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Cover Page Footnote

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Reel Outcomes as Discriminative Stimuli: A Case for Reporting Single Subject Data

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While slot machine gambling research in behavior analysis is on the rise, we still have many unanswered questions. Exploring the putative discriminative functions a series of reel outcomes might have on the perceived likelihood of future success (i.e., winning) might prove useful in understanding what motivates gamblers to continue gambling despite losses. In the current study, undergraduate participants watched eight videos of five reel spins each of varying win and loss (including near-miss) outcomes. Participants then provided estimations of the likelihood of winning on five upcoming hypothetical spins. While participants viewed their chances of winning as poor, strategic placement of wins and near misses influenced the probability of winning endorsed. Most importantly, idiosyncratic patterns differed markedly from grouped and overall-averaged data. A call is made to emphasize more single-subject analyses in gambling research.

A slot machine can only produce one of two outcomes: a loss or a win. However, the degree of win varies depending on which symbols matched[1], and the loss can come in either the form of a complete loss (no matching symbols) or a near-miss outcome (most symbols matching). Undoubtedly, the series of reel outcomes experienced influences decisions of future play, and thus these outcomes might have a discriminative effect on predicting future success on a particular slot machine.

To be considered a discriminative stimulus, the stimulus must signal a differential likelihood of reinforcement for responding with the caveats that presence of the discriminating stimulus is unnecessary for responding (Malott, 2008; pp. 217-218) and that the consequence is reinforcing regardless of discriminative stimulus presence (i.e., not a motivating operation or setting factor; see Michael, 2004). We distinguish discriminative stimuli as an environmental condition with developing a discriminative function with respect to other, non-discriminative stimuli; that is, discriminative functions based on design versus perception. In the case of the slot machine, we argue that reel spin outcomes might serve a discriminatory function as the reel outcomes are not needed to engage in the response (i.e., spinning the reels), and the reinforcement (winning) is arguably always reinforcing. We do recognize that a series of losses might be an establishing operation for winning, though this in no way assumes that all outcomes must have a motivational component. If a particular outcome or series of outcomes were to have discriminative properties, then the gambler would be more likely to endorse future spins as either wins (discriminative stimulus; S^D) or losses (s-delta; S^Δ). Conceptually, the discriminative nature of reel outcomes could be owed to experience, such as with superstitious reinforcement. Alternatively, gamblers might be constructing explanations for patterns of outcomes, which in turn generate rules. Rule-governed

[1] Losses disguised as wins we count here as a win, just of small magnitude in relation to the bet size.

behavior, then, might transform the reel outcomes from being non-discriminatory stimuli to discriminatory stimuli (see Dixon, Whiting, Gunnarsson, Daar, & Rowsey, 2015 for review and examples of rule-formation in gambling). The cognitive literature provides behavior analysts with two discriminative concepts from which to explore decision-making under different reel outcome arrangements: the gambler's fallacy and the hot hand fallacy[2].

In the gambler's fallacy, the gambler believes a particular event automatically reduces the chances of that same event occurring subsequently (aka negative recency; e.g., Ayton & Fischer, 2004; Clotfelter & Cook, 1993). The gambler's fallacy is exemplified when contacting a series of losses on a slot machine leads to a gambler believing that a win is more likely to be produced on the next spin, and vice versa. However, the reality of slot machines is that no one outcome is the product of previous outcomes as all are independent.

The gambler's fallacy stands in opposition to the hot hand fallacy, in which a series of one particular outcome leads to the belief that the sequence will continue in a similar fashion (aka positive recency; e.g., Ayton & Fischer, 2004). Variations of the hot hand fallacy are seen in slot machine gambling. Jensen (2010) advised slot machine gamblers to attend to the series of wins and losses in a particular slot machine to determine if the machine is 'cold' or 'hot.' According to Jensen, a cold machine is one in which your first six consecutive spins are losses, and the advice is to leave the machine. A hot machine is one in which you gain at least a 75% return on investment over a 40-spin sequence, and any upward movement in return over subsequent 40-spin sequences is a sign of the machine "getting hotter" (p. 67)[3].

In slot machine gambling, the gambler's fallacy and hot hand fallacy are subsumed under the general category of the illusion of control (see Langer, 1975), as both result in the gambler perceiving that some advantage can be gained by attending to prior reel outcomes. In this sense, it is an illusion of predictability that permits perceived control. Individual endorsements of the illusion of control in slot machine gambling, however, are inconsistent. For example, when Witts, Loudermilk, and Kosel (2014) asked participants if the statement "If a machine has produced a series of small wins, it will continue to do so" was true or false, 15.58% of a Midwest sample endorsed 'true,' as did 82.00% of a Western sample and 51.28% of an online sample from the United States. While 'cold' runs were not assessed, and neither was the gambler's fallacy (i.e., a win is due), this evidence suggests that aspects of the illusion of control are perceived to be true, at least by some.

Ayton and Fischer (2004) reviewed the literature on positive (hot hand fallacy) and negative (gambler's fallacy) recency. Their review concluded that any fallacy-related effect is likely due to generalization, or a failure to discriminate chance and less-than-chance events. In terms of the gambler's fallacy, a streak of one outcome indicates a different outcome is likely, and thus one should act accordingly. The streak, then, has discriminative properties (S^D for a streak of losses, and S^Δ for a streak of wins). For example, in playing scratch-off lotteries or pull-tabs, a series of losses automatically increases the chances of a win, given the finite number of winning and losing

[2] The term "fallacy" is perhaps incorrect, as we speak of the organism behaving the only way it knows how. Any fallacious response pattern must be in relation to some average response pattern or a logical standard.
[3] Jensen's advice is not to be confused with any concrete definition of hot or cold machines, but is supplied here for illustrative purposes.

tickets (assuming winning tickets are still available). The streak and discriminative property relations are inversed for the hot hand fallacy.

As part of a larger study, Dillen and M. R. Dixon (2008) explored the possibility of reel outcomes having discriminative effects by having participants record subjective probabilities of winning on the next spin on a simulated slot machine post-win and -loss. In their study, participants played 50-trial sequences of monetary-absent or monetary-present outcomes for wins on a slot machine simulation. The monetary-present condition produced wins worth $0.50 for one group and $2.00 for the other. These 50-trial sequences alternated (ABAB) and contained 5 wins, 45 losses, and no near-miss presentations. A 5-minute adaptation period was used before the first 50-trial sequence. After the last trial in the final sequence, a near-miss-present extinction condition (5 near-misses for every 50-trial block) followed in which participants continued to rate subjective probabilities until retiring from the study. Results showed no significant differences with respect to mean subjective probabilities between groups, trials, or both during ABAB and extinction trials.

Two limitations in Dillen and M. R. Dixon's (2008) analysis that might account for their lack of significant findings center on run length assessed and confirmatory feedback. These limitations are highlighted by comparison to Ayton and Fischer (2004). Ayton and Fischer had participants indicate whether they believed the next spin of a simulated roulette wheel would match the previous spin's color (red or blue), and the extent to which they felt confident in their predicted outcome's occurrence (form 0-100 in 5-unit increments). Ayton and Fischer found the clearest evidence for the gambler's fallacy when a run of 5, rather than 1, 2, 3, or 4, similar outcomes occurred. Dillen and M. R. Dixon used the most recent outcome for analysis (a win, loss, or near-miss), and so any effect might have been lost due to the short run length considered.

Ayton and Fischer (2004) also found that the hot hand fallacy accounted for participant confidence in predictions. Specifically, as runs of failed predictions increased from 1 to 5, participant confidence waned, while equal-length runs of successful predictions produced opposite trends in confidence. As Dillen and M. R. Dixon (2008) used a Likert-type scale to assess likelihood of a win on the next spin, one would suspect degree-of-endorsement effects might have been moderated by subsequent spins confirming or disconfirming participant endorsement. Thus, confirmation feedback was a likely confound that might have masked or altered any effect; though without single-subject analyses of within-session changes given feedback, such statements are speculative.

The current study extends Dillen and M. R. Dixon's (2008) investigation into particular outcomes' influence over the predictability of upcoming outcomes. However, our approach departs in four major ways. First, based on Ayton and Fischer's (2004) results, we restricted the reel outcome sample to runs of five spins. We based our decision to include multiple outcomes on a logical conclusion that the gambler's and hot hand fallacies could only be produced when considering a series of outcomes. Second, we expanded the range of trials for predictability analyses to gather preliminary data on any potential discriminative effects. Specifically, if different outcomes are not perceived as discriminatory stimuli, then predictability endorsements should remain consistent across machines and trials. Third, we removed prediction feedback by refraining from confirming participant predictions. Finally, we subjected our data to overall-averaged, group, and individual analyses to better understand the degree of agreement between group and single-subject data in gambling research. While our study lacks some of the external validity aspects from Dillen and M. R. Dixon's study, the emphasis on internal validity helps to shed light on variables of interest in future replications of Dillen and M. R. Dixon's procedures.

METHOD

Participants and Setting

Twenty-two undergraduate students at a mid-sized Midwest university participated. We removed 7 participants' data for failure to meet a priori data sequence requirements (see below). The remaining participants included 12 females and 3 males with a mean age of 22.93 years (*SD* = 3.49, range 19-31). One participant identified as African-American, 1 as Hispanic or Latino, 1 as Asian, 1 preferred not to say, and the remaining 11 as Caucasian (non-Latino). Seven participants reported personal annual incomes of less than $10,000, 3 between $10,001 and $15,000, 2 between $15,001 and $20,000, 1 between $25,001 and $30,000, and 1 between $30,001 and $50,000. An additional participant opted not to report annual income. Seven participants reported never playing a casino slot machine, 7 about once each year, and 1 reported playing casino slot machines about once each month. All participants verified volunteer status through signing an Institutional Review Board-approved consent form.

The study was conducted in an approximately 6.5 m by 2.6 m divided research room. An approximately 1.5 m by 2.6 m space in the back of the room was partitioned off and dedicated to storage. The participant space consisted of two long tables (1.21 m and 1.05 m) each with a computer monitor and chair. Only one monitor was operational during this study.

Materials

Videos. Eight videos of five consecutive reel spins were recorded and made into playable mp4 video files (see Figure 1 for presentation example, Table 1 for video contents and backgrounds, Table 2 for reel outcome parameters, and Table 3 for counterbalancing). Videos were made by screen-recording pre-determined 5-reel spin sequences, later edited for uniform duration. Each 5-reel sequence was correlated with a particular background color (see Table 2 for sequences and colors). Reel sequences were programmed into AlljSlots (v. 2.2) and screen recorded with Open Broadcaster v.0.637b.

Predictability Records. Participants indicated the likelihood of winning, recorded as percentage of chance, in the next 1, 2, 3, 4, or 5 spins (see Figure 2) on the predictability record, an 8.5 in by 1.5 in strip of paper. Additional space in the upper right-hand corner was left blank to house participant and video codes. Given that participants might not understand the cumulative nature of the spin prediction we asked for (i.e., a single spin, a group of two spins, a group of three spins, etc.), the a priori decision was made to remove participant data that showed any decreasing trend in percentage change to win data within any 5-spin prediction sequence. As spins are grouped in these predictions, their likelihood of producing a win with each additional spin should either improve or remain constant.

Figure 1. Screenshot of reel spin outcome for Video C, Spin 1.

Table 1. Video codes, spin outcomes, and background colors.

Video	Spin 1	Spin 2	Spin 3	Spin 4	Spin 5
G	L1	L2	L3	L4	L5
R	W	L1	L2	L3	L4
B	L1	L2	L3	L4	W
Y	L1	L2	W	L3	L4
O	L1	L2	L3	L4	NM1
GR	NM1	L1	L2	L3	L4
W	NM1	W	L1	L2	NM2
BL	NM1	L1	L2	W	NM1

Table 2. Reel outcomes and reel symbol positions. While some outcomes are redundant (e.g., L1 & L3), the reel-stop positions on the virtual reels were different (reel stop positions not presented here).

Spin Code	Reel 1	Reel 2	Reel 3
L1	Bell	Bar	Seven
L2	Seven	Bar	Bell
L3	Bell	Bar	Seven
L4	Seven	Bar	Bell
L5	Bell	Seven	Bar
W	Bell	Bell	Bell
NM1	Bell	Bell	Bar
NM2	Bell	Bell	Seven

Table 3. Video code counterbalancing by participant (see Table 1 for video codes).

	Sequential Video Ordering							
Participants	1	2	3	4	5	6	7	8
P1, P4, P8, P9, P10	G	B	O	W	R	Y	GR	BL
P2, P11, P12, P13, P14	BL	GR	Y	R	W	O	B	G
P3, P5, P6, P7, P15	BL	Y	G	O	GR	R	B	W

Figure 2. Predictability records given to each participant after each 5-spin video.

What is the likelihood of winning <u>at least once</u> in the next:

1 Spin	2 Spins	3 Spins	4 Spins	5 Spins
%	%	%	%	%

Procedure

Participants were brought into the lab and were seated next to the experimenter and in front of a computer monitor. After consent was provided, demographics were completed and the following instructions regarding the study were read:

> During this study you will watch a short video for each of 8 different slot machines. Each video will consist of 5 complete spins on that slot machine.
>
> After watching each video, you will be asked to complete a short task. In this task, you are to guess how likely it is that the slot machine you just watched will produce a winning spin in the next 1, 2, 3, 4, or 5 spins.
>
> In other words, you will be asked the following 5 questions:
>
> Given 1 more spin on the slot machine you just watched, what is the chance that a win will be produced?
>
> Given 2 more spins on the slot machine you just watched, what is the chance that <u>at least</u> 1 of those 2 additional spins will produce a win?
>
> Given 3 more spins on the slow machine you just watched, what is the chance that <u>at least</u> 1 of those 3 additional spins will produce a win?
>
> And so on for 4 and 5 spins.
>
> Do you have any questions at this point?
>
> (if they have questions, re-read the section of the script that pertains to the question)

Once all questions were answered, the first video was played (see Table 3 for sequence of videos). After watching the first video, the participant completed one predictability record. The video and predictability recording process continued until all eight videos and records were completed. Once completed, the participant was thanked and dismissed, and extra course credit was provided by the participant's instructor for their respective course.

Data Analysis

Hot hand and gambler's fallacies. The Green (G) video (5 losses) served as the test for hot hand and gambler's fallacy, and as such was the base from which all videos are compared. We decided a priori that at least 80% of subsequent spins (i.e., 4 or 5 spins) rated as winning (i.e., ≥ 50% chance of winning) were required to label the sequence as evidence of gambler's fallacy. Requiring 80% wins we consider conservative, and would indicate a meaningful change from G (5 losses), which typifies the gambler's fallacy. Any other pattern was relegated as hot hand (i.e., 2, 3, 4, or 5 spins as losses).

Changes in endorsement patterns relative to G suggested how the addition and arrangement of near-miss and non-losing symbols influenced responding. For the purposes of this initial investigation, stimulus arrangements were deemed influential when the endorsed percentage chance of winning deviated positively or negatively by 25% of the average endorsement on G. For example, P4 indicated the probability of winning after G as 50%, 55%, 70%, 80%, and 85% (M = 68%). Thus, to consider any other endorsement pattern as influential, the pattern would need be 17 points[4] from P4's average, totaling either 51% or less or 85% or more. Changes in endorsement influenced responding toward hot hand or gambler's fallacy patterns depending on the video observed. For example, the Red (R) video ends with 4 losses, and thus an increase in chance of winning endorsement favors a gambler's fallacy pattern. The Blue (B) video, however, ends on a win, and thus a similar increase in endorsement would instead favor a hot hand endorsement pattern. Decreases in win endorsement for R and B would indicate hot hand and gambler's fallacy endorsement patterns, respectively. Failure to meet the 25% threshold resulted in no influence toward either a hot hand or gambler's fallacy pattern. Each pattern of responding is documented in Table 4.

Two videos, White (W) and Black (BL), were subjected to additional comparisons. The W video was used to investigate how an early near-miss outcome preceding a win alters the early winning spin's influence over endorsement patterns, and this is compared to the similarly arranged R. Likewise, BL's early near-miss preceding a loss and late win/near-miss combination is compared to the similarly arranged B (see Table 4). Thus, the 25% threshold is also anchored on R and B for W and BL, respectively.

Player profiles. Player profiles were created based on visual inspection of individual response patterns across the five subsequent spins in relation to all videos. From this visual analysis, five player profiles emerged; Low Riser, Medium Riser, Variable, Pessimist, and Optimist. Low Risers were participants who initially endorsed a low percentage chance of winning, and over subsequent

[4] "Point" is used here in place of "percentage" as to not confuse a percentage change versus a change in the participant reported percentage he or she endorsed. That is, a change from 50% to 55% is a 5 point change, and not a 10% change.

spins, raised their endorsements (increasing trend). Medium Risers were similar to Low Risers with the exception that initial endorsements were higher overall than the Low Riser profile endorsements. Variables had no obvious or consistent trend between the different reel sequences. Pessimists were participants who initially endorsed low percentage chances of winning which remained low with only small increases across spins. Optimists were participants who initially endorsed high percentage chances of winning, which remained high[5]. Six participants were determined to be Low Risers, 3 were Medium Risers, 2 were Variables, 2 were Pessimists, and 2 were optimists. Graphs from which these profiles were generated are seen in the left pair in Figure 3. While data from player profiles might be limited in direct utility, they might be of use in describing individual player data in subsequent research. For example, particular patterns of responding (e.g., Optimist) might relate to gambling patterns or beliefs, which in turn could be of use in designing individualized treatment plans.

RESULTS

Overall-Average Results

Figure 4 displays averaged percentage chance of winning within 1, 2, 3, 4, or 5 spins by video condition, and Table 4 contains a detailed account of overall-averaged, profile, and individual data changes. Overall-averaged data show that G produced a hot hand effect. No other video produced a bias more toward hot hand or gambler's fallacy that met the minimum threshold criteria when compared to G. W produced a -0.63 point change in chance-of-winning endorsement compared to R, while BL produced a 6.36 point increase compared to B. Neither of W nor BL altered gambler's fallacy of hot hand endorsements in relation to R and B compared to G, respectively, and thus from this point forward we will only report those times where W or BL exceeded the threshold criteria for G.

Player Profile Results

Low Riser. Figure 3 shows the average Low Riser response pattern for endorsed percentage chance at winning on five subsequent spins. Low Risers met criteria for a hot hand endorsement pattern. When compared to G, videos R, Yellow (Y), Gray (GR), and W resulted in participant endorsements that were biased more toward gambler's fallacy, suggesting that early or middle wins or near-misses led to higher percentage chance of winning endorsements. Bias toward hot hand endorsement patterns was achieved in BL when compared to G. There was no participant endorsement difference between G and B or Orange (O). These latter analyses suggest that late wins either increase or have no effect on percentage chance of winning endorsements.

Medium Riser. Figure 3 shows the average Medium Riser response pattern for endorsed percentage chance at winning on five subsequent spins. Medium Risers produced hot hand endorsement patterns. When compared to G, R, B, and W resulted in a participant endorsement pattern biased toward the gambler's fallacy. Bias toward hot hand was not achieved in any spin sequence. There was no difference in participant endorsement between G and Y, O, GR, or BL.

[5] The endorsements had to remain high due to the a priori decision to remove participants that showed a decreasing trend.

The BL video resulted in an increase of participant endorsement from B, biasing responding more toward hot hand play from gambler's fallacy when compared to G. These data suggest no discernable patterns on endorsement ratings in relation to early, middle, and late wins/losses/near-misses in this group.

Pessimist. Figure 3 shows the average Pessimist response pattern for endorsed percentage chance at winning on five subsequent spins. Pessimists produced hot hand patterns of endorsement. When compared to G, Y resulted in a pattern of endorsements biased toward the gambler's fallacy. When compared to G, bias toward hot hand endorsements was achieved in BL. There was no difference in participant endorsement between G and R, B, O, GR, or W. Both the W and BL video endorsements were above the threshold change relative to R and B, respectively. The W video resulted in a decrease in endorsement from R, whereas the BL video resulted in an increase of endorsement from B. While most videos resulted in no discernable patterns, the inclusion of near-misses in W and BL lead to a more hot hand pattern of endorsement over R and B.

Optimist. Figure 3 shows the average Optimist response pattern for endorsed percentage chance at winning on five subsequent spins. Optimists produced a gambler's fallacy pattern of endorsement. Bias toward gambler's fallacy or hot hand patterns of endorsement was not achieved from any video compared to G.

Variable. Figure 3 shows the average Variable response pattern for endorsed percentage chance at winning on five subsequent spins. Variables produced a gambler's fallacy pattern of endorsement. When compared to G, B, GR, and BL resulted in participant endorsement patterns biased toward the gambler's fallacy. Bias toward hot hand was achieved in R, Y, and W when compared to G. There was no endorsement difference between G and O. B, GR, and BL resulted in conflicting trends in relation to early and late wins/near-misses, while a bias toward hot hand endorsement patterns in R, Y, and W suggests losses might produce lower endorsements (though not under GR).

Single Subject Results

Figure 5 shows the individual endorsements and changes in endorsements between G and the other spin sequences for P2 (individual graphs for the other participants are available in the supplemental materials). As G is the baseline comparison video, all other videos show how changes to environmental arrangements (i.e., spin type and sequence) might produce discriminative effects.

P1's endorsements for G were biased toward a hot hand pattern. Early wins and near-misses and late wins produced endorsements biased toward a gambler's fallacy pattern (refer to Table 4 or supplemental figures for all participant outcomes). Middle wins produced endorsements biased toward a hot hand pattern. When a late near-miss was presented without an accompanying win, it produced a biased endorsement toward a hot hand pattern. W and BL both produced endorsement biases toward hot hand patterns away from R's and B's gambler's fallacy endorsement patterns, respectively.

Table 4. All outcomes and comparisons between videos as well as their respective hot hand and gambler's fallacy relations. A 25% change in endorsement was required to cross a threshold, and that change must be in one direction with respect to the current comparison.

Participant	Fallacy	Green	Threshold	**GF + HH -** G vs R	**GF- HH+** G vs B	**GF + HH -** G vs Y	**GF- HH+** G vs O	**GF + HH -** G vs GR	**GF + HH -** G vs W	**GF- HH+** G vs BL	NM sequences v. no NM sequences* R vs W	B vs BL
Player Profiles and Aggregate												
Low Riser	HH	19.35%	±4.84	GF (+9.78)	INS (+3.05)	GF (+10.80)	INS (-2.08)	GF (+6.53)	GF (+10.13)	HH (+7.13)	+0.35	+4.08
Med Riser	HH	43.53%	±10.88	GF (+15.53)	GF (-12.13)	INS (+3.13)	INS (+3.00)	INS (+6.53)	GF (+12.27)	INS (-0.20)	-3.27	+11.93
Pessimist	HH	16.10%	±4.03	INS (+0.30)	INS (+2.00)	GF (+4.10)	INS (-0.70)	INS (+3.80)	INS (-4.00)	HH (+10.20)	-4.30	+8.20
Optimist	GF	78.50%	±19.63	INS (+0.90)	INS (-12.40)	INS (-10.60)	INS (-3.00)	INS (-0.30)	INS (+3.30)	INS (-14.50)	+2.40	-2.10
Variable	GF	53.00%	±13.25	HH (-27.00)	GF (-28.50)	HH (-15.00)	INS (-10.50)	GF (+17.00)	HH (-26.00)	GF (-17.00)	+1.00	+11.50
Overall	HH	36.13%	±9.03	INS (+3.58)	INS (-6.39)	INS (+2.08)	INS (-2.13)	INS (+6.65)	INS (+2.95)	INS (-0.03)	-0.63	+6.37
Low Riser												
P2	HH	12.60%	±3.15	GF (+10.20)	HH (+22.40)	GF (+31.40)	INS (+3.00)	GF (+14.20)	GF (+14.80)	HH (+13.80)	+4.60	-8.60
P5	HH	27.00%	±6.75	INS (-6.00)	GF (-8.60)	INS (-2.50)	GF (-7.00)	HH (-7.50)	HH (-10.50)	INS (-3.50)	-4.50	+5.10
P8	HH	5.00%	±1.25	GF (+10.00)	HH (+10.00)	GF (+10.00)	INS (0.00)	INS (0.00)	GF (+20.00)	HH (+10.00)	+10.00	0.00
P9	HH	12.50%	±3.13	GF (+20.50)	GF (-12.50)	GF (+5.90)	INS (+2.50)	GF (+16.50)	GF (+22.50)	INS (+1.50)	+2.00	+14.00
P12	HH	30.00%	±7.50	GF (+17.00)	INS (0.00)	GF (+17.00)	INS (+2.00)	GF (+17.00)	GF (+13.00)	HH (+12.00)	-4.00	+12.00
P14	HH	29.00%	±7.25	INS (+7.00)	INS (+7.00)	INS (+3.00)	GF (-13.00)	INS (-1.00)	INS (+1.00)	HH (+9.00)	-6.00	+2.00
Medium Riser												
P1	HH	40.00%	±10.00	GF (+20.00)	GF (-30.00)	HH (-10.00)	HH (+10.00)	GF (+15.00)	GF (+10.00)	GF (-19.00)	-10.00	+11.00
P3	HH	20.60%	±5.15	GF (+38.60)	HH (+27.60)	GF (+19.40)	INS (-1.00)	INS (+4.60)	GF (+28.80)	HH (+24.40)	-9.80	-3.20
P15	GF	70.00%	±17.50	INS (-12.00)	GF (-34.00)	INS (0.00)	INS (0.00)	INS (0.00)	INS (-2.00)	INS (-6.00)	+10.00	+28.00
Pessimist												
P11	HH	18.80%	±4.70	INS (+4.20)	HH (+6.00)	GF (+5.20)	INS (+2.60)	GF (+5.00)	HH (-9.00)	HH (+6.00)	-13.20	0.00
P13	HH	13.40%	±3.35	HH (-3.60)	INS (-2.00)	INS (+3.00)	GF (-4.00)	INS (+2.60)	INS (+1.00)	HH (+14.40)	+4.60	+16.40
Optimist												
P4	GF	68.00%	±17.00	INS (+2.00)	GF (-17.00)	INS (-13.00)	INS (-6.80)	INS (+6.80)	INS (+10.4)	INS (-14.00)	+8.40	+3.00
P7	GF	89.00%	±22.25	INS (-0.20)	INS (-7.80)	INS (-8.20)	INS (+0.80)	INS (-7.40)	INS (-3.80)	INS (-15.00)	-3.60	-7.20
Variable												
P6	GF	70.00%	±17.50	HH (-68.00)	GF (-70.00)	HH (-44.00)	INS (-2.00)	INS(0.00)	HH (-56.00)	GF (-30.00)	+12.00	+40.00
P10	HH	36.00%	±9.00	GF (+14.00)	HH (+13.00)	GF (+14.00)	GF (-19.00)	GF (+34.00)	INS (+4.00)	INS (-4.00)	-10.00	-17.00

G = Green; R = Red; B = Blue, Y = Yellow, O = Orange, GR = Gray, W = White, BL = Black, HH = Hot Hand Fallacy, GF = Gambler's Fallacy, INS = Insensitive
Green = Average endorsement of green video, G vs ... = Green total relative difference to that color machine
R vs W = Relative difference between Red and White of change in endorsement to Green, B vs BL = Relative difference between Blue and Black of change in endorsement to Green
Bold = Increase (+) or decrease (-) required above threshold for bias
* The differences of endorsement between the videos which have the same win sequences with the addition of near misses

Figure 3. Visual analyses used to derive Low Riser, Medium Riser, Pessimist, and Optimist player profiles.

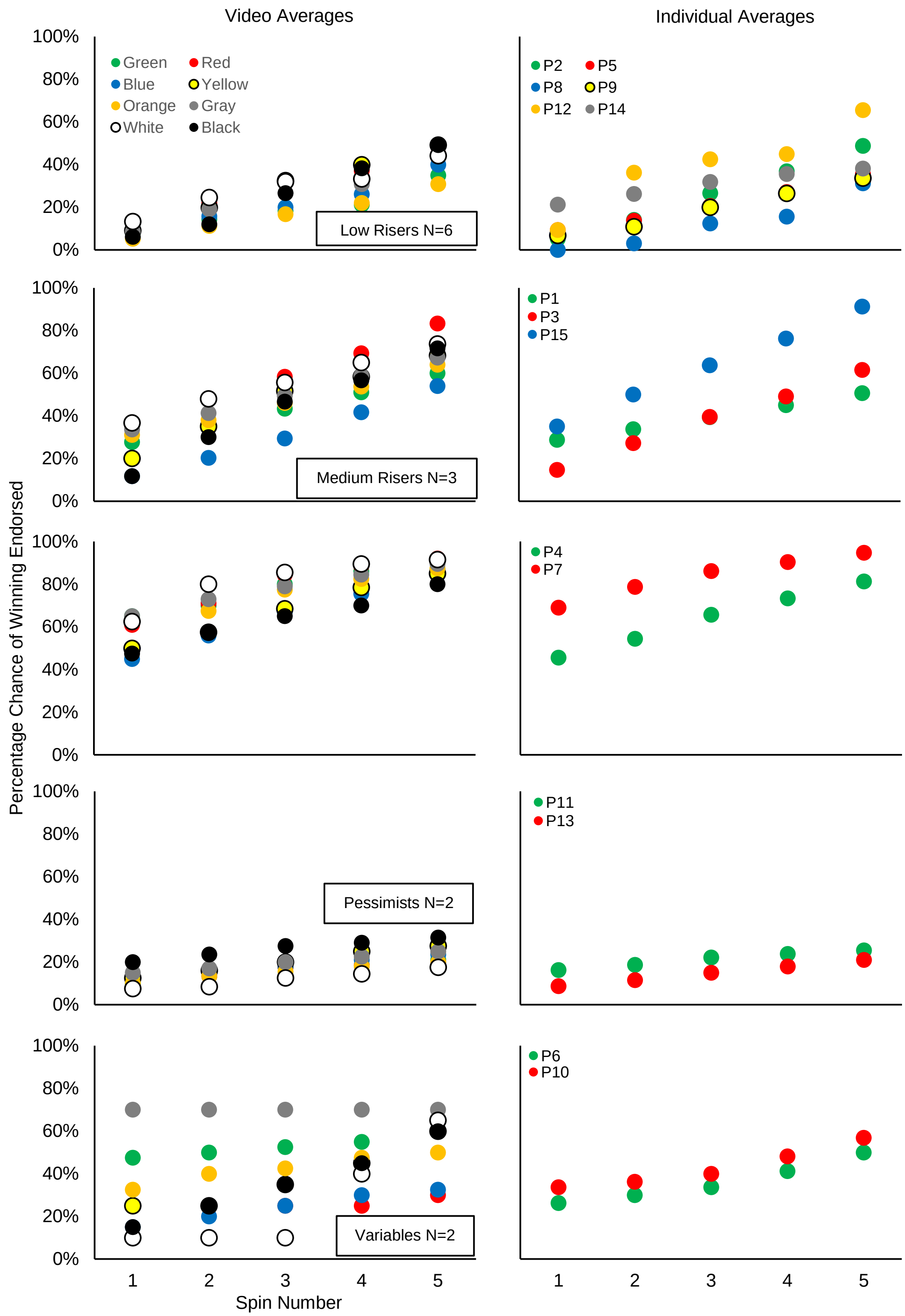
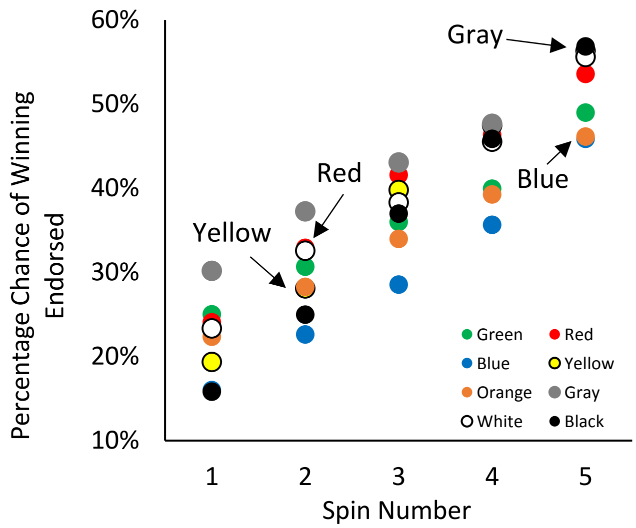


Figure 4. Average percentage chance of winning within 1, 2, 3, 4, or 5 spins by video condition. Each video is represented by its respective color. Arrows indicate overlapping data points with the hidden video data point indicated in text.



P2's endorsements for G were biased toward a hot hand pattern. Early and middle wins/near-misses produced endorsements biased toward a gambler's fallacy pattern. Late wins/near-misses produced either endorsements biased toward a hot hand pattern (B, BL) or no bias (O). Compared to R, W produced more of an endorsement bias toward a gambler's fallacy pattern. Compared to B, BL produced endorsements that shifted away from a hot hand pattern toward a gambler's fallacy pattern. Thus, near-misses enhanced the effects of an early win while they altered the effects of a late win.

P3's endorsements for G were biased toward a hot hand pattern. Middle and early wins, but not when near-misses were present, producing endorsements biased toward a gambler's fallacy pattern. Late wins, but not when near-misses were present, produced an endorsement pattern biased toward hot hand. Both near-miss videos (O and GR) resulted in an insufficient change in endorsements. W altered endorsement patterns away from gambler's fallacy toward hot hand when compared to R.

P4's endorsements for G were biased toward a gambler's fallacy pattern. Only R produced a change in endorsement, which was biased toward gambler's fallacy.

P5's endorsements for G were biased toward a hot hand pattern. Early near-miss and near-miss-win combinations (i.e., W) produced endorsements biased toward hot hand. However, an early win without accompanying near-misses produced no change in endorsement. A late win and late near-miss produced an endorsement bias toward gambler's fallacy, but not a late near-miss-win combination (i.e., BL), which produced no change in endorsement. W enhanced R's endorsement bias toward hot hand. BL produced more of an endorsement bias toward hot hand when compared to B. Generally, near-misses produced endorsement biases more toward hot hand, except for O.

P6's endorsements for G were biased toward a gambler's fallacy pattern. Middle win and early win and win-near-miss combinations produced endorsements biased toward a hot hand pattern. Late win and win-near-miss combinations produced a gambler's fallacy bias. No independent near-miss events (i.e., GR and O) produced a change in endorsement. BL produced more of a hot hand bias in comparison to B, which was gambler's fallacy.

P7's endorsements for G were biased toward a gambler's fallacy pattern. No video produced a change in endorsement pattern.

P8's endorsements for G were biased toward a hot hand pattern. Middle win and early win and win-near-miss combinations produced endorsements biased toward a gambler's fallacy pattern. Late win and win-near-miss combinations produced endorsements biased toward a hot hand pattern. No independent near-miss events produced a change in endorsement. W produced more of an endorsement bias toward gambler's fallacy patterns compared to R, which also produced endorsements biased toward a gambler's fallacy pattern.

P9's endorsements for G were biased toward a hot hand pattern. All independent wins and early win-near-miss combinations produced endorsements biased toward a gambler's fallacy pattern. Late near-misses with (BL) and without (O) wins produced no changes in endorsement. Compared to B, BL produced endorsement more biased toward a hot hand pattern, away from B's endorsements toward a gambler's fallacy pattern.

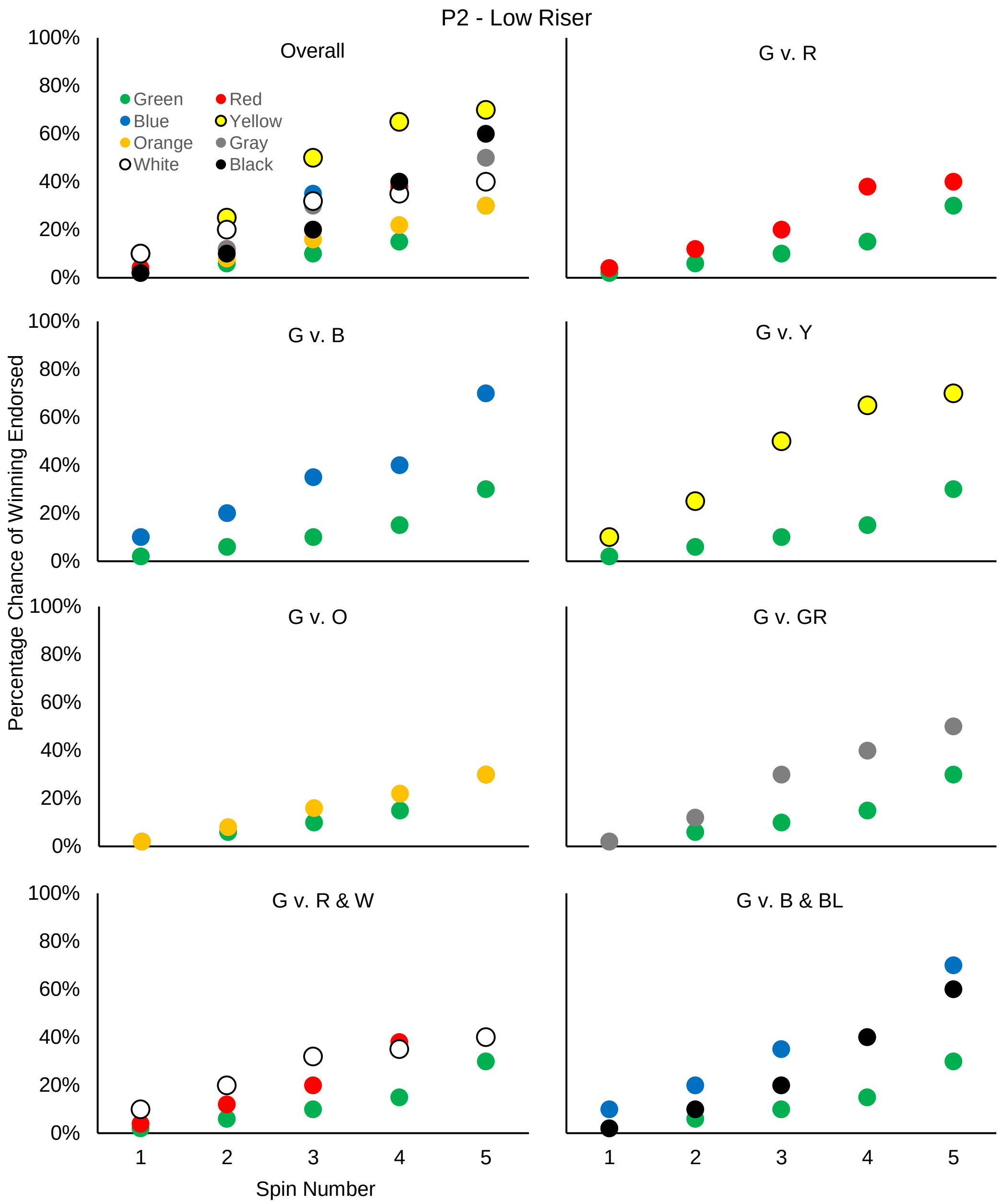
P10's endorsements for G were biased toward a hot hand pattern. Early wins and near-misses and middle wins produced endorsements biased toward a gambler's fallacy pattern. Late wins produced endorsements biased toward a hot hand pattern. When early and late wins were combined with near-miss outcomes (i.e., W and BL), no change in endorsement from G was observed.

P11's endorsements for G were biased toward a hot hand pattern. Undiscernible patterns of endorsement were produced given the various early, middle, and late positions of wins and near-misses.

P12's endorsements for G were biased toward a hot hand pattern. Middle wins and early wins, near-misses, and win-near-miss combinations produced endorsements more biased toward gambler's fallacy patterns. Late wins and late near-misses failed to produce a change in endorsement. Late win-near-miss combinations produced endorsements biased toward a hot hand pattern. BL produced a shift in endorsement toward a hot hand pattern from B, which did not produce a change in endorsement.

P13's endorsements for G were biased toward a hot hand pattern. Early wins produced endorsements biased toward a hot hand pattern. Middle wins, early near-misses, and early win-near-miss combinations failed to produce a change in endorsement. Late near-misses produced endorsements biased toward a gambler's fallacy pattern, while late win-near-miss combinations produced endorsements biased toward a hot hand pattern. BL produced endorsements biased toward a hot hand pattern when compared to B, which did not produce a change in endorsement.

Figure 5. Comparisons of video sequences for P2.



P14's endorsements for G were biased toward a hot hand pattern. A late near-miss produced endorsements biased toward a gambler's fallacy pattern, while late win-near-miss combination produced endorsements biased toward a hot hand pattern.

P15's endorsements for G were biased toward a gambler's fallacy pattern. Only B produced a change endorsement, which biased endorsement toward a gambler's fallacy pattern. This endorsement was mitigated when near-miss events were added in BL, biasing endorsement more toward a hot hand pattern.

P7 was the only participant whose endorsement patterns agreed fully with their profile's endorsements pattern (e.g., toward hot hand, gambler's fallacy, or neither, relative to G) —in this case, Optimist. No other participants had 10 of 10 agreements in endorsement patterns with either their designated profile, the overall-averaged, or other participants. The range of agreements for endorsement patterns between participants was 0 to 9. P4 (Optimist), was the only participant who had 9 of 10 endorsement patterns agree with two other participants; P7 (Optimist) and P15 (Medium Riser). P3 (Medium Riser) and P8 (Low Riser) had 9 of 10 endorsement patterns agree with each other. There were 3 pairs of participants that had 8 of 10 endorsement patterns agree with each other; P2 and P8 (Low Risers), P7 (Optimist) and P15 (Medium Riser), and P9 and P12 (Low Risers). There were 5 instances of 7 of 10 endorsement pattern agreements; P2 (Low Riser) with P3 (Medium Riser) and P12 (Low Riser), P3 (Medium Riser) and P11 (Pessimist), and P14 (Low Riser) with P7 (Optimist) and P13 (Pessimist). All other combination of participants and their comparative endorsement agreements were 6 of 10 or fewer.

Comparisons between Overall-Averaged, Profiles, and Individual Data

In sum, no grouped and averagedf profile category matched with the overall-averaged data. In individual data, while the degree of overlap in gambler's fallacy and hot hand endorsement pattern directions differed, absolute endorsement was never identical (i.e., percentages endorsed). For example, P2 moved from endorsements biased toward a hot hand pattern in G to a gambler's fallacy pattern in R, as did P9. However, the actual percentages endorsed are not equivalent between the two. Analyzing trends as opposed to raw data or averages permits greater overlap in data, and thus we have inflated the degree of overlap.

We note here that a ceiling effect might have resulted in no changes above G's gambler's fallacy endorsement pattern trend. Specifically, with a 25% change threshold criteria, the Optimist gambler had no room with which to alter responding as cumulative spins could only produce positive or no change in endorsement. Alternatively, the Pessimist and Low Riser's initial endorsements were so low that a 25% point change in endorsement is easily achievable and might overestimate any effect.

Statistical Analyses

We ran dozens of statistical analyses (several post-hoc) within- and between-subjects and within and across videos[6]. Many analyses proved significant, such as with ANOVAs conducted on percentage chance of winning across five subsequent spins for each video (e.g., R, B, Y, and BLK, $ps < .05$). Exploratory t-tests found that the most significant results emerged after the fourth spin endorsements, consistent with Ayton and Fischer (2004). However, we find these statistically significant findings uninformative in the current investigation for two reasons. First, overall averaged, profile, and individual subject data were disparate. Recall that our trend-based analyses inflated agreement, and that even under these circumstances we did not achieve agreement between profiles and individuals with the overall average. Indeed, if we find that gambler's fallacy and hot hand responding to reel-spins-as-discriminative-stimuli differentiate problem and non-

[6] In an effort to maximize identifiability of potential significant results, no statistical corrections were applied (e.g., Bonferroni correction) despite the multiple analyses—truth inflation is likely present in our statistical findings.

problem gamblers[7], use of averaged data would be of little help in identification and intervention. Because of these reasons, we opted to omit further details of the statistical analyses in favor of a more individualized approach to player profile and individual data[8]. Second, and perhaps more important in analyzing statistical results, we had a relatively small sample size. However, given the differences between individuals, the argument for idiographic, rather than nomothetic measurements is self-evident.

DISCUSSION

Analyzing cumulative probabilities over several upcoming spins provides a means by which we can begin exploring discriminatory effects reel outcomes have on future slot machine play. This approach is distinct from Dillen and M. R. Dixon (2008) which assessed each spin's influence on predicting a win in the next spin, irrespective of recent outcome history. Logically, to study the gambler's fallacy and the hot hand fallacy in terms of behavioral principles, one must consider a series of prior outcomes. What is still to be determined, though, is how many prior outcomes are necessary to see any effect, how long that effect lasts, how the number and positioning of outcomes influences the effect, and how automatic feedback in the form of prediction confirmation alters future predictions. Furthermore, how these elements just described influence other aspects of gambling, such as risk, will need attention.

We argue that these data are best analyzed in terms of within-subject variation rather than group aggregation and variation. The latter analysis investigates variability from averaged responding either within the group as a whole or between particular groups separated by some conditional element(s). This is not to say that aggregated data are not without their use, but that the behavior analyst is more concerned with the prediction and control of the individual (see Skinner, 1953/1965, p. 19). Given the relative rarity of the problem gambler, who is arguably of great importance in understanding gambling behavior, a within-subject analysis of behavior holds the best chance of achieving prediction and control over his or her behavior. Through systematic replication (see Sidman, 1960), the researcher and practitioner concerned with gambling will find him or herself in a position of influence over problematic gambling, perhaps even in a preventative manner.

In analyzing our within-subject data, we see two possible orientations to our independent variable (win arrangements in the videos). First, we can look at the entire sequence as a temporally bound stimulus. In this sense, the particular sequence is the stimulus in question. Placing near-misses or wins early in the sequence rather than later alters the stimulus and thus its function or effect. Consider, for example, that for most residents in the U.S. "blue, white, and red" does not control responding as does "red, white, and blue." The opposite would be true for many French citizens, where France's flag is blue, white, and red.

Second, we can treat the sequence as a contextual cue regarding the stimulus-in-question's function. This latter approach retains the uniqueness of the stimulus-in-question, but adds the additional difficulty in dismantling each stimulus-as-context and stimulus-as-stimulus. Some

[7] Goodie and Fortune (2013) found that gambler's fallacy was prominent in pathological gambling in general.
[8] SPSS outputs are, however, available by contacting the first author.

explanation is required. Consider the White video trial in which a near miss is followed by a win, two losses, and a second near miss. With which near miss are we concerned when asking about the function of a win with respect to near misses? Is it the losses in the latter half that influences the first near miss, the win, or the second near miss? Therefore, to consider the variable in isolation during a sequence, we must consider each variable as both context and stimulus simultaneously. In relation to the U.S. flag example above, we would ask, "What does 'blue' mean when it precedes white which precedes red?" While such an analysis is sophisticated, it is perhaps beyond necessary in our current analysis. We advocate for the 5-spin video sequence to be viewed as a temporally bound stimulus, though acknowledge that sequence-as-context might need further exploration in future work.

While this study extends Dillen and M. R. Dixon (2008), our data are not necessarily comparable to Dillen and M. R. Dixon's data. In their study, participants rated the likelihood of a win on a next trial with a scale from 1 (a losing spin) to 10 (guaranteed winning spin). Overall mean subjective probabilities following wins during AB components were approximately 3.25, while following losses they were approximately 3.60. In our study, we rarely saw endorsements above 30% until the third subsequent spin. We see two possible reasons for this difference. First, the scales, while seemingly equivalent, were not. Dillen and M. R. Dixon used whole-number increments in a scale of 1-10, while we used percentages from 0%-100%. Second, our procedures differed enough that had we used Dillen and M. R. Dixon's measurement procedure, we might have achieved similar results. Regardless, both studies come to a similar conclusion: typically, participants perceived that the chances of winning were not in their favor, and previous outcomes influenced perceptions of the degree to which subsequent spins might produce a win.

One potential limitation in our study might shed light on why the Green video (i.e., five losses) produced less of a gambler's fallacy effect than one with an early win. As Gilovich (1991) summarized, small runs of outcomes that do not appear to reflect overall probabilities are viewed with suspicion. Here the participant might believe that in any five-spin sequence, something other than a loss *should* appear. The random number generator on a slot machine, and thus the random ratio schedule of reinforcement, does not guarantee any particular outcome. However, procedure and perception are, again, two different things. As such, assessing how well each run represents a run that might be experienced in an actual casino slot machine would have enhanced these results.

Three additional limitations need mentioning. First, we failed to include a five-win sequence video to counterbalance the Green video's five-loss sequence. Second, player profiles were not determined a priori. Future research should balance our post-hoc profile creation with reasoned profiles that might be anticipated given particular arrangements. Third, our sample size was not justified with an a-priori power analysis, which restricts bolder claims of our data. The small sample size further limits any generalization made of the profiles, as larger sample might see some profiles eliminated or the creation of other profiles not represented in our sample. However, we believe our findings provide sufficient evidence to justify dedicating further resources to analyzing differences in idiographic and nomothetic assessments of slot machine play.

CONCLUSION

This is the second study to find evidence suggesting prior outcomes in simulated slot machine gambling correlate with differential endorsements of winning on subsequent spins. The current study found mixed results between overall-averaged, profile, and individual player data, with some data supporting the gambler's fallacy and other the hot hand fallacy. The inconsistent nature of endorsement patterns suggests an idiosyncratic influence from the different videos. However, what is clear from these data is that particular arrangements, when viewed as a temporally bound stimulus, can produce discriminative effects on responding, here defined as an endorsed chance of winning on subsequent spins.

Particularly important in this analysis are the many new questions about conceptualizing our independent variables as units rather than discrete elements. Viewing these elements as members of a larger stimulus that works as an ever-evolving functional unit might be the most pragmatic approach when analyzing these and similar data. We must also consider our conceptions of what an effect is, how long we should expect it to last, and how this effect changes with subsequent outcomes. For example, some research examines pausing between spins as an indication of a potential reinforcement effect (e.g., M. J. Dixon, MacLaren, Jarick, Fugelsang, & Harrigan, 2013; M. R. Dixon & Schreiber, 2004). But we must ask if pausing between spins reflects an influence from proximal, distal, or perhaps aggregated outcomes. Is the pause between spins the effect of interest, or is it a patterning of pauses and their different topographies as they change over time in relation to changing outcomes that is more interesting? Future research that addresses actual gambling in single-subject analyses will help to uncover the particular relations that are most valuable in identifying and treating problematic gambling.

Perhaps most revealing in these data is the idiosyncratic nature of responding. The differences in patterning suggests an emphasis on studying the individual, rather than the group. Behavior analysts have tended to rely on averaged data to support their findings in gambling research. For example, when reviewing articles in volumes 1-8 in *Analysis of Gambling Behavior*, the flagship gambling journal for behavior analysts, we find that reporting averaged data is common (see also Witts & Harri-Dennis, 2015). Specifically, in slot machine studies, 19 of 26 experiments report averaged data, and of these, 9 failed to report any individual data. The data presented here shed light on the importance of attending to individual, rather than group data. While we acknowledge that averaged data might be useful in orienting toward particular topics of interest, as they provide an overall effect, we have evidence here that the effect (if there is one) might be too misleading for any practical use.

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