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# Symbolic Generalization of the Near-Miss in Simulated Slot-Machine Gambling

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## Abstract

Symbolic generalization refers to the transfer of learning to symbolically related stimuli. In slot-machine gambling, near-misses describes instances where a losing stimulus display resembles an actual win display (e.g., two out of three matching stimuli on the payout line) and may promote excessive patterns of play. The present study sought to further examine the role of symbolic generalization in near-misses using a simulated slot-machine gambling task. A sample of 91 recreational gamblers first underwent relational training and testing involving gambling-specific stimuli (e.g., cherries and bells). Next, one stimulus (labelled, for the purposes of clarity, 'X') was presented as an image on slot-machine reels depicting win, near-miss and loss displays. Symbolic generalization was tested with presentations of stimuli indirectly related to X via same ('C') and opposite ('D') relations. We expected higher closeness to win ratings of displays consisting of C compared to D, with similar ratings given to near-miss outcomes involving these stimuli. Results supported these predictions and highlight ways in which symbolic generalization via same and opposite relations may influence player preference in three-reel simulated slot-machines.

*Keywords:* slot-machine gambling, near-miss, symbolic generalization, relational frame theory.

Symbolic Generalization of the Near-Miss in Simulated Slot-Machine Gambling

Gambling is an increasingly popular leisure activity, yet it is associated with a range of profound harms affecting individuals, their families, and society (Wardle, Reith, Langham & Rogers, 2019). It has long been acknowledged that forms of electronic gaming machines (EGMs), such as slot-machines, may promote excessive and harmful patterns of play (Binde, Romild, & Volberg, 2017; Griffiths, 2010; Markham, Young, & Doran, 2016; Schull, 2012). Indeed, modern multi-reel slot-machine games include numerous structural characteristics designed to promote continued play embedded within multiple reinforcement schedules (Griffiths, 1993). For instance, EGMs may induce a sense of "almost winning" through the presentation of lights, sounds and various outcome displays that usually accompany wins but where a player wins less money they actually bet (Barton et al., 2017; Dymond et al., 2014). Structural characteristics like this are designed to promote continued play. Indeed, as Skinner (1953) described, "almost hitting the jackpot increases the probability that the individual will play the machine, although this reinforcement costs the owner of the device nothing" (p. 397).

A well-studied structural characteristic in slot-machine gambling is the 'near-miss' (Pislak, Yong, & Spetch, 2019). Near-misses are generated when a losing display physically resembles an actual win display (i.e., the presentation of two out of three matching symbols on a payline, with the third appearing above or below the payline; Reid, 1986). A growing body of empirical literature shows that near-misses contribute to both gambling persistence (Parke & Griffiths, 2006) and game enjoyment (Sharman, Aitken, & Clark, 2015). It is also known that, in general, recreational gamblers initiate trials faster and rate their chances of winning as higher following near-misses relative to wins or (full) losses (Barton et al., 2017; Billieux et al., 2012; Dillen & M.R. Dixon, 2008; M.R. Dixon & Schreiber, 2004; M. Dixon et al., 2013; Kassinove & Schare, 2001; MacLin et al., 2007). Near-misses, then, may play a role in the acquisition and maintenance of excessive slot-machine gambling resulting in harm.

Traditional explanations for the effectiveness of near-misses have long emphasised a generalized reinforcement basis. According to this view, the near-miss display acquires some of the functions of win displays through discriminative stimulus generalization (Ghirlanda & Enquist, 2003; Skinner, 1953). That is, some of the conditioned reinforcing functions of the win displays transfer or spread to perceptually-similar loss displays. This form of generalization may then be considered perceptually based, with two out of three matching symbols on a three-reel slot-machine display the simplest illustration. In the behavioural laboratory, near-misses have been generated via generalization to total wins (Belisle & M. R. Dixon, 2015) and their neurobiological effects explained, at least in part, on conditioned reinforcement via generalized physical similarity with actual win displays (Clark et al., 2009; Dymond et al., 2014; Habib & M.R. Dixon, 2010). Belisle and M. R. Dixon (2015), for instance, found that post-reinforcement pauses on their simulated slot machine task were arranged along a generalization gradient with greater pauses following losing outcome displays, such as near-misses, that were formally similar to total wins, relative to losing outcomes that were formally dissimilar.

Near-misses are also susceptible to other, more symbolic forms of generalization (M. R. Dixon, Nastally, Jackson, & Habib, 2009; M. R. Dixon, Bihler, & Nastally, 2011; Dymond, McCann, Griffiths, Cox, & Crocker, 2012; Nastally, M. R. Dixon, & Jackson, 2010). Symbolic generalization research provides an empirical model of how non-perceptual similarities may interact with conditioned reinforcement to generate near-miss effects in slot machine gambling (Hoon, Bickford, Samuels, & Dymond, 2019). In this way, symbolic generalization seeks to explain how near-misses, while being “conceptually equivalent to total losses” (Belisle & M. R. Dixon, 2015, p. 2), may evoke paradoxical behaviour (e.g., ratings of closeness to wins, likelihood of winning on the next spin, and gambling persistence, etc.) as if they were directly experienced like total wins.

Symbolic generalization refers to the transfer or spread of directly trained responses to indirectly related stimuli sharing symbolic/relational properties in common. Several decades of research on derived relational responding have helped better understand the nature and extent of symbolic generalization effects, which were first described as the transfer or transformation of functions (Dymond & Rehfeldt, 2000; Dymond et al., 2018). The basic finding shows that when language-able humans are taught a series of interrelated conditional discriminations involving physically dissimilar stimuli, the stimuli involved often become related to each other in ways not explicitly trained (D. Barnes-Holmes, Finn, McEnteggart, & Y. Barnes-Holmes, 2018; Critchfield, D. Barnes-Holmes, & Dougher, 2018; Sidman, 1994, 2018). To illustrate, if choosing Stimulus X in the presence of Stimulus A is directly taught (i.e., A-X), and choosing Stimulus Y in the presence of Stimulus A (i.e., A-Y) is also taught, it is likely that untrained relations will emerge between X and A, Y and A, X and Y, and Y and X, all in the absence of any further feedback (Dymond & Roche, 2013; Hayes & Hayes, 1992).

The relevance of derived relational responding processes like symbolic generalization for gambling research stems from the observation that an outcome paired with one member of a stimulus relation readily emerges for other, indirectly related members, without further training (Wilson & Grant, 2014). That is, using the nomenclature described above, if X is paired with, or becomes discriminative for, a winning outcome on a slot-machine, then presentations of Y may also evoke respondent win-related behaviour and promote positive self-reports. Because the stimuli are physically dissimilar, symbolic generalization may aid our understanding of the near-miss effect. That is, symbolic generalization effects may be assumed to occur via the interplay between perceptually-based structural characteristics like the stimulus control exerted by the physical format of near-misses, the underlying schedule of reinforcement, and derived relational responding (Dymond & Whelan, 2007; Dymond et al., 2012; Hoon, Dymond, Jackson, & M. R. Dixon, 2008; Hoon et al., 2019). For instance, on a three-reel slot-machine, a near-miss display consisting of two images of cherries and one image of the number 7 may come to acquire some of the reinforcing properties of a win display consisting of either three images of cherries or three images of the number 7. The directly learned conditioned reinforcement functions of cherries and the number 7 likely interact with the relational histories attached to the other, non-matching stimulus in the near-miss display. That is, if the number 7 has never before appeared in a total win display, then its presence in near-miss displays may impact on continued gambling and thoughts about winning, etc. On the other hand, if the number 7 has appeared equally often as cherries in win displays, then its presence as the non-matching image in near-miss displays may have a negligible impact on gambling behaviour. In this way, the symbolic or relational basis of elements of the near-miss displays may interact to promote or reduce gambling-related preferences and behaviour.

M.R. Dixon et al. (2009) investigated the role of symbolic relations in altering the near-miss effect in recreational gamblers. In their study, M.R. Dixon et al. employed stimuli consisting of three abstract images, the written text “win”, “loss” and “almost”, and three images of slot-machine win, near-miss and loss outcome reel displays, respectively. Following a pre-test phase involving rating slot-machine outcomes on how close they were to a win, participants were taught to match one abstract image to “win” (A1-B1), another to “loss” (A2-B2) and another to “almost” (A3-B3) before being taught to match the images with win (A1-C1), near-miss (A2-C2) and loss (A3-C3) outcome displays, respectively. Verbal relations consisting of the untrained B-A, C-A, B-C and C-B relations were then tested in the absence of feedback. According to the training received, “win” was equivalent to a winning display, “loss” was equivalent to a near-miss display, and “almost” was equivalent to a loss display. Then, the critical post-test occurred in which the slot machine outcomes were rated on how close they were to a win. Dixon M.R., et al. found that 10/16 participants reversed their ratings from pre-test to post-test by rating loss stimuli as closer to a win than near-miss stimuli. These findings indicate that the near-miss effect, in which near-misses are rated as closer to a win than losses, may be altered through derived (symbolic) relations (Belisle, Paliliunas, M.R. Dixon, & Speelman, 2018; M. R. Dixon, et al., 2011; Dymond et al., 2012).

Other forms of symbolic relations, such as same and opposite relations, may also help explain the development and influence of near-misses on slot-machine gambling persistence and preference. They may also offer an opportunity to replicate and extend the existing research on altering the near-miss effect via symbolic relations and help delineate the interaction between verbal/symbolic processes and physical similarity. Symbolic generalization of the near-miss effect in accordance with relations of “sameness” (i.e., coordination or equivalence) and “opposition” entails the following multi-step procedure. First, training is needed to establish two abstract shapes as contextual cues for same and opposite, respectively. These cues may then be presented simultaneously with arbitrary stimuli, such as nonsense words, and the following relations trained: same cue-A1-B1, same cue-A1-C1, opposite cue-A1-B2, and opposite cue-A1-C2. These relations lead to the untrained relations, B1-C1 are same, B2-C2 are same, B1-C2 are opposite, and B1-C1 are opposite (Dymond & Roche, 2013). According to this approach, responses associated with slot-machine outcome displays, such as near-misses, should be altered or transformed in line with the untrained relations in terms of "same" and "opposite”.

Evidence from related domains (e.g., experimental psychopathology) indicates that emotional responses may readily generalize symbolically via same and opposite relations

(Dymond et al., 2018; Hayes & Hofmann, 2018). Previous laboratory-based gambling research has, however, also provided supportive empirical evidence for the role of symbolic generalization via sameness relations in slot machine preference (Dymond et al., 2012; Nastally et al., 2010) and roulette wagering (M. R. Dixon, Enoch, & Belisle, 2017). For example, Dymond et al. (2012) demonstrated that participants showed greater preference for, and gave higher ratings to, the slot machine related symbolically to a directly experienced high-payout probability machine than a slot-machine related symbolically to a low-payout probability machine. In this way, the high-payout gambling experience symbolically generalized via arbitrary sameness relations to an indirectly related (labelled) machine, despite never experiencing payouts (or even playing) the machine. Extending this effect to opposite relations allows for an investigation of relative increases and decreases in slot machine preference as a function of the relatedness of the stimuli involved. For instance, if A is the same as B, and B is paired with winning, A will also evoke some of these reward-related properties and lead to increased preference, but if C is the opposite of B, then it may be chosen less frequently and result in decreased preference. The impact of near-miss frequency on modulating this effect also remains to be seen.

The present study sought to further examine the role of symbolic generalization of near-misses via same and opposite relations in a simulated slot-machine gambling task. Our aim was to determine whether gambling-specific stimuli, such as cherries and bells, presented on the slot-machine reels in differing frequencies of wins, losses and near-misses would influence participants' choices and self-reported ratings of the likelihood of winning. This was achieved by training and testing same and opposite relations between the gambling-specific stimuli and then presenting the stimuli on reels in win, near-miss and loss display formats. Presenting the actual symbolic cues on the reels and testing symbolic generalization have not been investigated before. This is perhaps surprising given that the arrangement speaks to an obvious and natural extension of neurobehavioural findings on cue reactivity (Limbrick-Oldfield et al., 2017) and attentional biases (McGrath et al., 2018) in gambling.

Following relational training and testing to establish a network of same and opposite relations consisting of images from slot-machine reels, participants were given payout training involving one of these images (B1) presented in win (i.e., B1-B1-B1), near-miss (e.g., B1-B1-X1) and loss (e.g., X1-B1-X2) display formats. The number of wins, near-misses and losses were determined by the literature on the near-miss suggesting that the optimum number of near-misses for persistence in play is approximately one-third of all experienced outcomes (Kassinove & Schare, 2001). Thus, given the role of prior learning history in discriminating payback percentages and volatility (Coates & Blaszcynski, 2013), we sought to examine a further role for symbolic generalization in influencing player choice of three-reel simulated slot machine games differing in critical near-miss frequencies. Accordingly, groups were randomly assigned to either 33% or 50% near-miss frequencies during payout training. Then, during the slot-machine outcomes test phase, participants rated displays depicting wins, near-misses, and losses using combinations of stimuli from the relational test: C1 win (C1-C1-C1), C2 win (C2-C2-C2), C1 near-miss (C1-C1-X1 and X1-C1-C1), C2 near-miss (C2-C2-X1 and X1-C2-C2), C1 loss (X1-C1-X2), and C2 loss (X1-C2-X2).

It was predicted that outcomes containing C1 would be rated as closer to a win than outcomes containing C2 (as stimulus C2 participates in a derived opposite relation with B1). Similarly, we expected that near-miss outcome displays containing either C1 or C2 (e.g., C1-C1-X1, C2-C2-X1, X1-C1-C1 and X1-C2-C2) would be rated equally. We also predicted that that near-miss outcomes in which the matching symbols appeared on the left-hand side would be rated more highly than those in which the matching symbols were on the right-hand side.

# Method

## Participants

Ninety-one participants were recruited from Swansea University and randomly assigned to one of two groups: 33% and 50% near-miss trials, respectively. The 33% near-miss group consisted of 49 participants, 19 men, with a mean age of 22.6 ($SD$ = 6.1). The 50% near-miss group consisted of 42 participants, 15 men, with a mean age of 22.9 ($SD$ = 6.2).

Participants completed the *South Oaks Gambling Screen* (SOGS; Lesieur & Blume, 1987) as a proxy measure of gambling history and symptom severity (if any). The SOGS adopts a 20-point scale, with a score greater than 5 indicating potential pathological gambling. The mean SOGS score of the 33% group was 1.3 (range 0-6, $SD$ = 1.7) and was 1.9 (range 0-17, $SD$ = 3.0) for the 50% group. Hence, both groups included primarily recreational, non-problem gamblers. Groups did not differ by either age ($p$ =.784) or SOGS score ($p$ = .308).

The study protocol was approved by the Department of Psychology Research Ethics Committee, Swansea University.

## Apparatus

The study took place in a small room containing a desk, a desktop computer with 24-inch display, keyboard and a two-button click mouse. Stimulus presentation and the recording of responses were controlled by the computer, which was programmed in *Visual Basic* (M. R. Dixon & MacLin, 2003). Two arbitrary stimuli from the Wingdings font were trained as contextual cues for SAME (♓) and OPPOSITE (❄) relations, respectively[1]. One nonsense syllable (CUG) and six images commonly seen on slot-machine reels (i.e., cherries, plums,

[1] In line with convention, we refer to the actual images employed as contextual cues in capitals (i.e., SAME and OPPOSITE) and to emphasize that real words were never presented as contextual cues.

lemons, watermelons, bells, and the number 7; see Figure 1a) were employed during arbitrary relational training and testing and slot machine learning and testing phases. The nonsense syllable CUG served as the sample stimulus during arbitrary relational training and testing and will for the purposes of clarity be designated A1. The images of cherries served as the winning outcome display during the slot-machine payout training phase and will be designated B1. The remaining stimuli were randomly assigned across participants and served as the B2, C1, C2, X1 and X2 stimuli during the arbitrary relational training and testing and slot-machine outcomes ratings test phases.

***Insert Figure 1 About Here***

**Procedure**

Participants were first administered the SOGS (Lesieur & Blume, 1987) and then proceeded to the relational training and testing and slot machine training and testing tasks. The Relational Completion Procedure (Figure 2) was employed for all relational training and testing phases (Dymond & Whelan, 2010; Dymond, Ng, & Whelan, 2013).

***Insert Figure 2 About Here***

**Phase 1: Nonarbitrary relational training and testing.** This phase commenced with the following onscreen instructions:

> Thank you for agreeing to participate in this study. You will be presented with a series of images or nonsense words on the top half of the screen from left to right. Then, you will be presented with three images at the bottom of the screen. Your task is to observe the images or words that appear from left to right and drag one of these images or words from the bottom to the blank, yellow square. Click and hold the mouse over the image or word to drag it to the blank square. To confirm your choice, click 'Finish Trial'. If you wish to make another choice, then click 'Start Again'. Sometimes, you will receive feedback on your choices, but at other times you will not. Your aim is to get as

many tasks correct as possible. It is always possible to get a task correct, even if you are not given feedback.

The purpose of this phase was to train contextual cues to function as or stand for “same” and “opposite”, respectively. Participants were presented with a screen which consisted of a grey section at the bottom third of the screen whereas the top two thirds of the screen appeared blue. The sample stimulus appeared at the left of the blue section of the screen; followed one second later by the contextual cue to the right and, after a further one second, a third blank square appeared towards the right of the screen. One second later the three comparison stimuli appeared in the grey section of the screen below (Figure 2). The positioning of the comparison stimuli was randomised across trials. To make a response, participants were required to select one of the comparison stimuli, by dragging it with the mouse, and dropping it in the blank square in the blue section of the upper screen. This made two new buttons appear below the comparison stimuli, with the options ‘Finish Trial’ or ‘Start Again’. Clicking ‘Start Again” resulted in the comparison stimuli being reset. Clicking the ‘Finish Trial’ button ended the trial, therefore clearing the screen and presenting feedback. A correct response produced the word ‘Correct’, whereas an incorrect response produced the word ‘Incorrect’. Once feedback had been presented a new trial commenced.

The sample and comparison stimuli consisted of shapes or objects that differed along a specified physical dimension. For example, one stimulus set consisted of a tall tree, a medium sized tree and a small tree. A total of six stimulus sets were used during training, and sets were presented in a pseudorandom order. Once a participant responded correctly across ten consecutive trials, they progressed to nonarbitrary testing. The nonarbitrary relational test was identical in format to training except that no feedback was given, and six novel stimulus sets were employed. Ten consecutive correct responses were required to complete this phase. If this criterion was not met, participants were reexposed to nonarbitrary training.

**Phase 2: Arbitrary relational training and testing.** The purpose of this phase was to train a relational network of arbitrary images using the established contextual cues of same and opposite from Phase 1. The format of arbitrary relational training was identical to that of the non-arbitrary training trials, except that the stimuli were arbitrary, that is, they did not differ along a physical dimension. The stimuli were arbitrarily selected images from slot-machine reels (cherry, plum, lemon, watermelon, bell, and the number seven), along with a nonsense word (CUG). Apart from the nonsense word, which was fixed across participants, the stimuli used were varied quasi-randomly and, for the purposes of clarity, will be referred to using alphanumeric labels (A1, B1, B2, C1, C2, X1 and X2; participants were never exposed to these labels).

In arbitrary relational training, sample stimulus A1 was first presented, followed by the contextual cue for same or opposite, and then the blank square. Following this, the three arbitrary comparison stimuli were displayed at the bottom of the screen (Figure 2). Across trials, different combinations of comparison stimuli were presented. For example, on some trials the contextual cue for SAME, the with sample stimulus A1, and the comparison stimuli B1, B2 and X2 were presented and selecting comparison stimulus B1 was reinforced (with the word 'Correct'). There were four types of training trials in total (the predicted, correct response is shown in italics): SAME/A1 [*B1*-B2-X1], SAME/A1 [*C1*-C2-X2], OPPOSITE/A1 [B1-*B2*-X1], OPPOSITE/A1 [C1-*C2*-X2]. Participants were required to select one of the comparison stimuli by dragging and dropping it on to the blank square. On confirming their choice, feedback was given. Training trials were presented in eight trial blocks so that each trial was presented twice per block. A criterion of ten consecutive correct trials was required before progressing to testing.

The purpose of the test phase was to identify whether participants could respond correctly to derived relations of same and opposite. The format was identical to that of arbitrary training except that no feedback was given (the words ‘Correct’ and ‘Incorrect’ were removed). The following eight novel trials were presented during the test (again, correct or predicted responses are italicised): SAME/B1 [*C1*-C2-X2], SAME/C1 [*B1*-B2-X2], SAME/B2 [C1-*C2*-X1], SAME/C2 [B1-*B2*-X1], OPPOSITE/B1 [C1-*C2*-X1], OPPOSITE/C2 [*B1*-B2-X1], OPPOSITE/B2 [*C1*-C2-X1], and OPPOSITE/C1 [B1-*B2*-X1]. The test phase consisted of two blocks of eight trials, with each trial presented twice. A criterion of 14 consecutive correct responses was required in order to pass the test. If participants did not meet this criterion, they were re-exposed to the entire experimental sequence from Phase 1 until criterion was met.

**Phase 3: Slot-machine payout training.** The purpose of this phase was to present participants with displays of wins, near-misses and losses consisting of stimuli (B1 and X1) from the relational training and testing phases on a simulated slot-machine. Winning trials always consisted of the B1 stimulus (B1-B1-B1), a near-miss display consisted of the B1 and X1 stimuli (i.e., reading left-to-right: B1-B1-X1 and X1-B1-B1), and a loss display consisted of one B1 stimulus with the X1 and X2 stimuli (X1-B1-X2 and X2-B1-X1). Participants were presented with blocks of 12 trials consisting of 2 (16.6%) win, 4 (33.3%) loss, and 6 (50%) near-miss outcomes, which were repeated 10 times to generate a total of 120 trials.

All participants started with 150 credits. To play the slot-machine required pressing the Bet 1 button which deducted one point from the total credits box, and then pressing the Spin button. One credit, plus the credit bet, was awarded for a winning spin and participants completed this phase with 142 credits (10 losses and 2 winning outcomes per trial block). Following each twelve-trial-block, participants rated how closely each outcome display was to a win. The winning image consisted of B1-B1-B1, the near-miss image consisted of B1-B1-X1, and the losing image consisted of X1-B1-X2. Participants responded using a scale of 1 to 10 (where 1 = *not a win* and 10 = a *win*.). It was predicted that participants would rate the win slot-machine outcome images as being closest to a win (i.e., 10), the total loss images as a loss (i.e., 1 or 2), and the near-miss images as being closer to a win than the total loss images.

**Phase 4: Slot-machine outcomes ratings test.** In this phase, images of the payout line of a slot-machine depicting wins, near-misses, and losses were presented using combinations of all of the arbitrary stimuli from the arbitrary relational test phase. These eight displays consisted of a C1 win (C1-C1-C1), C2 win (C2-C2-C2), C1 near-miss (C1-C1-X1 and X1-C1-C1), C2 near-miss (C2-C2-X1 and X1-C2-C2), C1 loss (X1-C1-X2), and C2 loss (X1-C2-X2). Each image was presented five times, generating a total of 40 trials. At the end of this phase, participants again rated how close each image was to a win.

It was predicted that participants would rate the slot-machine outcome images containing a stimulus C1 as being closer to a win (as C1 participated in a derived same relation with B1) than displays containing the C2 stimulus (as C2 participated in a derived opposite relation with B1). It was predicted that the C1-C1-X1 and C2-C2-X1 near-miss outcomes would be rated equally, and that the X1-C1-C1 and X1-C2-C2 outcomes would also be rated equally. Additionally, it was predicted that the near-miss outcomes in which the matching symbols appeared on the left-hand side would be rated more highly than those in which the matching symbols were on the right-hand side.

## Results

The number of trials to criterion and the number of correct responses in the non-arbitrary and arbitrary relational training and testing phases (Phases 1 and 2) for each participant are shown in the Supplementary material. Exposures to the nonarbitrary relational training phase did not differ between groups ($p$ = .910), with participants requiring between 17.9 ($SD$ = 13.2) trials in the 33% near-miss group and 18.1 ($SD$ = 14.2) trials in the 50%

near-miss group, respectively, to reach criterion (Table 1). Participants required between one and eight exposures to the nonarbitrary relational test. Again, performance did not differ (*p* = .069) and was highly accurate: 96.9% (*SD* = 11) in the 33% near-miss group and 99.3% (*SD* = 12.6) in the 50% near-miss group, respectively.

***Insert Table 1 About Here***

Exposures to trials of the arbitrary relational training phase did not differ between groups (*p* = .540), participants took between 15.6 (*SD* = 8.5) trials in the 33% near-miss group and 16.4 (*SD* = 12.1) trials in the 50% near-miss group, respectively, to reach criterion (Table 1). Participants required between one and seven exposures to pass the arbitrary relational test. Performance was highly accurate and did not differ between groups: 85.5 (*SD* = 19.7) in the 33% near-miss group and 87% (*SD* = 20.3) in the 50% near-miss group, respectively, $t(166) = -4.87$, $p > .05$.

***Insert Figure 3 About Here***

During the slot machine payout training phase (Figure 3a), both groups similarly rated the win display (B1-B1-B1) as closest to a win, with the near-miss display (B1-B1-X1) rated as intermediary to a win. The loss display (X1-B1-X2) was rated as the least close to a win. As expected, a 3 x 2 mixed ANOVA found that ratings differed across the win, loss and near-miss displays consisting of the learned stimuli B1, X1 and X2 ($F_{(2,60)} = 606.679$, $P<.001$, $\eta_p^2 =.95$). However, groups did not differ in ratings made of the three displays (*p* = .652).

During the slot machine outcomes ratings test phase, there was a decreasing trend for outcomes to be rated close to a win as the symbolic characteristics of the display were altered (Figure 3b). As predicted, 8 (outcome display) x 2 (group) mixed ANOVA revealed that closeness to win ratings differed across the win, loss and near-miss displays consisting of symbolic stimuli from the relational network ($F_{(7,55)} = 166.314$, $P<.001$, $\eta_p^2 =.95$). Groups did not differ in ratings made of the various displays (*p* = .206).

Follow-up, repeated-measures ANOVA for the combined near-miss frequency groups were conducted and showed significant linear, $F_{(1,62)} = 1122.44$, $p < .001$, quadratic, $F_{(1,62)} = 17.64$, $p < .001$, and cubic, $F_{(1,62)} = 65.24$, $p < .001$, trends. in the ratings given to the different displays. These combined data show a significant trend, independent of near-miss frequency, in the closeness to win ratings which changed very little from C1 and C2 win displays and which then decreased consistently as the stimuli progressively changed to the full loss displays.

Overall, the C1-C1-C1 win display was rated as marginally closer to a win than the C2-C2-C2 win display, particularly by the 50% near-miss frequency group, although no between-group differences were found. At the single-subject level, the predicted response pattern was evident in 39 out of 49 participants in the 30% group and 36 out of 42 participants in the 50% group, where consistently higher ratings (10 or 9) were given to the C1 and C2 win displays and consistently lower ratings (1 or 2) to the loss displays. Near-miss displays consisting of either C1 or C2 were rated as similarly close to a win, with no effect of structural order (left-right or right-left) detected, while loss displays (e.g., X1-C1-X2) were uniformly rated low by both groups.

## Discussion

The present study investigated symbolic generalization of the near-miss effect using same and opposite relations consisting of gambling-specific stimuli displayed on the reels of a simulated slot-machine. Following relational training and testing, participants were given payout training with one image (B1) presented in win (i.e., B1-B1-B1), near-miss (e.g., B1-B1-X1) and loss (e.g., X1-B1-X2) displays. Ratings of closeness to a win were made and then, participants were tested with displays depicting wins, near-misses, and losses using combinations of stimuli from the relational test: C1 win (C1-C1-C1), C2 win (C2-C2-C2), C1 near-miss (C1-C1-X1 and X1-C1-C1), C2 near-miss (C2-C2-X1 and X1-C2-C2), C1 loss (X1-C1-X2), and C2 loss (X1-C2-X2). In line with predictions, we found that outcomes with C1 displays were rated as closer to a win than outcomes with C2 displays, and that near-misses containing either C1 or C2 (e.g., C1-C1-X1, C2-C2-X1, X1-C1-C1 and X1-C2-C2) were rated equally. No differences were found between groups that received either 33% or 50% frequency of near-misses. Taken together, these findings demonstrate, for the first time, a role for symbolic generalization in the near-miss effect using a paradigm in which actual slot machine reel displays were members of a derived same and opposite relational network.

When humans choose to play slot-machines they are interacting verbally with a complex, multi-sensory environment replete with numerous sources of symbolic stimulus control. By “verbally” we refer to the fact that the stimuli involved have their functions based at least in part on participation in derived relations. According to a contemporary behavioural theory of language and cognition (relational frame theory; RFT; Hayes, Barnes-Holmes, & Roche, 2001; Dymond & Roche, 2013), this verbal interaction involves symbolic generalization as a learned process that impacts other operant processes. Previous studies conducted under the rubric of RFT have found that background colours may exert control over response allocation and preference, to the extent that they override the underlying probability schedules (Hoon et al., 2008). Such studies demonstrate that non-arbitrary, physically-defined (i.e., perceptual) properties, such as colours, may at least partially influence gambling session length and choice of which particular machine or game to play. The present findings lend further support for this position by showing that the control exerted by the physical format of the near-miss in slot machine gambling interacts with the symbolic/relational histories of the reel stimuli to control ratings of closeness to a win and, ultimately, actual choices.

Previous findings indicate that the near-miss effect in simulated slot machine gambling may be altered through verbal relations (Belisle et al., , 2018; M. R. Dixon et al., 2011; Dymond et al., 2012) but only when win, near-miss and loss outcome reel displays are related to the written text, “win”, “loss” and “almost”. Our findings show that gambling-specific stimuli commonly associated with slot machines may acquire symbolic properties of same and opposite which then exert a subsequent influence over win expectancy. In this way, the present approach builds on previous analyses by first associating one stimulus from a relational network with a high pay-out probability and then transferring this conditioned reinforcement-like property to indirectly related slot machine characters. It also extends the effects obtained to derived relations of same and opposite as a behavioural means of understanding relative increases and decreases in slot-machine preference. For instance, we observed that if A is the same as B, and B is paired with winning, A will also evoke some of these reward-related properties and lead to increased preference, but if C is the opposite of B, then it may be chosen less frequently and be least preferred overall. Moreover, these effects interacted with the physical format of the near-miss effect such that a display containing a cue symbolically the same as the learned cue (C1) was rated as closer to a win than outcomes containing a cue symbolically opposite to the learned cue (C2).

The present findings, while preliminary, have potential limitations which should be addressed in future research. First, we recruited a sample of recreational gamblers, and if the present approach is to inform understanding of excessive slot-machine gambling then it will be important to recruit groups of at-risk and problem/disordered gamblers. Second, the crucial test phase was conducted under conditions of non-reinforcement (extinction) and involved rating different displays as to the likelihood of winning. It would be salutary to test persistence of the symbolic generalization effect under different conditions of feedback by, for instance, altering pay-out probabilities and/or near-miss frequency. Third, further examining the role of symbolic generalization in the near-miss effect requires a suitable control group or procedure. For instance, in order to demonstrate the central role of relational training and testing in generating the observed effects, a control group could be given phases 3 and 4 only (Dymond & Rehfeldt, 2000). Such a control procedure might be expected to demonstrate learning of the relative likelihood of different winning and losing displays in Phase 3 yet produce inconsistent patterns of selection in the test phase as these participants would lack knowledge of how C1 and C2 were related. It is possible, however, that the physical format of the near-miss displays, even though consisting of C1 and C2 stimuli not seen before, might override any effects of symbolic generalization. Future research on this issue is warranted. Fourth, while we did not find any evidence for the impact of near-miss frequency, further work is needed to delineate the interaction between near-miss displays and derived relations. Finally, the present study employed a well-validated, yet simplified three-reel simulated slot-machine task which allowed for precise control over the outcome displays. Given the complexity of modern, multi-line slot machine games and features such as ‘losses disguised as wins’ (Barton et al., 2017; Sharman et al., 2015), it will be important for future work to investigate the impact of symbolic generalization on slot-machine gambling in complex, multi-sensory environments.

In conclusion, the present findings demonstrate a role for symbolic generalization in the near-miss effect with same and opposite relations in simulated slot-machine gambling.

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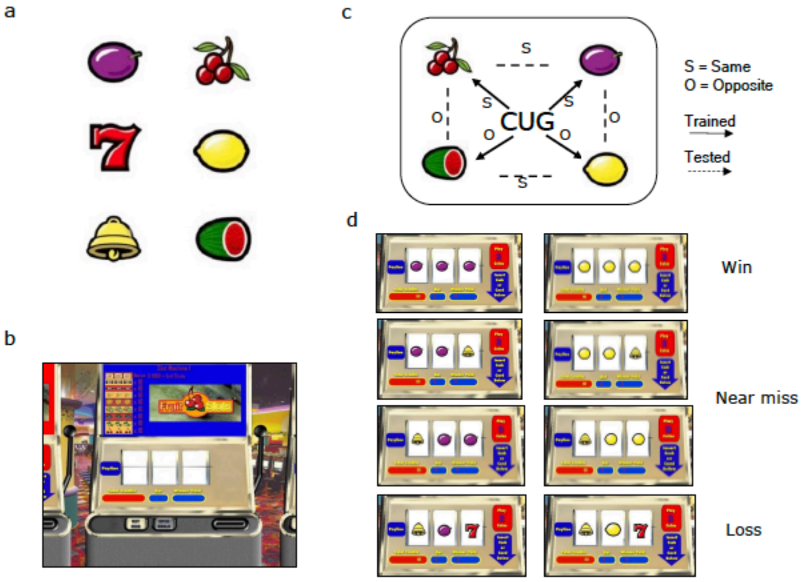
**Figure Captions**

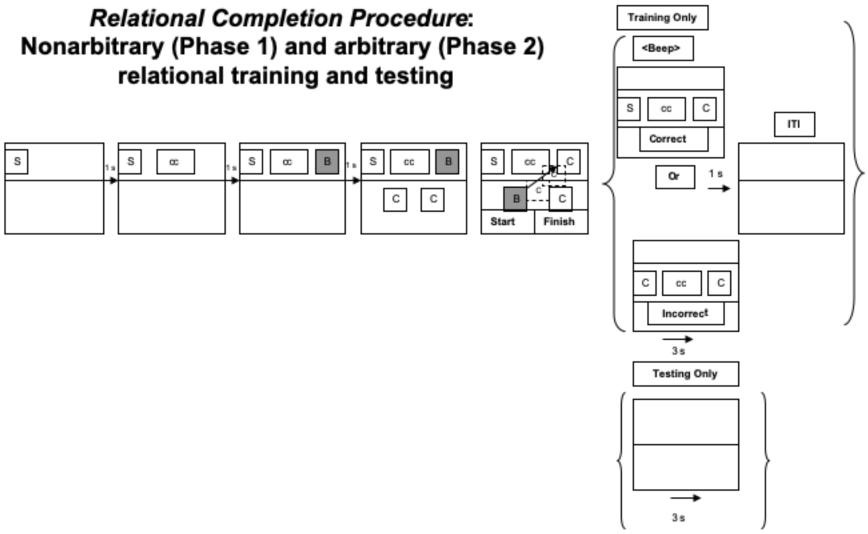
*Figure 1.* (a) The six images commonly seen on slot-machine reels (cherries, plums, lemons, watermelons, bells, and the number 7) used during arbitrary relational training and testing and slot machine payout training and outcome testing phases. A nonsense syllable, not shown, was used as the sample stimulus during arbitrary relational training and testing phases. For all participants, a series of cherries served as the winning outcome display during the slot machine learning phase, and the remaining stimuli were randomly assigned across participants during the arbitrary relational training and testing and slot machine testing phases. (b) User interface of the simulated slot machine task (without images on the reels). (c) Relational network of same (S) and opposite (O) trained (solid lines) and tested (dashed lines). (d) The user interface of the simulated slot-machine win, near-miss and loss displays.

*Figure 2*. Schematic diagram of the Relational Completion Procedure. The sequence of presentation of stimuli during the constructed-response (a) nonarbitrary and (b) arbitrary relational training and test phases. *Note*: S = sample; B = blank square; cc = contextual cue; C = comparison; ITI = inter-trial interval. A dashed line represents dragging of a comparison stimulus. ‘Finish’ and ‘Start’ indicate the confirmatory response buttons, respectively. Arrows pointing from B to C illustrate that once selected, the comparison stimulus moved to the top portion of the screen, while its original screen position was replaced by a blank square. See text for details.

*Figure 3*. (a) Closeness to win ratings of the win, near-miss and loss displays consisting of the B1 stimulus from the slot-machine payout training phase for both groups. Error bars are SEM. (b) Closeness to win ratings of the win, near-miss and loss displays consisting of the

derived C1 and C2 stimuli from the slot machine test phase for both groups. Error bars are SEM.


a
b
c
S
S
S
O
O
O
O
S
CUG
S = Same
O = Opposite
Trained
Tested
d
Win
Near miss
Loss


*Relational Completion Procedure*:
Nonarbitrary (Phase 1) and arbitrary (Phase 2)
relational training and testing
S
1 s
cc
B
C
Start
Finish
Training Only
<Beep>
Correct
Or
ITI
Incorrect
3 s
Testing Only

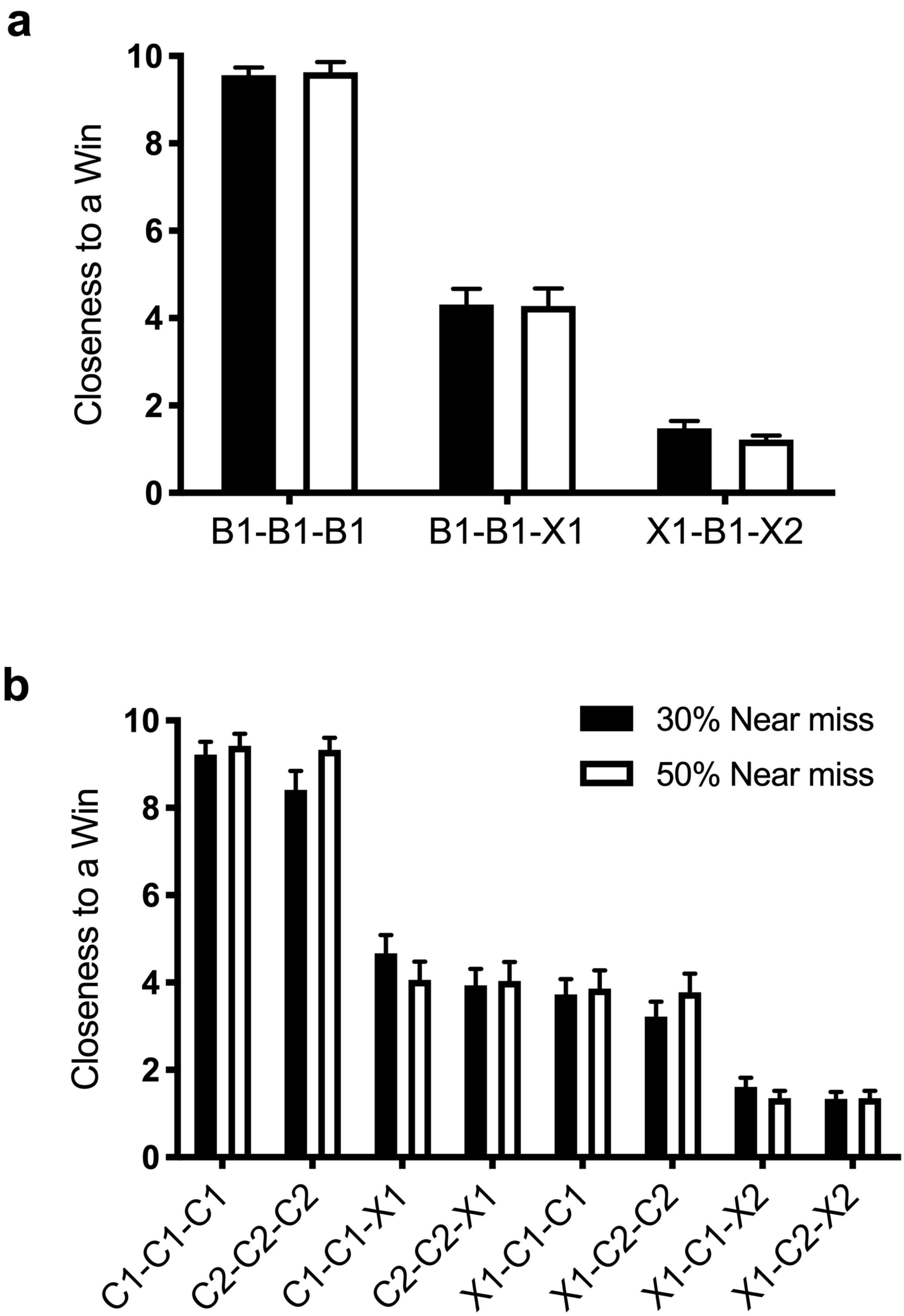

a
Closeness to a Win
0
2
4
6
8
10
B1-B1-B1
B1-B1-X1
X1-B1-X2
b
30% Near miss
50% Near miss
Closeness to a Win
0
2
4
6
8
10
C1-C1-C1
C2-C2-C2
C1-C1-X1
C2-C2-X1
X1-C1-C1
X1-C2-C2
X1-C1-X2
X1-C2-X2

*Table 1*. Mean (SD) trials to training criterion and proportion of accurate test responses during Phases 1 to 4.

| Group | Phase 1: Nonarbitrary Relational Training | Phase 1: Nonarbitrary Relational Testing | Phase 2: Arbitrary Relational Training | Phase 2: Arbitrary Relational Testing |
|---|---|---|---|---|
| 30% Near-miss | 17.9 (13.2) | 96.9% (11%) | 15.6 (8.5) | 85.5% (19.7%) |
| 50% Near-miss | 18.1 (14.2) | 99.3% (12.6%) | 16.4 (12.1) | 87% (20.3%) |

**Supplementary Material: Hoon, Freegard & Dymond**

*Individual participant data from non-arbitrary relational training and testing and arbitrary relational training and testing phases.*

**30% Near-Miss Group**

| Participant | Non-Arbitrary Training | Non-Arbitrary Testing | Arbitrary Training | Arbitrary Testing |
|---|---|---|---|---|
| 1 | 15 | 100 | 14 | 79 |
| | 10 | 100 | 10 | 100 |
| 2 | 20 | 86 | | |
| | 21 | 100 | 30 | 93 |
| | 10 | 100 | 10 | 75 |
| | 10 | 100 | 10 | 77 |
| | 10 | 100 | 10 | 93 |
| | 10 | 100 | 10 | 93 |
| | 10 | 100 | 10 | 93 |
| | 10 | 100 | 10 | 100 |
| 3 | 20 | 100 | 10 | 100 |
| 4 | 11 | 100 | 14 | 22 |
| | 10 | 100 | 12 | 86 |
| | 15 | 100 | 10 | 93 |
| 5 | 13 | 100 | 24 | 100 |
| 6 | 36 | 100 | 33 | 55 |
| | 13 | 100 | 18 | 93 |
| 7 | 26 | 100 | 29 | 30 |
| | 17 | 100 | 13 | 77 |
| | 10 | 100 | 10 | 100 |
| 8 | 40 | 100 | 46 | 93 |
| 9 | 38 | 100 | 14 | 100 |
| 10 | 36 | 100 | 22 | 60 |
| | 13 | 100 | 10 | 77 |
| | 10 | 100 | 10 | 100 |
| 11 | 48 | 86 | | |
| | 10 | 100 | 23 | 100 |
| 12 | 10 | 100 | 10 | 100 |
| 13 | 27 | 100 | 17 | 77 |
| | 10 | 100 | 10 | 100 |
| 14 | 11 | 100 | 13 | 100 |
| | 62 | 100 | 37 | 86 |
| | 10 | 100 | 10 | 100 |
| 15 | 21 | 100 | 32 | 58 |
| | 10 | 100 | 16 | 55 |
| | 10 | 100 | 10 | 100 |
| 16 | 52 | 100 | 15 | 100 |
| 17 | 18 | 100 | 15 | 93 |

| | | | | |
|---|---|---|---|---|
| 18 | 10 | 100 | 53 | 77 |
| | 10 | 100 | 10 | 100 |
| 19 | 24 | 87 | | |
| | 10 | 100 | 12 | 100 |
| 20 | 21 | 100 | 15 | 100 |
| 21 | 24 | 100 | 21 | 100 |
| 22 | 13 | 100 | 12 | 100 |
| 23 | 21 | 100 | 25 | 100 |
| 24 | 21 | 87 | | |
| | 10 | 100 | 32 | 100 |
| 25 | 12 | 100 | 18 | 86 |
| | 10 | 100 | 10 | 100 |
| 26 | 24 | 100 | 24 | 100 |
| 27 | 50 | 100 | 17 | 86 |
| | 14 | 100 | 10 | 93 |
| 28 | 13 | 100 | 13 | 100 |
| 29 | 10 | 86 | | |
| | 10 | 100 | 13 | 86 |
| | 10 | 100 | 10 | 100 |
| 30 | 13 | 91 | 12 | 86 |
| | 10 | 100 | 10 | 100 |
| 31 | 61 | 77 | 34 | 46 |
| | 10 | 45 | 15 | 67 |
| | 11 | 93 | 10 | 67 |
| | 10 | 91 | 10 | 40 |
| | 19 | 100 | 10 | 86 |
| | 10 | 100 | 10 | 93 |
| 32 | 40 | 77 | 19 | 45 |
| | 11 | 93 | | |
| | 10 | 100 | 10 | 69 |
| | 10 | 100 | 10 | 93 |
| | 10 | 100 | 10 | 100 |
| 33 | 11 | 100 | 14 | 77 |
| | 10 | 100 | 10 | 100 |
| 34 | 46 | 100 | 24 | 100 |
| 35 | 18 | 100 | 12 | 100 |

**50% Near-Miss Group**

| Participant | Non-Arbitrary Training | Non-Arbitrary Testing | Arbitrary Training | Arbitrary Testing |
|---|---|---|---|---|
| 36 | 20 | 100 | 10 | 100 |
| 37 | 12 | 100 | 13 | 77 |
| 38 | 26 | 100 | 11 | 100 |
| 39 | 64 | 100 | 23 | 93 |
| | 10 | 100 | 10 | 86 |
| | 11 | 100 | 10 | 100 |
| 40 | 23 | 100 | 20 | 46 |
| | 10 | 93.3 | 10 | 79 |
| | 10 | 100 | 10 | 67 |
| | 10 | 100 | 10 | 100 |
| 41 | 22 | 100 | 16 | 67 |
| | 21 | 100 | 10 | 100 |
| 42 | 21 | 100 | 26 | 100 |
| 43 | 15 | 100 | 12 | 93 |
| 44 | 11 | 100 | 14 | 100 |
| 45 | 11 | 100 | 20 | 100 |
| 46 | 23 | 100 | 18 | 77 |
| | 10 | 199 | 10 | 93 |
| 47 | 11 | 100 | 19 | 93 |
| | 14 | 100 | 10 | 93 |
| | 10 | 91.7 | 10 | 100 |
| 48 | 23 | 100 | 32 | 93 |
| | 10 | 100 | 10 | 100 |
| 49 | 10 | 100 | 13 | 100 |
| 50 | 21 | 100 | 13 | 100 |
| 51 | 31 | 100 | 39 | 100 |
| 52 | 11 | 100 | 14 | 100 |
| 53 | 89 | 100 | 11 | 100 |
| 54 | 27 | 100 | 12 | 100 |
| 55 | 18 | 100 | 10 | 100 |
| 56 | 16 | 100 | 13 | 100 |
| 57 | 11 | 92 | 27 | 86 |
| 58 | 10 | 100 | 10 | 100 |
| 59 | 30 | 100 | 23 | 93 |
| 60 | 18 | 100 | 13 | 100 |
| 61 | 24 | 100 | 20 | 100 |
| 62 | 13 | 100 | 13 | 86 |
| | 10 | 90 | 10 | 100 |
| 63 | 11 | 100 | 13 | 100 |
| 64 | 18 | 79 | | |
| | 10 | 100 | 34 | 100 |

| | | | | |
|---|---|---|---|---|
| 65 | 13 | 100 | 16 | 93 |
| | 10 | 100 | 10 | 100 |