B. The mean difference in cumulative responses towards the response circle during extinction was compared between the S^D and S^Δ treatment phases. The results are shown in Figure 4. Resistance to extinction in the S^D 20% group (*M* = 394.50, *SD* = 182.97) and the S^D 80% group (*M* = 395.88, *SD* = 264.62) appeared to be nearly identical. A paired t-test indicated that the difference between these treatments was nonsignificant, *t*(7) = -0.020, *p* = .985, [-165.13, 162.38], *g* = -0.0057, *BF* = 0.34.

Discussion

During the pre-exposure phase, the subjects showed an extreme effect (as indicated by the large Bayes Factor) of responding towards the S^D stimulus although they were never trained to respond towards the feedback stimuli. This showed that the S^D acquired a clear conditionally reinforcing function despite the fact that the subjects were never trained to respond towards the feedback stimuli. However, presenting the S^D more or less during extinction did not influence perseveration. In fact, there was nearly no difference in resistance to extinction between the treatment groups. The estimated Bayes Factor also suggested that the results were better accounted for by a model that assumes no effect of the treatment during extinction. In this experiment, the S^D clearly acquired a conditionally reinforcing function, but it was unrelated to pecks on the response circle during extinction.

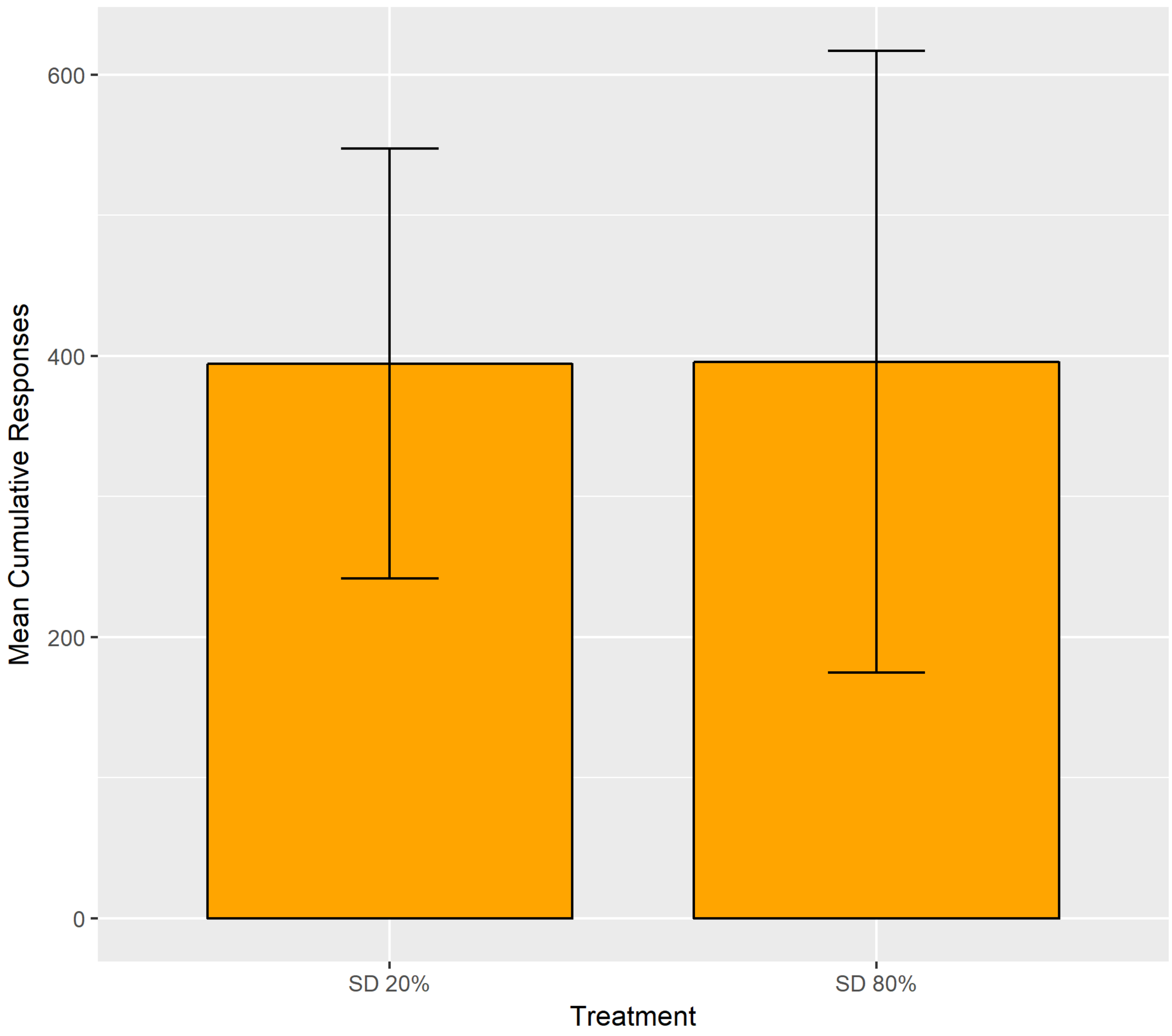

Figure 4. Average number of responses made towards the response circle during extinction in Experiment 3. During the pre-exposure phase, primary reinforcement was preceded by a red circle (i.e., the S^D) and blue circles (i.e., S^Δ) were presented on nonreinforced trials. In the extinction phase, the S^D was either presented 20% of the time (results depicted on the left) or 80% of the time. Error bars show 95% confidence intervals.

Experiment 4

Given the nonsignificant results of the above extinction procedures, the near-miss effect was tested using a different approach. Instead of examining persistence, this experiment assessed people's proportions of choices towards two concurrently available simulated slot machines. Two of four groups served as positive controls where participants were expected to prefer the slot machine that was programmed with the higher rate of reinforcement. The remaining two groups chose between two slot machines that presented near misses 30% of time, or no near misses at all. Preference towards the machine that presented near misses would indicate a near-miss effect.

Method

Participants and apparatus. This study had 240 participants that were recruited from the subject pool of introductory psychology courses at the University of Alberta. They were compensated with partial course credit and an honorarium up to $5.00 CAD. As in Experiment 2, data was collected from up to 14 participants at a time, and each session was conducted in the same large room as before.

The experimental task involved betting between two concurrently available slot machines. All participants started with 2500 points and each bet cost 10 points. Their total score was always presented at the top of the screen (see Figure 5). On wins, participants were awarded 38 points and a central "Win!" stimulus changed from gray to yellow. The two slot machines were located on the left and right sides of the screen. Each machine had three feedback reels and text in the middle of each machine read "Press '$' to Play". A small circle below the text contained a "$" sign and it functioned as the response circle. Clicking on this circle would place a bet on that machine, which would then initiate that slot machine's reel sequence from left to

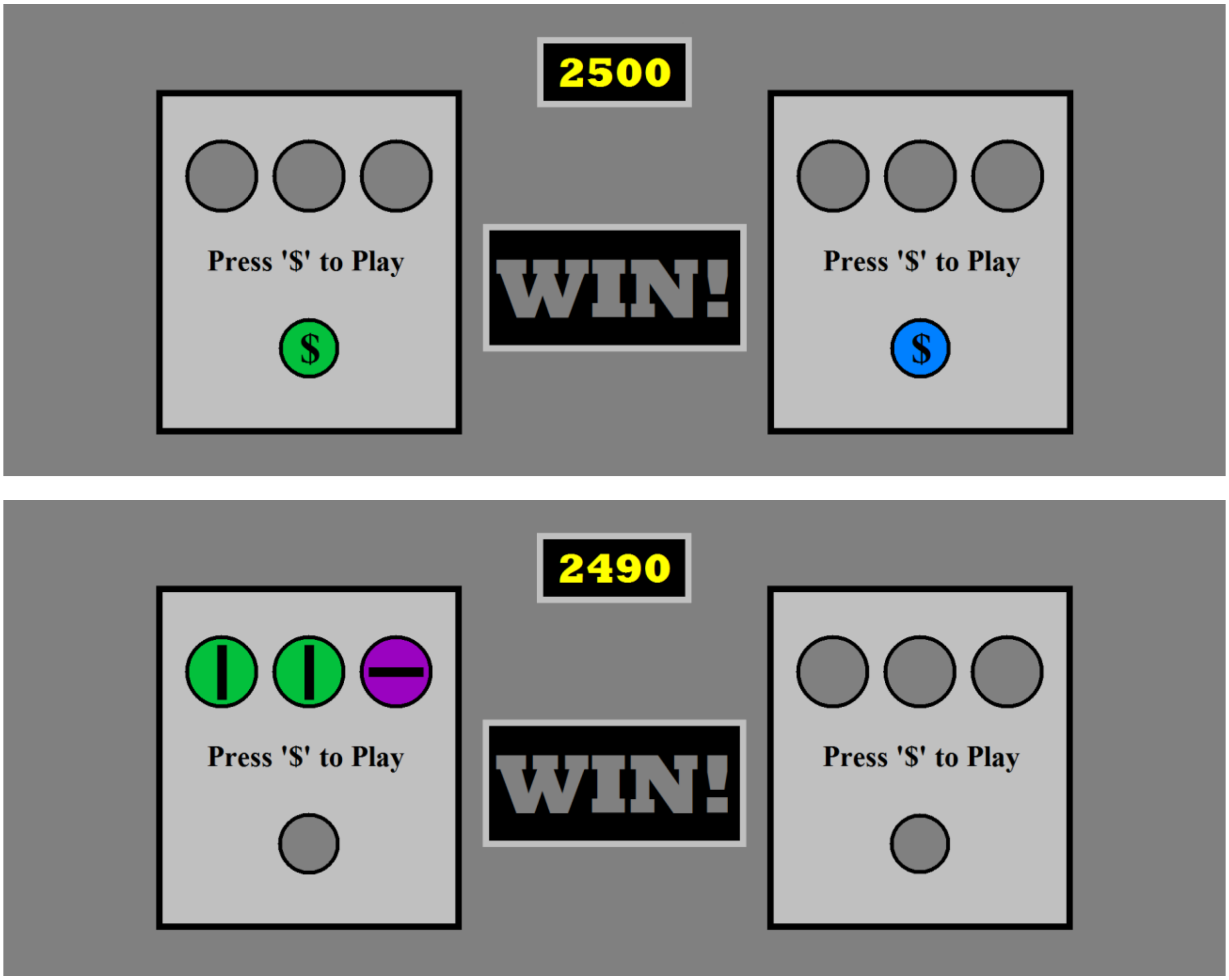

Figure 5. Diagram of Experiment 4. Points were always displayed at the top, and the central “Win!” stimulus would turn yellow on wins along with a reward of 38 points. Top image shows the start of a choice trial. A single click at either the green or blue button would bet 10 points and initiate the trial. Lower image illustrates a near miss after choosing the left machine.

right as in the previous studies. The response circle's colour matched the colour that corresponded with wins on the respective machine. One machine used green and purple circles as the feedback reels where getting all three green circles led to a win. The other machine presented blue and orange circles and getting all blue circles led to wins. As in the previous experiments, the reels were presented sequentially from left to right, and either one or two of the reels became purple or orange on losses. To enhance discriminability, a horizontal line or a vertical line corresponded with each colour on one machine, and a circle or a plus symbol corresponded with the colours of the other machine. To further aid in learning, the location of each machine was fixed to the left or right side for the duration of each participant's session. However, the side in which the stimuli and contingencies were assigned was randomized across participants.

The contingencies of the machines depended on which of the four groups a participant was assigned to (see Table 1). Two of the groups comprised a positive control condition where one machine was programmed on a RR4 schedule and the other machine was on a RR7 schedule (the RR4 machine offered the higher rate of reinforcement). One of these groups was termed the *0% NM* group because both slot machines did not present any near misses. The other group was called the *30% NM* group where both machines presented near misses on one-third of all loss trials. In the experimental phase, both of these groups chose between a slot machine that presented near misses on 30% of the loss trials and a machine that did not present near misses at all. One of these groups was called the *RR4* group because both machines were on a RR4 schedule. The other was the *RR7* group in which both machines were on a RR7 schedule.

Table 1

Summary of Groups in Experiment 4.

Group	NM Frequency	Reinforcement Schedule	n
0% NM	0% & 0%	RR4 vs RR7	54
30% NM	30% & 30%	RR4 vs RR7	59
RR4	0% vs 30%	RR4 & RR4	58
RR7	0% vs 30%	RR7 & RR7	58

Procedure. Participants first read and signed a consent form before the experiment. They were then each assigned to an individual testing room and completed the task on a computer. The computer screen first prompted them to enter their age, and then a brief set of instructions was presented to them for 1 min where they were told to try and earn as many points as they could which would translate to their monetary honorarium. In the first phase of the experiment, participants were presented with just one of the two slot machines at a time. This ensured that all participants had equal exposure to both machines at the start of the experiment. This phase lasted 60 trials, where every ten trials alternated between each slot machine. Following that, participants were given 300 choice trials where both slot machines were available on each trial.

Results

Analyses were performed on data from participants that completed all trials in the experiment. Eleven participants failed to complete all 300 decision trials, so the data from these participants were excluded from the analysis. Of the 229 remaining participants, 54 were randomly assigned to the 0% NM group, 59 participants were in the 30% NM group, 58 in RR4, and 58 in the RR7 group as well.

First, a score representing the proportion of responses towards the RR4 machine (for the control groups) or the near-miss machine (for the experimental groups) was calculated for each participant using the last 100 trials. Then, four two-tailed one-sample *t*-tests were conducted on these scores for the four groups. Cohen's *d* was calculated for effect sizes. JZS Bayes Factors were calculated to compare the fit of the data under the alternative hypothesis (i.e., participants' scores are significantly above or below indifference) over the null hypothesis (participants' scores reflect indifference; i.e., not significantly different from 0.50). The results for the four groups are depicted in Figure 6. Figure 7 shows the participants' cumulative responses aggregated across the control and experimental conditions. Analysis for the 0% NM group (*M* = 0.57, *SD* = 0.22) showed that their scores were significantly above indifference, *t*(53) = 2.46, *p* = .0173, [0.51, 0.63], *d* = 0.33, *BF* = 2.29. Participants' scores in the 30% NM group (*M* = 0.57, *SD* = 0.19) were also significantly above 0.50, *t*(58) = 2.93, *p* = .00484, [0.52, 0.64], *d* = 0.38, *BF* = 6.63. Thus, both of the positive control groups significantly preferred the machine that provided a higher rate of winning.

However, the analysis for the RR4 group (*M* = 0.53, *SD* = 0.20) showed that participants did not significantly prefer the near-miss machine, *t*(57) = 1.24, *p* = .221, [0.48, 0.58], *d* = 0.16, *BF* = 0.30. Participants in the RR7 group (*M* = 0.46, *SD* = 0.19) appeared to prefer the 0% near-miss machine over the 30% near-miss machine, but this preference only approached significance, *t*(57) = -1.79, *p* = .0784, [0.41, 0.50], *d* = 0.24, *BF* = 0.64.

Discussion

As expected, participants in the positive control groups preferred the machine that was programmed with the higher reinforcement rate. The effect sizes were small to medium, and the Bayes Factors indicated support for the alternative hypothesis over the null hypothesis for both groups. Note, however, that discriminating between the RR4 and RR7 machine was not a simple task, as evidenced by the mean choice proportions being only slightly above the 0.5 mark during the last 100 trials. An easy task would show a clear ceiling effect where the mean choice proportions are at or approach 1.0. Anecdotally, laboratory personnel were unable to ascertain which slot machine was the RR4 or the RR7 during pilot testing.

Analyses for the experimental groups indicated that participants did not significantly prefer or avoid the near-miss machines. Taking the inverse of the Bayes Factors shows that the data are 3.33 times more likely to occur assuming indifference for the RR4 group and 1.56 times more likely to occur assuming indifference for the RR7 group. Although the results appear to suggest a preference away from near misses on the RR7 schedule, only further testing can determine if this could be a real effect. Furthermore, aggregated data shown in Figure 7 shows that participants preferred the higher reinforcement rate over the course of the experiment, whereas participants appeared to be indifferent with respect to the 0% NM machine versus the 30% NM machine. Overall, the results from this experiment demonstrated that participants were sensitive to subtle differences in reinforcement rates, but the presence or lack of near misses did not significantly bias their choices.

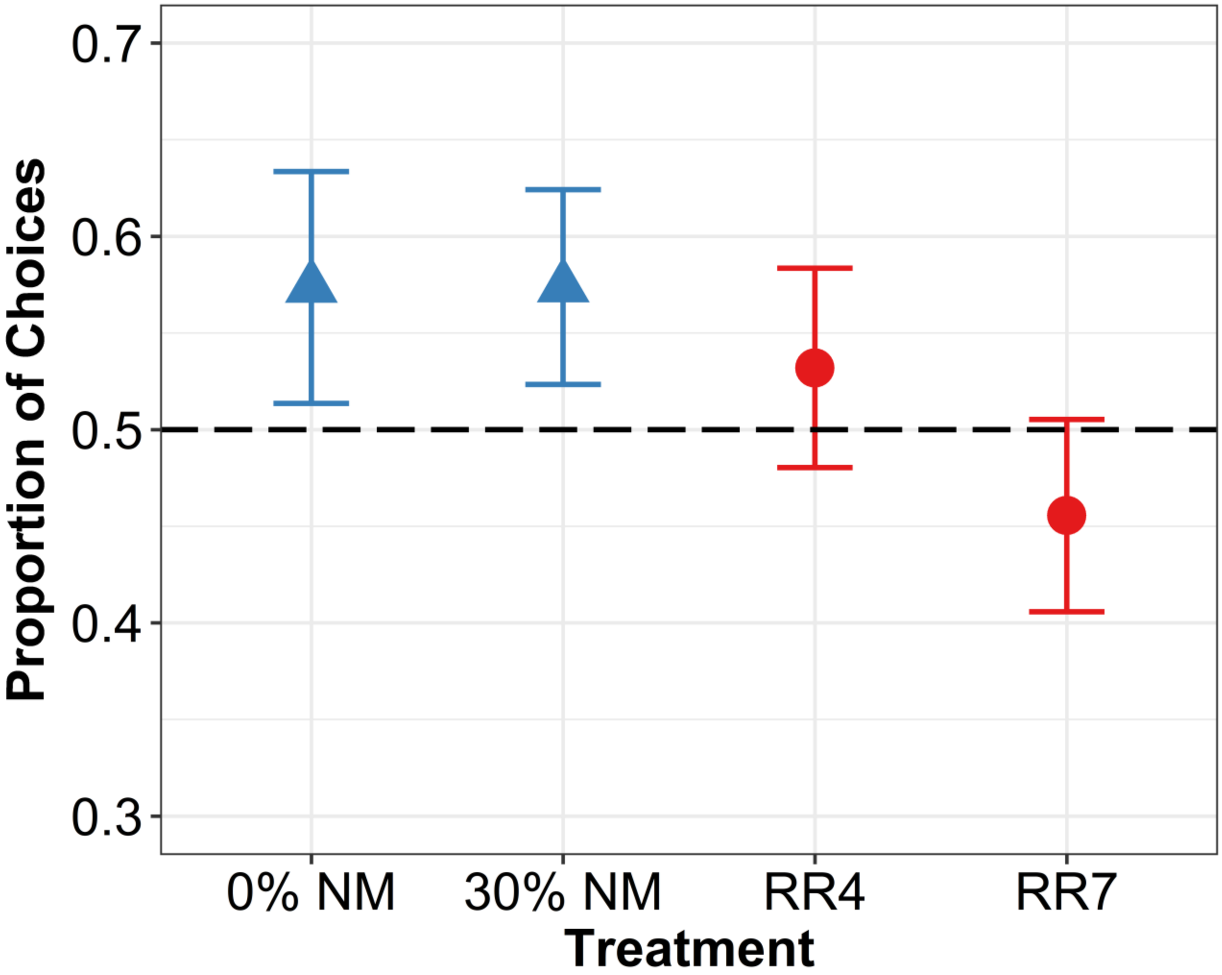

Figure 6. Proportions of choices over the last 100 trials from Experiment 4 with 95% confidence intervals. Blue plots show data from the positive control groups. Plots above the 0.5 mark indicate preference towards the RR4 over the RR7 machine. Red plots show data from the experimental groups. Plots above the 0.5 mark indicate preference towards the near-miss machine over the no-near-miss machine.

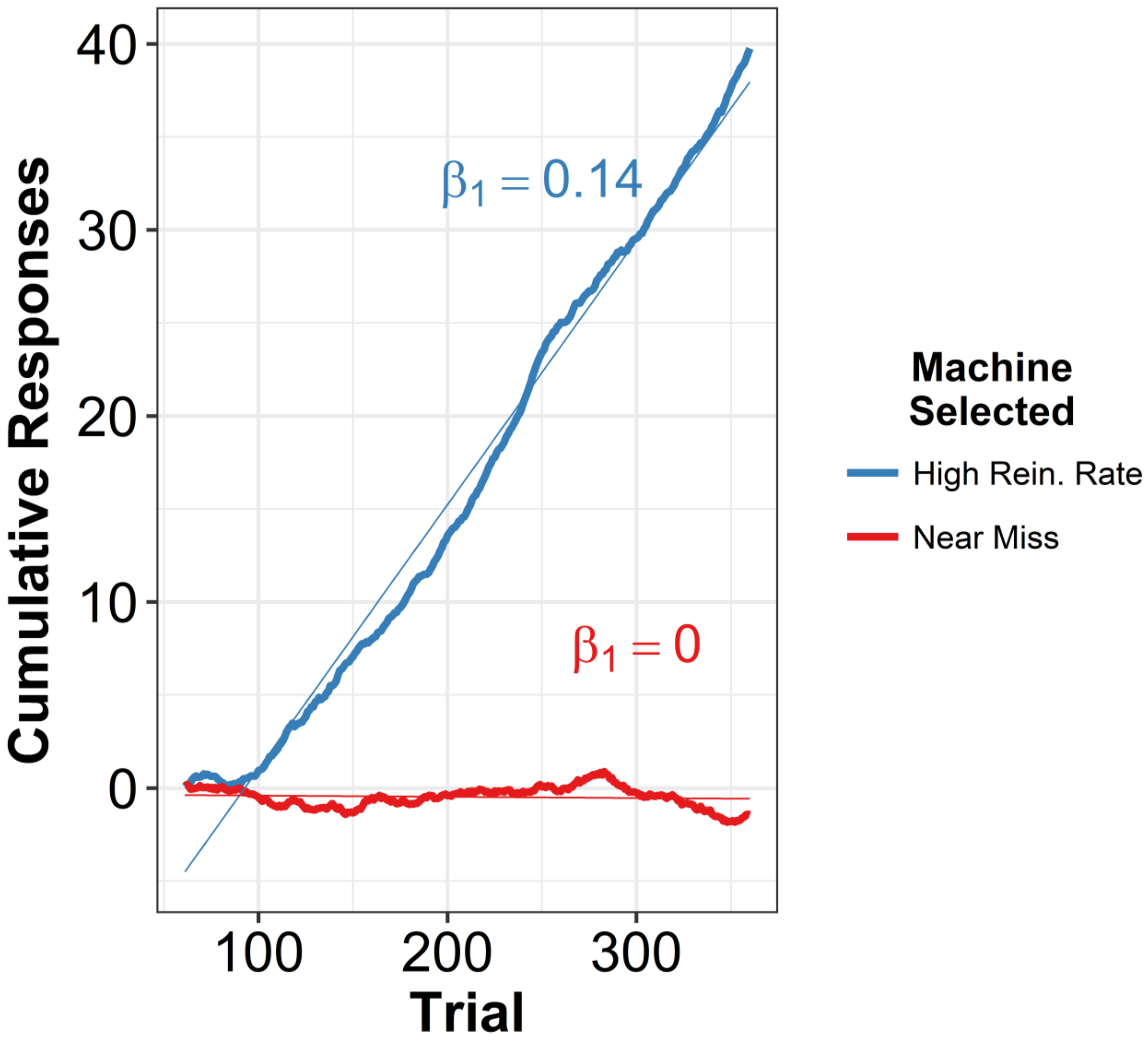

Figure 7. Cumulative responses during choice trials from Experiment 4 aggregated across control and experimental conditions. Blue line shows data from the control groups: Responses were scored as +1 if the higher reinforcement rate – the RR – was chosen, and responses to the RR7 machine were scored as -1. Red line shows data from the experimental groups: Choosing the 30% near-miss machine was scored as a +1, else -1 if the 0% near-miss machine was chosen. *β* represents the slope of the best-fit line.

General Discussion

Experiments 1A, 1B and 2 showed that extinction rates were similar across both treatments; overall, they did not demonstrate that near misses enhance persistence relative to the far miss. Additionally, the inclusion of explicit S^{Δ} stimuli did not appear to have any influence on behaviour. Experiment 3 was conceived of as a “proof-of-concept” to test the extinction treatment’s ability to detect a conditional reinforcement effect. Although this experiment showed evidence for conditional reinforcement (i.e., extreme responding towards the feedback stimulus that signaled terminal reinforcement), the effect did not apply to behaviour towards the response key. Extrapolating this to near misses suggests that even if near misses possess a conditionally reinforcing function, it may not actually influence the gambling response but some unrelated behaviour instead. Granted, the S^{D} in Experiment 3 was more functionally similar to the feedback for wins in the other studies so the results from Experiment 3 may not be indicative of the putative reinforcing function of the near miss. Additionally, the choice procedure in Experiment 4 corroborated the findings from the extinction studies. The positive control groups indicated that people were sensitive to subtle differences in reinforcement rates, but they were indifferent towards the presence or lack of near-miss feedback. A critical examination of these experiments followed by a discussion on the state of the literature and implications for future research are outlined below.

Potential Shortcomings of the Present Work

Although the tasks in the above experiments were simplified relative to previous work, some complexity was still inherent to the reels due to the sheer number of configurations involved. Therefore, the reels themselves may have still been problematic. Since there were many different types of loss-feedback, this could have introduced enough variability in the data to mask a small but otherwise significant near-miss effect. Also, the subjects and participants did not have to interact with the reels which is similar to true slot machines, but this may have introduced more variability as well. In the other animal studies, the subjects had to respond on the first reel to make the next reel appear and so on (see Fortes et al., 2017; Scarf et al., 2011; Winstanley et al., 2015). These authors implemented this requirement to ensure that their subjects were in fact looking at the reels. Since the pigeons from the present work were not required to peck at the reels, it is possible that these subjects simply ignored them. In Fortes et al.'s (2017) study, a group of pigeons that were required to peck at the reel stimuli were compared to a group of pigeons that were not required to do so. Although they still found a preference for the clear loss option in both groups, the preference of the no-peck-required group took longer to establish, it was slightly weaker, and there was more variance. However, requiring responses on the reels introduces an additional contingency that does not exist in normal gambling situations. Whether or not responses must be made towards the reels necessarily compromises either internal validity or external validity, and implementing a response requirement on the reels would have further detracted from the presumed lack of external validity in the present work's experiments. Future studies could examine if implementing a response requirement for humans would induce a near-miss effect. However, if near-miss effects are only found when responses are required on the reels, then the effect in natural settings could be so weak that it is almost nonexistent.

Second, there are potential issues with extinction procedures. The treatment contains an inherent compromise in that the effect that is being tested is simultaneously being weakened (see Kelleher & Gollub, 1962; Gollub, 1977). If a small near-miss effect existed, a period of nonreinforcement could have extinguished its conditionally reinforcing function so rapidly that no meaningful difference in perseveration could have been observed relative to the far miss. However, such a small near-miss effect may not meaningful. Also, Williams (1994) cautioned that the difference in context between extinction and pre-extinction may be larger than initially presumed. Indeed, the above experiments did not only remove wins and their associated stimuli but also overrepresented the near misses. A future study could manipulate the presence or lack of near-miss and far-miss feedback prior to extinction, and then only eliminate terminal reinforcement but include all of the reel stimuli (including those for wins) from the pre-exposure phase. However, given the results from Experiment 3, even if a conditional reinforcement effect existed, it may not apply to the gambling response. Finally, there are other factors outside of the experiment that could have undermined the extinction procedure – especially for humans. Witts et al. (2015) commented that competing contingencies such as washroom needs or simply having access to more reinforcing activities can influence participants to leave. The results from Experiment 2 support this: the sheer number of participants that left even before extinction suggests that the amount of money that they were earning was not sufficiently reinforcing. Providing a larger monetary incentive could alleviate this, but precisely how much more is arbitrary, and this is often unfeasible given the number of participants that need to be recruited to achieve sufficient statistical power. Given these shortcomings, near misses were studied through a choice procedure. However, this also failed to find support for the near-miss effect.

Arguments Against the Behavioural Near-Miss Effect

Although the notion that near misses enhance gambling persistence cannot be discounted solely based on the lack of evidence here, the results of this work combined with the existing literature currently weigh against the notion. Instead, there appear to be additional factors that could be responsible for enhancing persistence. For instance, the near-miss effect found by Côté et al. (2003) may not be solely due to the near-miss feedback but rather due to the contingency between near misses and wins. A proper procedure would have included an additional control where near misses were noncontingent with wins. To conclude that near misses themselves cause greater persistence, the effect ought to still occur – albeit perhaps weaker – even when near misses are not followed by wins. Further examinations could then compare near misses against other losses, but given the trend of current research, empirical examinations may not even progress to this stage. Additionally, Kassinove and Schare (2001) suggested that the density of near-miss feedback may be important. Witts et al. (2015) manipulated near-miss densities to determine if an optimal proportion of near misses would conditionally reinforce an observing response. However, they failed to find an optimal near-miss density. Similarly, MacLin et al. (2007) failed to find a statistically significant optimal density of near misses but they obtained a nonsignificant trend towards the *higher* near-miss density which contrasts with the conclusion originally drawn by Kassinove and Schare (2001). Whether or not there is an optimal density of near misses is unknown, but the validity of the near-miss effect ought to be established in the first place.

Empirical studies so far have not provided convincing evidence regarding the near-miss effect, so theoretical perspectives may offer a clearer perspective. However, counter to Skinner's (1953) initial proposal, theoretical accounts of conditional reinforcement may also weigh against the near-miss effect. As mentioned earlier, the effect was originally conceived by Skinner according to the pairing hypothesis of conditional reinforcement. This perspective assumes that the near-miss effect occurs based on local events (i.e., a consideration of how each reel relates to the others) rather than treating the near miss as a global event (i.e., how it relates relative to the other types of feedback). However, later research has demonstrated that pairing is not a sufficient explanation for conditional reinforcement (see Fantino, 1977; Mazur & Fantino, 2014 for reviews). Rather, there are more nuanced factors regarding the role of delay to reinforcement and the *contingencies* of the conditional reinforcer that determine how strongly a stimulus acquires a reinforcing status. The pairing hypothesis on near misses is insufficient because it ignores the importance of contingency. In other words, although consecutive reel images sometimes occur, each reel is more often followed by a nonmatching reel which would undermine any pairing that might have occurred. Considered globally, near misses in the present work's experiments and in true slot machines do not share any contingency with wins in the first place. Since they occur randomly, they do not indicate when a win will occur next. Therefore, it is more likely that near misses will have no influence on the gambler because their consequence is no different from the other losses and because they do not reliably signal a reduction in delay to wins.

Implications: Hunting for "Woozles"?

Given the arguments above, is near-miss research still worth pursuing? The status of near-miss research may be characterized by a phenomenon called the *Woozle effect* which describes a problematic trend in research (as cited in Gelles, 1980). The "Woozle" originates from Milne's (1926) beloved *Winnie-the-Pooh* where the characters Pooh and Piglet search for alleged honey-stealing creatures called Woozles. Eventually, they discover that the footprints that they had been tracking were in fact their own and not the mythical Woozle's. In research, the "Woozle effect" occurs when erroneous or incomplete information is perpetuated through citation. Gelles (1980) outlined an example where an original study produced some result along with its qualifying and cautionary statements. However, later studies would cite the findings without their associated qualifying remarks which leads to a perpetuation of inaccurate and incomplete information. This can create a misinformed or even wholly misguided understanding of a topic, or at least make an effect seem more robust than it really is.

In psychological near-miss studies, the seemingly robust finding that near misses enhance the motivation to play is likely a Woozle effect (see Clark et al., 2009; Clark et al., 2013; Dixon et al., 2013; Winstanley et al., 2011). The original study by Clark et al. (2009) showed enhanced motivation according to self-reports when participants could choose the outcome on one of the slot machine reels. However, the opposite result was found when the reels were purely computer selected. Brain activity in win-related regions also showed an opposite trend when comparing computer-selected versus participant-selected trial, but this was only marginally significant. Since the computer-selected trials are more representative of normal slot machine gambling, it may have been more accurate to suggest that people are less motivated following near misses compared to full misses. However, the studies that followed from Clark et al. (2009) continued to base their findings on participant-selected trials and this has perpetuated a misleading conclusion regarding near misses and motivation (e.g., Billieux et al., 2012; Clark, Crooks, Clarke, Aitken, & Dunn, 2012; Clark et al., 2013). Additionally, participants were required to report their desire to play after every trial. Although this was procedurally necessary, it is not representative of what occurs in normal gambling situations. Indeed, when Kassinove and Schare (2001) asked participants at the end of the task to report their desire to play the game again, they found no difference in motivation to play between the different near-miss densities.

The Woozle effect has arguably occurred in behavioural near-miss studies as well. For instance, studies that cited Kassinove and Schare (2001) for positive evidence of the near-miss effect have not mentioned their flawed procedure and analysis (e.g., Clark et al., 2009; Côté et al., 2003; Fortes et al, 2017; Scarf et al., 2011; Winstanley et al., 2011;). Similarly, studies that cited Côté et al.'s (2003) experiment did not mention that a contingency was contrived between near misses and wins (e.g., Fortes et al., 2017; Winstanley et al., 2011; Witts et al., 2015). The positive findings from behavioural near-miss studies are questionable, but the existing literature has portrayed the effect as being more robust than it may actually be.

Finally, near-miss research was premised on an assumption (Skinner, 1953) that was drawn from an early and incomplete understanding of conditional reinforcement (see Fantino, 1977). Therefore, near-miss research may have been misguided from the beginning, and studies in addition to this work have done more to discount the near-miss effect rather than support it (e.g., Reid, 1986; Fortes et al., 2017; Witts et al., 2015). But if the effect exists at all, it is likely unreliable or idiosyncratic (Witts et al., 2015), and it could be too small to have any practical significance. The results from Experiment 4 support this notion. Future studies on near misses may only find positive effects in separate domains (e.g., fMRI, ERPs, subjective reports, etc.) or in highly contrived settings that merely demonstrate that other variables create an illusion of a behavioural near-miss effect (e.g., Côté et al., 2003). Although persistence from near-miss feedback appears questionable, the focus on near misses has ironically persisted in the literature. Rather than "chasing Woozles", a clearer understanding of gambling behaviour may be achieved by abandoning the near miss and examining how other environmental factors and schedules of reinforcement give rise to gambling addiction.

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