PAR Sheets, probabilities, and slot machine play: Implications for problem and non-problem gambling

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Abstract

Through the Freedom of Information and Protection of Privacy Act, we obtained design documents, called PAR Sheets, for slot machine games that are in use in Ontario, Canada. From our analysis of these PAR Sheets and observations from playing and watching others play these games, we report on the design of the structural characteristics of Ontario slots and their implications for problem gambling. We discuss characteristics such as speed of play, stop buttons, bonus modes, hand-pays, nudges, near misses, how some wins are in fact losses, and how two identical looking slot machines can have very different payback percentages. We then discuss how these characteristics can lead to multi-level reinforcement schedules (different reinforcement schedules for frequent and infrequent gamblers playing the same game) and how they may provide an illusion of control and contribute in other ways to irrational thinking, all of which are known risk factors for problem gambling.

Keywords: problem gambling, slot machines, video slots, PAR Sheets, structural characteristics, reinforcement schedules

Introduction

Slot machines are a very popular form of gambling in North America. For example, Ontario, Canada, has approximately 23,000 slot machines, which in the fiscal year 2002-2003 generated approximately three billion dollars "after prizes/winnings but before operating expenses" (Williams & Wood, 2004, p. 25). This revenue is greater than that from all other types of gambling in Ontario combined (Williams & Wood, p. 25). According to Williams and Wood, approximately 60% of slot machine revenue, around 1.8 billion dollars annually, is generated from problem gamblers. This percentage is higher than that for horse racing (53%), casino table games (22%), bingo/raffles (22%), and lotteries/instant-win scratch tickets/sports betting (19%).

In an effort to understand the popularity and addictiveness of slot machines, one approach is to investigate what potential effects the slot machine's structural characteristics have on the player. The underlying math and computer algorithms for the design of many of the structural characteristics, such as hit frequency, payback percentage, and odds of winning, are contained in the manufacturers' design documents, called probability

accounting reports (PAR Sheets; sometimes called paytable and reel strips [PARS]). To date, the study of slot machine structural characteristics has been hampered by the fact that researchers have not had access to the manufacturers' PAR Sheets to see how the games are designed. We have been successful with requests for PAR Sheets through the Freedom of Information and Protection of Privacy Act (FIPPA, 2007) for four slot machine games that are approved for use in Ontario.

We analyzed the PAR Sheets and played the four games for approximately 60 hr at an Ontario casino, Grand River Raceway, which has 200 slot machines. This paper begins with a detailed description of the structural characteristics of the slot machine games, and then discusses these characteristics in terms of their potential implications for problem gambling. To our knowledge, this is the first report in problem gambling literature that has drawn on actual PAR Sheets for games that are approved and being used in a North American jurisdiction.

The design of slot machine games

In response to our FIPPA requests, we were given copies of the following 23 PAR Sheets, all of which were provided by the North American slot machine manufacturer International Game Technology:

- One version of *Double Diamond Deluxe*
- Eight versions of *The Phantom of the Opera*
- Seven versions of *Lucky Larry's Lobstermania*
- Seven versions of *Money Storm*

Double Diamond Deluxe and *The Phantom of the Opera* are traditional mechanical three-reel slot machines with physical reels that spin. On both games, the player can see a 3 x 3 matrix of symbols, with the middle row being the payline. The player plays the game by using buttons and/or the handle on the slot machine. *Lucky Larry's Lobstermania* and *Money Storm* are five-reel video slots games that have a touch screen on which an animation of five spinning reels is displayed in a 3 x 5 matrix (three rows, five columns). Both video slots games have a bonus mode that a player enters infrequently, but once there, the player always experiences frequent wins (from the gambler's point of view, the bonus mode is a very good place to be). Players play the video slots games by using the touch screen and/or buttons on the cabinet.

Detailed descriptions of PAR Sheets for traditional mechanical three-reel slot machine games are contained in the gaming industry trade magazine *Slot Tech Magazine*; these descriptions are a useful reference source (Locke, 2001; Wilson, 2003, 2004a, 2004b, 2004c, 2004d, 2004e, 2004f). However, they are limited in that (a) the audience for *Slot Tech Magazine* is slot machine technicians and so the articles focus on the practical issues of how the information contained in PAR Sheets can be used by individuals who are servicing slot machines, (b) the descriptions cover only traditional mechanical three-reel slots, and (c) the descriptions use PAR Sheet examples without indicating whether those games are actually used in a specific jurisdiction.

Research has been published in the problem gambling literature related to the information included in PAR Sheets for traditional mechanical three-reel slot machine games (Harrigan 2007, 2008, 2009; Turner & Horbay, 2004), but the authors of these papers did not have access to actual PAR Sheets for games that are approved for use in a North American jurisdiction. Also, Griffiths (1993, 1994, 1995, 1999) and Parke and Griffiths (2004, 2006) have written extensively about the structural characteristics of slot machines in Britain. Although slot machines in Britain are similar to slot machines in North America, a significant difference, with respect to the present paper, is that British machines "use a compensator which monitors the payout ratio game by game and initiates action, as necessary, to influence the random selection of wins and thereby attempt to hold the ratio at all times close to the preselected level" (British patent GB 2 165 386A, as cited in Parke & Griffiths, 2006, p. 153), whereas in North America the machines do not have a compensator and the result of every spin is determined by a random number generator (for a detailed discussion of the differences between British and North American machines, see Parke & Griffiths, 2006, pp. 152-153). This paper focuses specifically on slot machines in Ontario, Canada, as we have obtained PAR Sheets for Ontario slot machine games.

Observations from actual play

As we studied the PAR Sheets, we frequently visited a casino to play, and to watch others play, the four games to (a) observe several structural characteristics, focusing on the bonus mode, to ensure that our understanding of the PAR Sheets reflected the way that slot machines actually behave; and (b) observe several structural characteristics that are not contained in the PAR Sheets, including speed of play, stop buttons, and "hand-pays." In this section, we provide details on the structural characteristics that we observed.

Speed of play

We estimated the speed of play by using the second hand on a watch. On the two traditional mechanical reel slot machine games, the player can play approximately every 6 s, which is approximately 10 spins per minute, or 600 spins per hour. On the two video slots games, the player can play approximately every 3 s, which is 1,200 spins per hour.

Stop buttons

Both *Money Storm* and *Lobstermania* provide two methods to speed up the game by approximately 50% (i.e., approximately 1.5 s per spin). One method is for the player to press "spin" to begin play, and then press spin again as the reels begin to spin, which causes the reels to stop quickly. The second method is for the player to touch one or more of the reels as they are spinning, which causes the touched reel(s) to stop quickly.

Hand-pays

At the casino we frequently visited, the games are configured so that when the outcome of a spin is a win greater than a certain amount (the amount is $125.00 for *Lobstermania*), the following occurs:

- the screen freezes and thus the player cannot play the machine
- the light on the top of the machine lights up
- the machine makes a sound of a bell ringing
- an attendant comes by and adjusts the machine to silence the bell
- the attendant leaves
- the attendant returns with cash and pays the player the winning amount in cash
- the attendant makes further adjustments to the machine so that normal play can be resumed

Collectively, this procedure is called a "hand-pay." We observed over 20 hand-pays and we estimate that it takes an average of 5 min from the time the screen freezes until the game returns to normal play. These five min are usually a very social time during which fellow players gather and speak to the winning player. The amount required for a hand-pay varies from game to game and, in general, the amount is higher for games that allow the player to make higher wagers.

Summary of PAR Sheet analysis

In this section, we provide a brief description of various structural characteristics from the PAR Sheets, as summarized in Table 1, and then describe several structural characteristics in detail:

- The first column in Table 1 provides the game name, the number of reels, and the number of lines and indicates whether or not there are scatter wins.
    - The game name is abbreviated: "DD" for *Double Diamond Deluxe*, "P" for *The Phantom of the Opera*, "L" for *Lucky Larry's Lobstermania*, and "M" for *Money Storm*. If there are multiple versions of the game, the game abbreviation is followed by a number, such as L1, L2, and L3, to indicate the different versions of *Lucky Larry's Lobstermania*.
    - "Reels" refers to the number of reels, which is three for the mechanical reel slots and five for the video slots.

  - "Lines" refers to the number of lines that can be wagered upon. The mechanical reels slots are single-line games, whereas the video slots are multi-line games. To illustrate how multiple lines are designed, the top of Figure 1 shows the 15 lines in *Lucky Larry's Lobstermania*. To be a win, identical symbols on a line must start on the leftmost reel and be consecutive. For example, in *Lobstermania* a winning combination is three, four, or five consecutive "BOAT" symbols. The game outcome BOAT-BOAT-BOAT-CLAM-CLAM is a win, whereas BOAT-BOAT-CLAM-BOAT-BOAT is a loss, as there are not three consecutive BOAT symbols starting from the left.
  - On the lower panel of Figure 1, the "S" symbol denotes a "scatter" symbol. *Lucky Larry's Lobstermania* and *Money Storm* afford "scatter" wins. A scatter win is different from a line win in that scatter wins occur when the scatter symbol occurs three, four, or five times anywhere on the 3 x 5 matrix. Figure 1 shows two examples of scatter wins. Scatter wins occur frequently. As an example, the PAR Sheets show that in one version of *Lobstermania*, scatter wins account for 25.7% of all wins.
- "Min/max wager" refers to the minimum and maximum bet that a player can wager per spin. Both traditional slots games are "quarter" games and the player can wager 25, 50, or 75 cents. Both video slots games are "nickel" games and the player can wager 5, 10, 15, 20, or 25 cents per line, resulting in a maximum wager per spin of $3.75 for *Lobstermania* (25 cents x 15 lines = $3.75) and $5.00 for *Money Storm* (25 cents x 20 lines = $5.00).
- "Symbols per reel" denotes the number of symbols on each reel. On mechanical reel slots, this refers to the virtual reels (virtual reels are described later in this paper). Multiplying the number of symbols on each reel yields the total number of possible combinations. For example, *Lobstermania's* five reels have 47, 46, 48, 50, and 50 symbols, yielding a total of 259,440,000 possible combinations.
- "Payback %" is the payback percentage, which is the percentage of the wager that the player will receive back, on average, per spin. Payback percentage is the major distinguishing characteristic between multiple approved versions of the same game. Despite the fact that all versions of *Lucky Larry's Lobstermania* look identical to the gambler, a row of these machines in a casino could contain a range of payback percentages varying from a low of 85% to a high of 96.2%.
- "Hit freq" is the hit frequency, or the percentage of times, on average, that the player will win something on each line. Table 1 shows that this varies from a low of 4.9% for the 85% version of *Lobstermania* to a high of 16.7% for *Money Storm*. The hit frequency does not vary significantly between versions of the same slot machine game. For example, all versions of *Money Storm* have a hit frequency of approximately 16.6%.
- "Plays per jackpot" is the average number of plays before a jackpot is won. The maximum jackpot can be won only when the player has made the maximum wager on the winning line.

- "Jackpot amount" is the amount of the highest prize. On the mechanical reel slots, there is a bonus for wagering the maximum number of credits. For example, on *The Phantom of the Opera*, a wager of one credit pays a bonus of 1,000 credits, two credits pays 2,000, and three credits pays 5,000. The amount of the jackpot for both video slots games is linear in that the jackpot is 10,000 times the credits wagered and thus varies from 10,000 to 50,000, as the wager can vary from one to five credits.
- "Plays per bonus" is the number of plays, on average, before bonus mode is entered. Only video slots have bonus mode, with *Money Storm* having two bonuses.
- "VI" stands for "volatility index," and is an indication of how much the game's payback percentage will vary for a given number of games played. Games with a high volatility index have a larger variance in the payback percentage per gambling session than do games with a low volatility index. Only the PAR Sheets for the mechanical reel slots games include the volatility index. Table 2 describes the calculation of volatility index and the resulting confidence interval.

Multiple approved versions of the same game

As shown in Table 1, Ontario approves multiple versions of the same slot machine game, with the major difference between versions being the payback percentage. The differences in payback percentages have a direct effect on playing time. In *Lobstermania*, a player wagering $1.00 per spin would lose, on average, 3.8 cents per spin on the 96.2% game and 15 cents per spin on the 85% game. Thus, the player loses approximately four times more money per spin on the 85% game than on the 96.2% game (15 ÷ 3.8 = 3.95). A player arriving with a "bankroll" of $10.00 and wagering $1.00 per spin, who gambles until the bankroll is depleted, would make, on average, 263 one-dollar wagers on the 96.2% game ($10.00 ÷ $0.038 = 263), but only 67 one-dollar wagers on the 85% game ($10.00 ÷ $0.15 = 66.7); thus a player with a specific bankroll would have approximately four times more gambling time on the 96.2% version versus the 85% version (263 ÷ 66.7 = 3.95).

Table 1

Summary of PAR Sheets for 23 versions of two traditional mechanical reel slot machine games and two video slots games

Game / reels / lines/ scatter	Min/max wager ($)	Symbols per reel (virtual reels for DD and P)	Pay-back %	Hit freq (%)	Plays per jackpot	Jackpot amount (credits)	Plays per bonus	VI
DD/3/1	0.25/0.75	72/72/72	92.6	14.3	46,656	800/1,600/2,500	n/a	10.5
P1/3/1	0.25/0.75	256/256/256	98.0	13.6	114,131	1,000/2,000/5,000	n/a	16.3
P2/3/1	0.25/0.75	256/256/256	97.4	13.6	114,131	1,000/2,000/5,000	n/a	16.2
P3/3/1	0.25/0.75	256/256/256	95.0	13.0	114,131	1,000/2,000/5,000	n/a	17.4
P4/3/1	0.25/0.75	256/256/256	94.0	13.0	114,131	1,000/2,000/5,000	n/a	17.3
P5/3/1	0.25/0.75	256/256/256	92.5	12.9	133,153	1,000/2,000/5,000	n/a	16.1
P6/3/1	0.25/0.75	256/256/256	90.0	12.8	155,345	1,000/2,000/5,000	n/a	14.9
P7/3/1	0.25/0.75	256/256/256	87.5	12.3	155,345	1,000/2,000/5,000	n/a	15.6
P8/3/1	0.25/0.75	256/256/256	85.0	11.7	155,345	1,000/2,000/5,000	n/a	17.1
L1/5/15/S	0.05/3.75	47/46/48/50/50	96.2	5.2	8,107,500	10,000-50,000	1,730	n/a
L2/5/15/S	0.05/3.75	47/46/48/50/50	95.0	5.2	8,107,500	10,000-50,000	1,730	n/a
L3/5/15/S	0.05/3.75	47/46/48/50/50	94.0	5.2	8,107,500	10,000-50,000	1,730	n/a
L4/5/15/S	0.05/3.75	47/46/48/50/50	92.5	5.3	8,107,500	10,000-50,000	1,730	n/a
L5/5/15/S	0.05/3.75	47/46/48/50/50	90.0	5.0	8,107,500	10,000-50,000	1,730	n/a
L6/5/15/S	0.05/3.75	47/46/48/50/50	87.5	5.0	8,107,500	10,000-50,000	1,730	n/a
L7/5/15/S	0.05/3.75	47/46/48/50/50	85.0	4.9	8,107,500	10,000-50,000	1,730	n/a
M1/5/20/S	0.05/5.00	35/35/35/35/35	96.2	16.7	2,188,411	10,000-50,000	536/1,429	n/a
M2/5/20/S	0.05/5.00	35/35/35/35/35	95.0	16.7	2,188,411	10,000-50,000	536/1,429	n/a
M3/5/20/S	0.05/5.00	35/35/35/35/35	94.0	16.7	2,188,411	10,000-50,000	536/1,429	n/a
M4/5/20/S	0.05/5.00	35/35/35/35/35	92.5	16.7	2,188,411	10,000-50,000	536/1,429	n/a
M5/5/20/S	0.05/5.00	35/35/35/35/35	90.0	16.7	2,188,411	10,000-50,000	536/1,429	n/a
M6/5/20/S	0.05/5.00	35/35/35/35/35	87.5	16.5	2,188,411	10,000-50,000	536/1,429	n/a
M7/5/20/S	0.05/5.00	35/35/35/35/35	85.5	16.5	2,188,411	10,000-50,000	536/1,429	n/a

Note. DD = *Double Diamond Deluxe*; freq = frequency; L = *Lucky Larry's Lobstermania*; M = *Money Storm*; S = scatter wins are available; max = maximum; min = minimum; n/a = not applicable; P = *The Phantom of the Opera*; VI = volatility index.

Figure 1. Line and scatter wins in *Lucky Larry's Lobstermania*. The top shows the 15 lines and the bottom shows two sample scatter wins, one with three scatter symbols and one with four.

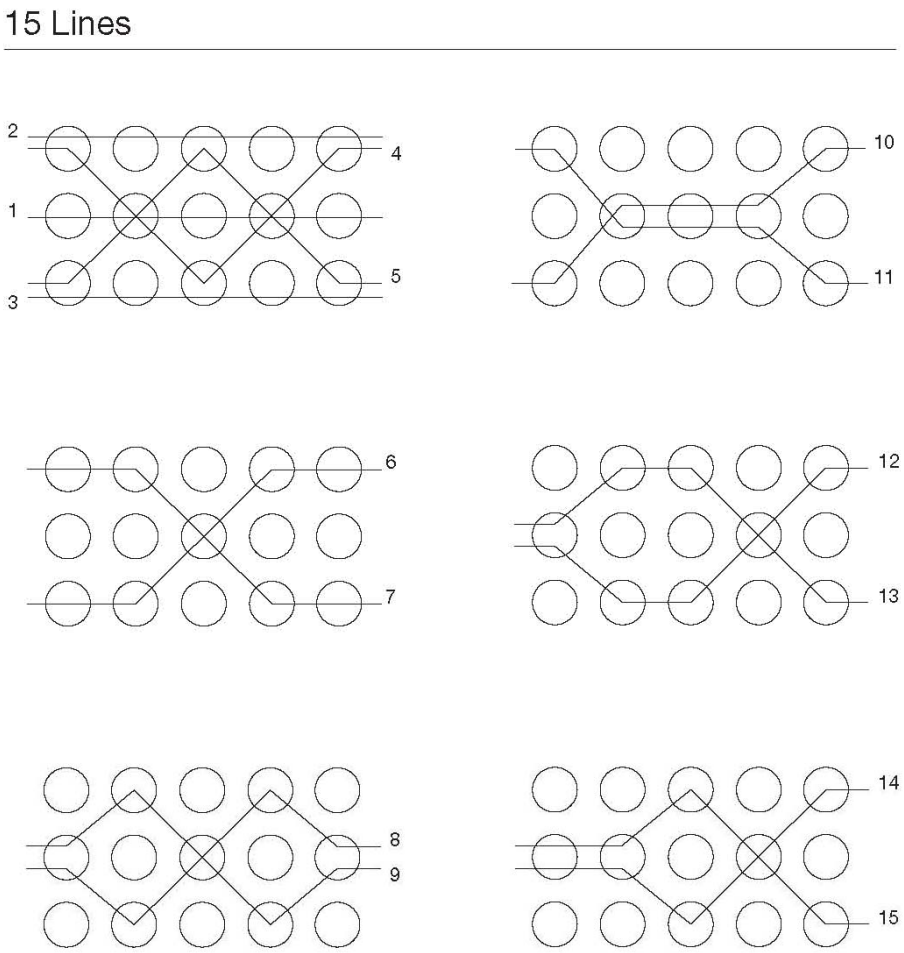


Table 2

Calculation of volatility index for the 92.5% version of *Double Diamond Deluxe*, for a three-credit wager of $0.75

For each possible win or loss, the casino's profit is recorded in column A. The amount of the win/loss is then compared with the expected value to determine the variance and standard deviation. The expected value is the Hold.

	A	**B**	**C**	**D**	**E**	**F**	**G**
Max pay	Net pay	# of hits	Probability	Expected values	A-D	E^2	C x F
0	1	319,928	0.85714592	0.07416	0.92584	0.8571797	0.7347281
6	-1	18,960	0.05079733	0.07416	-1.07416	1.1538197	0.058611
15	-4	24,354	0.06524884	0.07416	-4.07416	16.59878	1.0830512
30	-9	7,198	0.01928477	0.07416	-9.07416	82.34038	1.5879149
60	-19	1,510	0.00404557	0.07416	-19.07416	363.82358	1.4718729
75	-24	336	0.00090021	0.07416	-24.07416	579.56518	0.5217279
120	-39	274	0.00073410	0.07416	-39.07416	1526.79	1.120811
150	-49	362	0.00096986	0.07416	-49.07416	2408.2732	2.3356988
240	-79	110	0.00029471	0.07416	-79.07416	6252.7228	1.8427413
300	-99	104	0.00027864	0.07416	-99.07416	9815.6892	2.7349957
480	-159	80	0.00021433	0.07416	-159.07416	25304.588	5.4236515
960	-319	24	0.00006430	0.07416	-319.07416	101808.32	6.5463168
2500	-832	8	0.00002143	0.07416	-832.40749	692902.23	14.8513
						Variance	40.313421
		Combinations	373,248			Standard deviation	6.349285

Volatility index = (z-score for confidence interval) * (standard deviation of the game)
z-score for a 90% confidence interval is: 1.65
Volatility index: 10.476 i.e., 6.349285 x 1.65

To determine the upper and lower limits for a given number of games:
Payback percentage plus/minus (VI/(sqrt(games played)))

90% Confidence interval		
	Lower	Upper
Plays	percentage	percentage
1,000	59.45	125.71
10,000	82.11	103.06
100,000	89.27	95.90
1,000,000	91.54	93.63
10,000,000	92.25	92.92

Note. max = maximum; sqrt = square root; VI = volatility index.

In the games for which we have the PAR Sheets, the different payback percentages of the same game are achieved by changing the symbols on the reels while maintaining the number of symbols per reel. As an example, Table 3 shows the number of occurrences of each symbol on the five reels in the 85% and 96% versions of *Lobstermania*. The number of occurrences of the highest-paying wild card symbol (WS) and other special symbols (LO and LT) do not vary between versions (2-2-1-4-2, 2-5-6-0-0, and 2-2-2-2-2, respectively). The game designers have manipulated the number of occurrences of all other symbols, such as having 10-3-10-7-8 occurrences of the low-paying SF symbol on the 85.0% version and only 5-5-6-8-7 on the 96.2% version. The right-hand side of Table 3 shows the amount paid for two, three, four, or five occurrences of each symbol. *Lobstermania* is a nickel slot machine; hence, one credit equals one nickel. As can be seen in Table 3, two WS symbols pay five credits, and five WS symbols pay 10,000 credits. All of these payouts are for a wager of one credit on the winning line and are multiplied by the number of credits wagered. If five credits are wagered, two WS symbols pay 25 credits and five WS symbols pay the jackpot of 50,000 credits. Because this is a five-cent game, the jackpot is $2,500.00 (50,000 x $0.05). As shown in Table 1, one result of this manipulation is that the hit frequency is 5.2% in the 96.2% version and slightly lower at 4.9% in the 85.0% version. Table 4 shows a breakdown of the prize structure (i.e., the number of occurrences of each winning amount) for three versions of *Lobstermania*. Most prizes are small, with prizes of two and five credits accounting for approximately 70% to 75% of all winning hits.

Table 3
Game designers manipulate the symbols on the reels to achieve different versions of the same game

Lobstermania: Comparison of reels on 85.0% and 96.2% versions.														
Symbol	85.0%					96.2%					Payout (credits)			
	Symbols per reel					Symbols per reel					2	3	4	5
WS (wild)	2	2	1	4	2	2	2	1	4	2	5	100	500	10,000
LM Lobstermania	4	3	3	3	4	4	4	3	4	4	2	40	200	1,000
BU Buoy	3	4	3	8	5	4	4	5	4	5	0	25	100	500
BO Boat	4	3	4	3	4	6	4	4	4	4	0	25	100	500
LH Light House	3	4	6	3	7	5	4	6	6	7	0	10	50	500
TU Tuna	4	3	6	6	6	6	4	5	6	7	0	10	50	250
CL Clam	10	8	3	4	7	6	6	5	6	6	0	5	30	200
SG Sea Gull	3	9	4	10	5	5	6	5	6	6	0	5	30	200
SF Star Fish	10	3	10	7	8	5	5	6	8	7	0	5	30	150
LO (bonus)	2	5	6	0	0	2	5	6	0	0	0	331	n/a	n/a
LT (scatter)	2	2	2	2	2	2	2	2	2	2	0	5	25	200
Total	47	46	48	50	50	47	46	48	50	50				

Note. n/a = not applicable.

Table 4
The prize structure in the 85.0%, 92.5%, and 96.2% versions of *Lobstermania*

	85.0%		92.5%		96.2%	
Pays	Hits (%)	Pays (%)	Hits (%)	Pays (%)	Hits (%)	Pays (%)
2	22.50	2.59	25.77	2.93	26.23	2.82
5	52.65	15.17	48.18	13.71	44.66	12.01
10	6.73	3.88	7.25	4.13	8.56	4.60
25	6.36	9.16	6.88	9.78	9.05	12.16
30	4.78	8.27	4.53	7.73	3.47	5.60
40	1.96	4.52	2.15	4.90	2.19	4.71
50	1.15	3.30	1.43	4.07	1.75	4.71
100	0.88	5.08	0.86	4.90	1.22	6.53
150	0.57	4.93	0.36	3.11	0.28	2.22
200	0.83	9.55	1.02	11.61	0.86	9.22
250	0.13	1.89	0.17	2.39	0.19	2.58
330	1.18	22.45	1.10	20.63	1.12	19.84
500	0.24	6.79	0.25	7.12	0.38	10.10
1,000	0.04	2.27	0.05	2.87	0.05	2.76
10,000	0.00	0.15	0.00	0.13	0.00	0.13
Total	100.00	100.00	100.00	100.00	100.00	100.00

Mechanical reel slots: Virtual reel mapping, nudges, and near misses

Virtual reel mapping

The PAR Sheets show that the two traditional mechanical reel slot machines games use virtual reels, whereas the two video slots games do not. Physical reels on traditional mechanical reel slot machines have a limited number of stops, usually 22, which limits the number of possible outcomes to 10,648 (22 x 22 x 22 = 10,648). *Double Diamond Deluxe* and *The Phantom of the Opera* use virtual reels, with 72 and 256 stops, respectively, as shown in Table 1, which increases the number of possible outcomes to 373,248 and 16,777,216, respectively (72^3 = 373,248 and 256^3 = 16,777,216). Table 5 shows the mapping of Virtual Reel 1 to Physical Reel 1 for *Double Diamond Deluxe*:

- For each spin, the computer generates a random number between 1 and 72, which corresponds to a position on the 72-stop virtual reel. Each position on the virtual reel has an equal probability of occurring (i.e., 1 in 72).
- A weighted mapping is used to map each of the 72 stops on the virtual reel to one of the 22 stops on the physical reel, which will be on the payline at the end of a spin. As examples, the three Virtual Stops 1 to 3 are mapped to Physical Stop 1, which is a blank; Virtual Stop 4 is mapped to Physical Stop 2, which is the "7"

symbol; and the five Virtual Stops 5 to 9 are mapped to Physical Stop 3, which is a blank.
- Because of the weighting, each stop on the physical reel does not have an equal probability of occurring on the payline; the blank on Physical Stop 1 occurs on the payline 3 out of 72 times, the 7 on Physical Stop 2 occurs 1 out of 72 times, and the blank on Physical Stop 3 occurs 5 out of 72 times.

Nudges

Double Diamond Deluxe and *The Phantom of the Opera* are both "nudging" games. In these two games, the reels spin for approximately 5 s and then, 1 s later, one or more reels may nudge up or down. If the reels do nudge, a blank is always nudged away from the payline and a paying symbol is nudged to the payline. The design of nudges will be explained using Table 5:

- If the virtual stopping position is 10, 11, or 12, then Reel 1 will stop with Physical Stop 4 (i.e., a One Bar) on the payline and there will be no nudge.
- If the virtual stopping position is in the range of 13 to 19, then Physical Stop 5 (i.e., a blank) will stop on the payline after approximately 5 s.
- Then 1 s later, the reel will nudge so that Physical Stop 4 (i.e., the One Bar) will be on the payline.
- Thus, in this game, the blank in Physical Stop 5 is never on the payline at the end of a spin.
- The game's probabilities are not affected by the nudging, as the probabilities are calculated by using the final stopping position after the nudge.
- Importantly, not all physical stops containing blanks get nudged off the payline. Some physical stops associated with blanks do appear on the payline, a fact that contributes to near misses.

Near misses caused by clustering

A near miss is a failure that is close to a win, such as when the high-paying *Double Diamond* symbol appears on the payline on two reels and just above or just below the payline on the third reel. Wilson (2004a) and Harrigan (2007, 2008, 2009) show in detail how manufacturers of traditional mechanical reel slot machine games create this type of near miss by using virtual reels and a technique called clustering, a technique that is used in both *Double Diamond Deluxe* and the *Phantom of the Opera*. This technique is described briefly here with reference to Table 5:

- Using the clustering technique, game designers put a high ratio of blanks adjacent to the high-paying symbols in the virtual reel. As an example, the five virtual stops 22 to 26 are mapped to Physical Stop 7, which is a blank; Virtual Stop 27 is mapped to Physical Stop 8, which is the high-paying *Double Diamond* symbol; and the five Virtual Stops 28 to 32 are mapped to Physical Stop 9, which is a blank.
- This creates near misses as follows:

- Physical Stop 7 (a blank) appears on the payline 5 times out of 72 and when it does, Physical Stop 8 will be below the payline. Thus, the *Double Diamond* in Physical Stop 8 will appear below the payline 5 times out of 72.
- The *Double Diamond* on Physical Stop 8 will appear on the payline 1 time out of 72.
- Physical Stop 9 (another blank) appears on the payline 5 times out of 72 and when it does, Physical Stop 8 will be above the payline. Thus, the *Double Diamond* in Physical Stop 8 will appear above the payline 5 times out of 72.
- This clustering technique results in a near miss, in that the player sees the high-paying *Double Diamond* symbol five times more often in the non-winning position (i.e., above and below the payline) than it appears on the payline.

Table 5

Reel 1 of *Double Diamond Deluxe*: Virtual reel mapping, nudges, and near misses caused by clustering

Random Number Generator (RNG)	72 Stops on the Virtual Reel	# of Virtual Reel Stops Mapped to a Physical Reel Stop		Physical Reel Stop Number	Symbol on the 22-stop Physical Reel	
The Random Number Generator (RNG) generates a number between 1 and 72 which corresponds to a virtual reel stop position.	1 to 3	3		1	~ ~	
	4	1		2	7	
	5 to 9	5		3	~ ~	
	10 to 12	3	→	4	One Bar	Nudge
	13 to 19	7	→	5	~ ~	Nudge
	20 to 21	2		6	Cherry	
	22 to 26	5		7	~ ~	Clustering
	27	1		8	Double Diamond	Clustering
	28 to 32	5		9	~ ~	Clustering
	33 to 35	3		10	One Bar	
	36 to 39	4		11	~ ~	
	40	1	→	12	Three Bar	Nudge
	41 to 42	2	→	13	~ ~	Nudge
	43	1		14	7	
	44 to 51	8	↘	15	~ ~	Nudge
	52 to 54	3	↘	16	One Bar	Nudge
	55 to 59	5		17	~ ~	Clustering
	60	1		18	Double Diamond	Clustering
	61 to 65	5	↘	19	~ ~	Nudge
	66 to 67	2	↘	20	Two Bar	Nudge
	68 to 70	3		21	~ ~	
	71 to 72	2		22	One Bar	

Near misses caused by asymmetric reels

Lobstermania, *Money Storm*, and *The Phantom of the Opera* create another form of near miss with another technique called asymmetric reels. In this form of near miss, when there are several occurrences of a high-paying symbol on one line, it is frequently in non-winning combinations. As an example, in *Lobstermania*, the number of lobster symbols is 2-5-6-0-0 and lobster symbols on Reels 1, 2, and 3 on a played line initiate "Lobster Buoy Bonus." The player sees the lobster symbols 2.5 and 3 times more often on Reels 2 and 3 than on Reel 1. The fact that Reel 1 is "starved" of the lobster symbol (yet it is necessary to get into Lobster Buoy Bonus) elevates the occurrence of near misses (and simultaneously lowers the number of wins).

Near misses caused by wins less than the wager

In our computer analysis, we were also interested in outcomes in which the win is less than the wager, such as when the player wagers $0.75 by wagering $0.05 on each of the 15 lines and wins $0.45. The result of this play is a loss of $0.30 on the spin, but the slot machine game indicates that it is a win. In Table 6, the column "Wins < Wager" shows our results. As an example, when wagering on all 15 lines, the player wins something on 33.52% of the spins and of these wins, 60.73% are less than the wager. This situation can be construed as yet another form of the near miss, as the player sees one or more wins on the spin and yet has actually lost money on the spin. We also show "Wins = Wager," which is a unique situation, as the game outcome is neither a win nor a loss, but the game indicates that it is a win.

Hit frequency: Multi-line wins and scatters

As noted, *Lobstermania* and *Money Storm* are multi-line games. The PAR Sheets show the math for one line only, and as such, the PAR Sheets treat each line as a separate game. For example, as shown in Table 1, the PAR Sheets show that the hit frequency *per line* for the 92.5% version of *Lobstermania* is approximately 5.3%. Hit frequency is defined as "the percentage of time that a machine will give any payout" (Brisman, 1999, p. 258). For a simple single-line game, such as *Double Diamond Deluxe*, the hit frequency reported in the PAR Sheets accurately reflects the percentage of time that the game will give any payout.

However, for multi-line games with scatter wins, the hit frequency in the PAR Sheets does not reflect "the percentage of time that a machine will give any payout." When a player wins two or more times on the same spin, this adds one to the number of hits in the hit frequency for each winning line, as shown in the PAR Sheets, but it adds one only to "the percentage of time that a machine will give any payout" on the spin. To determine this percentage per spin, we wrote a computer program to analyze all 259,440,000 possible outcomes (47 x 46 x 48 x 50 x 50 = 259,440,000), for each potential number of lines wagered, in the 3 x 5 matrix in the 92.5% version of *Lobstermania*. In Table 6, the column "Spins ≥ 1 hit" shows that "the percentage of time that a machine will give any

payout" per spin varies from 5.25% for one line to 33.52% for 15 lines. If there were no scatters and the 15 lines were independent of one another, a player wagering on all 15 lines with a 5.25% hit frequency would expect to win something on 55.5% of the spins (calculated as $1-((1-0.0525)^{15})$). The fact that our analysis of all 259,440,000 possible outcomes shows that the percentage of times that a player wagering on all 15 lines wins something is only 33.52% is accounted for by two factors. First, scatters are counted only once per spin regardless of the number of lines wagered. Second, the 15 lines are not independent of one another. The outcome of a spin is determined by five random numbers that represent the middle row in the 3 x 5 matrix. As an example of the non-independence, if the middle row starts with two wild symbols, then we see from Figure 1 that this guarantees that Lines 1, 14, and 15 will all be wins, as they will all begin with two wild symbols and then some other symbol, which is always a win. Another example occurs when Line 1 begins with two non-wild symbols that are not the same, and then this guarantees that Lines 1, 14, and 15 will not be wins.

Hand-pays

Finally, in our analysis, we calculated the number of wins that are hand-pays. The right-hand side of Table 6 shows our results. The amount won is multiplied by the wager, so that players who make higher wagers will get more hand-pays. For example, when wagering on only one line, there are 32 wins that pay 2,500 (which is $125 and triggers a hand-pay on *Lobstermania*) or more, whereas there are 41,074 outcomes that pay 2,500 or more for a player wagering five credits. Thus, a player wagering five credits has 1,284 times the chance (41,074 ÷ 32 = 1,284) of getting a hand-pay as a player wagering one credit. This large increase in hand-pays is explained by the fact that when wagering one credit in *Lobstermania*, there are 32 wins of 10,000 credits, 6,880 wins of 1,000 credits, and 34,162 wins of 500 credits. Thus, a wager of one or two credits yields 32 wins that are greater than 2,500 credits. A wager of three or four credits yields 6,912 wins (32 + 6,880 = 6,912) of 2,500 credits or greater, as the 6,880 wins of 1,000 are multiplied by the wager and become wins of 3,000 and 4,000. A wager of five credits yields 41,074 wins (32 + 6,880 + 34,162 = 41,074) of 2,500 or greater, as the 34,162 wins of 500 are multiplied by five and become wins of 2,500.

With a maximum bet of five credits on all 15 lines (a total of 75 credits, or $3.75), there are 649,847 outcomes that are hand-pays, which means that, on average, a player gets a hand-pay every 399 spins (259,440,000 ÷ 649,847 = 399). When playing continuously every 3 s, 399 spins take 20 min (399 x [3 ÷ 60] = 20). We considered a scenario in which a player arrives with a bankroll of $100 and makes maximum wagers of $3.75 until broke. On average, the player would make 356 plays on the 92.5% version ($100 ÷ [$3.75 x .075] = 356) and thus have an 89% probability of getting a hand-pay ([356 ÷ 399] x 100 = 89%).

Table 6

The 92.5% version of *Lobstermania*

Lines wagered	Spins ≥ 1 hit (%)	Wins < wager (%)	Wins = wager (%)	# of hand-pays per credits wagered				
				1	2	3	4	5
1	5.25	0.00	0.00	32	32	6,912	6,912	41,074
2	8.77	0.00	29.45	64	68	13,824	13,952	82,632
3	12.16	31.66	0.00	96	119	20,811	21,322	124,102
4	15.34	32.53	0.00	128	215	27,725	28,943	165,298
5	18.37	32.95	28.25	160	445	34,877	37,094	206,184
6	19.93	60.31	0.00	192	511	41,821	45,179	247,457
7	21.50	57.63	1.19	224	590	48,857	53,411	288,615
8	24.07	58.35	0.00	256	703	55,833	62,094	332,858
9	26.51	57.86	0.60	288	848	64,318	72,278	375,890
10	27.72	56.43	6.83	320	1,133	71,678	82,158	419,168
11	28.86	64.34	0.00	352	1,627	80,018	94,174	461,667
12	30.08	62.72	0.44	384	1,804	87,299	104,283	505,445
13	31.34	61.74	0.00	416	2,178	94,907	114,658	549,036
14	32.44	60.20	1.10	448	2,661	103,173	127,610	600,288
15	33.52	60.73	0.81	480	3,439	112,447	142,517	649,847

Note. The table shows (a) the percentage of spins on which the players wins one or more prizes, (b) the percentage of times the win is less than or equal to the wager, and (c) the number of hand-pays of 2,500 credits or more.

Bonus mode wins

Both *Lobstermania* and *Money Storm* have a bonus mode that contributes to the winning hits and winning amounts. In this section, we will describe in detail the bonus mode in *Lobstermania* and note any significant differences compared with the bonuses in *Money Storm*.

Bonus mode wins (*Lobstermania*)

The PAR Sheets do not include any information about the sounds, graphics, and animations, and so in order to observe them, we played and watched others play the games. In particular, as bonus mode is not entered frequently, it took many hours before we entered bonus mode enough times to observe the sounds, graphics, and animations. Also, it took some time to understand the game play within bonus mode and to see how it correlated with the math and computer algorithms as shown in the PAR Sheets.

In *Lobstermania*, the Lobster Buoy Bonus is initiated when the lobster symbol occurs on Reels 1, 2, and 3 on a played line. The number of lobster symbols per reel is 2, 5, 6, 0, and 0, yielding 150,000 possible combinations to initiate the Lobster Buoy Bonus (2 x 5 x 6 x 50 x 50 = 150,000). Thus, the bonus mode is entered, on average, every 1,729 plays (259,400,000 ÷150,000 = 1,729). By playing one line every 3 s, it would take 86.5 min, on average, to enter the bonus mode and 5.8 min if playing all 15 lines. Note that using the "stop-spin" button would cut those times by approximately half.

Figure 2 shows line drawings of the screens that we observed in Lobster Buoy Bonus and is described as follows:

A. When the three lobster symbols appear on Reels 1, 2, and 3 of a played line, the lobster symbols change to contain the words "Pick Me," and they become active in that the screen waits until the player touches one of the lobster symbols (Figure 2A).

B. After the player touches one of the lobster symbols, the screen changes to reveal the numbers 2, 3, and 4 randomly placed behind the three lobster symbols, with the number behind the selected lobster being the only one used in Lobster Buoy Bonus (Figure 2B). The screen stays in this state for approximately 3 s before automatically moving on to the next screen.

C. The next screen is the main screen for the Lobster Buoy Bonus and is broken into two parts. The top part shows an animated, talking lobster fisherman in a boat. The bottom part of the screen shows nine buoys in the water. The player touches a number of buoys corresponding to the number revealed behind the selected lobster in the previous screen (Figure 2C).

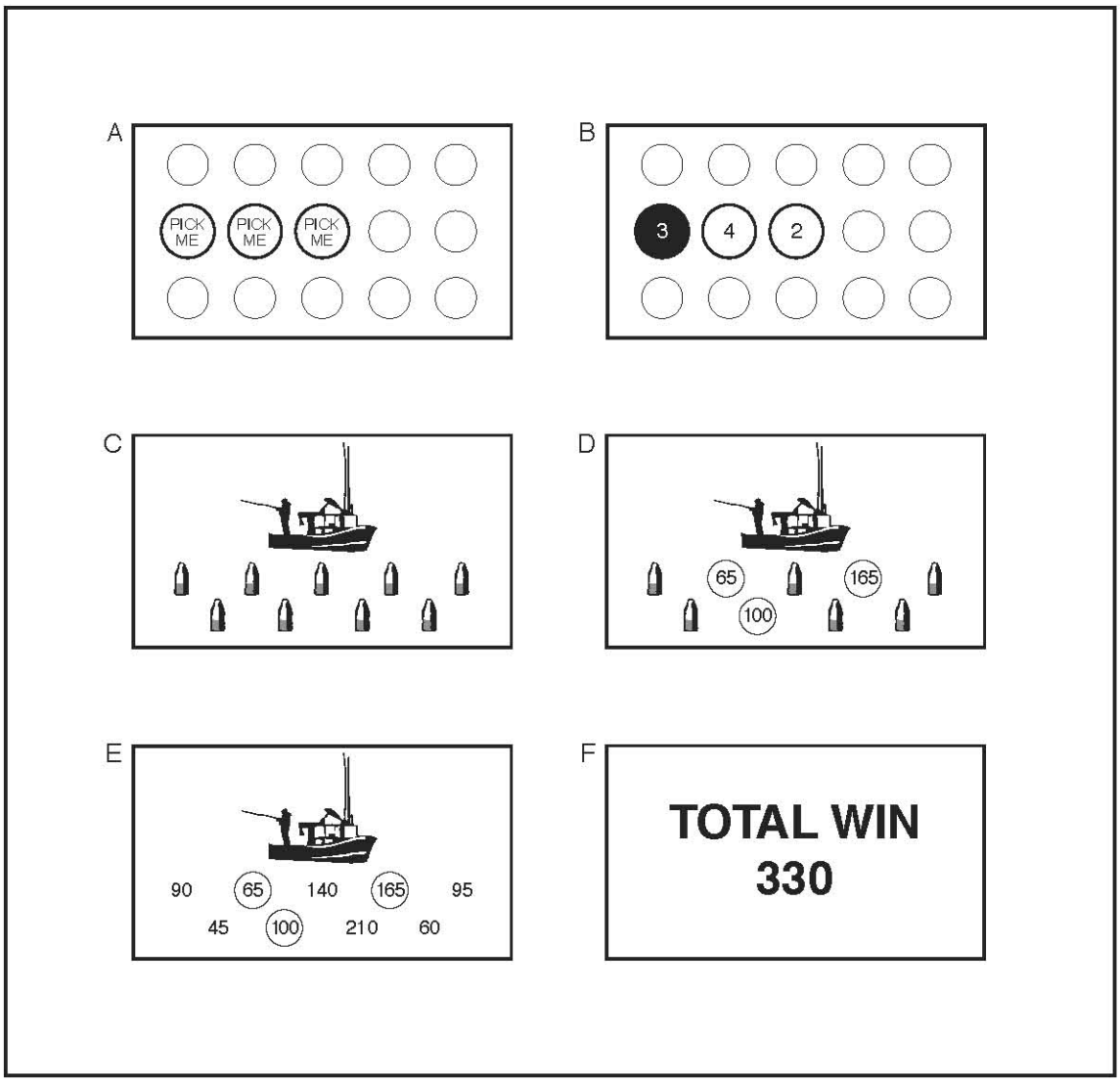
D. The animated and talking lobster fisherman then reveals prizes won within each buoy (Figure 2D).

E. The prizes in the unselected buoys are also shown (Figure 2E).

F. After all prizes are revealed, a screen appears showing the total amount won (i.e., credited to the player’s account; Figure 2F). All wins are multiplied by the bet on the initiating line.

G. The game then automatically returns to the standard game mode.

Figure 2. Various screens in Lobster Buoy Bonus *in Lucky Larry's Lobstermania*.



The PAR Sheets reveal the following:

- In Figure 2B, after the player selects a "Pick Me" shown in Figure 2A, the revealed numbers are always 2, 3, and 4 and the probability of each is equal at one third.
- In screens 2C and 2D, the number of prizes behind each selected buoy has an equal probability of being two or three. Thus, the total number of prizes can vary from a low of 4 (two prizes in each of two buoys) to a high of 12 (three prizes in each of four buoys).
- The amount of each of the two or three individual prizes within a buoy is determined by a random lookup table, with replacement. This is a weighted pay table, which is shown in Table 7. It has the following features:
    - A random number between 0 and 321 is generated and the computer determines where that number is within the lower bounds and upper bounds of the range columns (columns 1 and 2).
    - The corresponding prize column is what the player wins and this win can vary from 5 to 250 (times the wager). For example, if the random number is 100, the prize is 25 (times the wager), whereas a random number of 200 yields a prize of 45 (times the wager).
    - The weight and probability columns reflect the fact that the lookup table is weighted. As an example, the prize of 12 occurs 10 times out of 322, whereas the prize of 250 occurs 5 times out of 322.
    - The contribution column shows, on average, the amount that each potential prize in a buoy will contribute to the average amount won for that prize.
    - The average amount won in Lobster Buoy Bonus is 330.16 credits times the number of credits wagered on the initiating line.

The top half of Table 8 shows a detailed breakdown of all the wins in *Lobstermania* when wagering on one line only. Line wins and scatter account for approximately 90% of all wins. Lobster Buoy Bonus is initiated on 1.01% of all winning hits, but initiating the bonus does not in and of itself generate any winning amounts. Once in the Lobster Buoy Bonus, the player gets wins that account for 7.61% of all winning hits and 21.63% of the total winning amount.

Table 7

Weighted lookup table for determining prizes in *Lobstermania's* Lobster Buoy Bonus

Range		Prize	Weight	Probability	Contribution
Lower	Upper				
0	9	10	10	0.0311	0.3106
10	14	5	5	0.0155	0.0776
15	19	6	5	0.0155	0.0932
20	24	7	5	0.0155	0.1087
25	29	8	5	0.0155	0.1242
30	39	10	10	0.0311	0.3106
40	49	12	10	0.0311	0.3727
50	59	15	10	0.0311	0.4658
60	79	20	20	0.0621	1.2422
80	99	22	20	0.0621	1.3665
100	119	25	20	0.0621	1.5528
120	139	27	20	0.0621	1.6770
140	158	30	19	0.0590	1.7702
159	180	35	22	0.0683	2.3913
181	204	45	24	0.0745	3.3540
205	223	50	19	0.0590	2.9503
224	238	55	15	0.0466	2.5621
239	253	60	15	0.0466	2.7950
254	268	65	15	0.0466	3.0280
269	283	70	15	0.0466	3.2609
284	298	75	15	0.0466	3.4938
299	308	100	10	0.0311	3.1056
309	316	150	8	0.0248	3.7267
317	321	250	5	0.0155	3.8820
				Average number of buoys	3.00
				Average number of prizes per buoy	2.50
				Average pay per prize	44.02
				Lobster Buoy Bonus average pay	330.16

Table 8

Summary of calculations of the various forms of wins when wagering on one line in the 92.5% versions of *Lucky Larry's Lobstermania* and *Money Storm*

	Total Hits		Total Pays	
	Hits	Percentage	Pays	Percentage
Lobstermania				
Line wins	9,382,500	63.46	162,889,616	67.86
Scatter wins	4,126,464	27.91	27,617,760	11.51
Combinations to initiate Lobster Buoy Bonus	150,000	1.01	-	0.00
Lobster Buoy Bonus wins	1,125,000	7.61	49,524,000	21.63
All wins	14,783,964	100.00	240,031,376	100.00
Money Storm				
Line wins	5,164,600	55.42	26,351,150	54.79
Scatter wins	3,238,803	34.76	7,564,140	15.73
Weather Beakon Bonus wins (base)	294,000	3.15	983,920	2.05
Weather Beakon Bonus wins (bonus mode)	1,851	0.02	371,766	0.77
Combos to initiate Free Storm Scatter Bonus	36,750	0.39	1,094,250	2.28
Free Storm Scatter Bonus wins	582,891	6.25	11,733,233	24.39
All wins	9,318,895	100.00	48,098,459	100.00

Bonus mode wins (*Money Storm*)

Money Storm, like *Lobstermania*, has line wins, scatters, and two types of bonuses with the percentage of each winning type, as shown in the bottom half of Table 8. *Money Storm* has a simple bonus called "Weather Beakon [*sic*] Bonus," which has no additional screens and gives instant wins. In *Money Storm*, the combination that initiates the "Free Storm Scatter Bonus" generates instant wins as well as the subsequent wins that are won in Free Storm Scatter Bonus. Free Storm Scatter Bonus wins account for 6.25% of all wins and contribute 24.39% to the payback percentage.

Potential implications for problem gambling

Reinforcement schedules

The founder of the behaviourist movement in psychology, B.F. Skinner, believed that gambling behaviour could be explained by using principles of reinforcement. Of particular importance were the reinforcement schedules forming the patterns of wins and losses. He concluded that "the long-term net gain or loss is almost irrelevant in accounting for the effectiveness of this schedule" (Skinner, 1953, p. 104). Skinner did not, however, explain why some people gamble at problematic levels whereas others do not.

The more recent pathways model of problem and pathological gambling (Blaszczynski, 2000) includes various pathways that may account for problematic gambling, but states that all players, regardless of their pathway into gambling, go through "common processes," including classical and operant conditioning.

Slot machine play involves both operant and classical conditioning. In terms of operant conditioning, pushing the spin button is intermittently reinforced by using a random-ratio reinforcement schedule (the type of reinforcement schedule that yields high rates of responding and is impervious to extinction). One of the consequences of winning is that one becomes aroused. This arousal response is then involved in classical conditioning. The arousal itself serves as an unconditioned response and the proximal cues in the environment (e.g., the lights, the machines themselves) become conditioned stimuli. The upshot of this classical conditioning is that just seeing the machine will begin to trigger the (rewarding) arousal response. Thus, a seasoned gambler approaching a slot machine would be expected to show states of arousal before play has even commenced. As summarized by Blaszczynski and Nower, "Operant conditioning occurs when intermittent wins delivered on a variable ratio produce states of arousal often described as equivalent to a 'drug-induced high,' while with repeated pairings, this arousal is also classical conditioned to stimuli associated with the gambling environment" (Blaszczynski & Nower, 2002, p. 491).

We find it interesting to consider how the various structural characteristics of slot machines revealed by an analysis of the PAR Sheets, and by our field observations, might impact arousal, classical and operant conditioning, and reinforcement schedules.

Not all wins are created equal

In slot machine play, wins are accompanied by characteristic sights and sounds. The majority of these wins are low in value. For example, Table 4 shows that in the 85% version of *Lobstermania*, approximately 82% of the wins are for 10 credits (50 cents) or less (22.5% + 52.7% + 6.7%). Nevertheless, the sounds and sights associated with a win, even if it is for a small amount, serve as sensory cues that differentiate in the gambler's mind winning spins from losing spins.

Some of these small wins are actually losses. Recall that players on a nickel machine such as *Lucky Larry's Lobstermania* can wager on up to 25 cents per line and can wager on up to 15 lines per spin. For those playing the maximum, this translates to $3.75 per spin. For a gambler playing this maximum, two-thirds of their spins (66.48%) will result in losses, but one-third (33.52%) of the time, the lights and sounds of the machine will indicate a win. Crucially, however, on 60.73% of these wins, the amount gained will be *less than the amount that they wagered on that spin*. In other words, on these spins, the sensory cues (flashing lights and sounds that are so important to classical conditioning) point to a win, even though the net outcome of the spin is in fact a loss.

Hand-pay wins

Hand-pays occur when a relatively large amount of money is won (e.g., $125 for *Lobstermania*). Additional sensory stimuli accompany the hand-pay win (the rotating light atop the machine turns on and a siren-type sound begins). Also, the machine stops so that no further play can commence until the person receives the winnings from the attendant. Studies of slot machine gambling suggest that wins lead to increases in arousal (Coventry & Constable, 1999; Coventry & Hudson, 2001). Furthermore, when a gambler's spin results in a relatively big win, the gambler tends not to spin again right away but to pause in play (the so-called post-reinforcement pause – see, for example, Delfabbro & Winefield, 1999). Insofar as arousal is associated with wins, the pauses in game play may give the player adequate time to focus on the pleasurable feelings associated with the win, thereby increasing the reward value. The hand-pay may artificially lengthen this post-reinforcement pause and maximize the rewarding value of the win. In addition, the recipient of the hand-pay may receive reinforcing accolades from fellow players. Such a situation may be especially reinforcing to those who see themselves as skilled players. Our analysis reveals that for those who continuously make the maximum wager, the frequency with which the gambler will experience a hand-pay during an extended gambling session is surprisingly high (a player on a 92.5% *Lobstermania* machine who gambles until the $100 bankroll is gone will have an 89% chance of experiencing a hand-pay.

Bonus mode

The bonus mode is uniformly associated with wins (rewards) and hence likely associated with high levels of arousal. Just as arousal causes the sight of the machine to become classically conditioned (i.e., the machine becomes a conditioned stimulus), the heightened arousal in the bonus mode will also cause conditioning to occur. In the bonus mode, there is a very salient change in the context from regular game play (the animated fisherman appears along with the bonus buoys). In an experienced player, the sight of the animated fisherman, his boat and the bonus buoys would all become prime candidates for conditioning (i.e., these animated elements that appear in the bonus mode would become conditioned stimuli that would trigger the positively rewarding arousal). Thus in the bonus mode, classical conditioning leads to (rewarding) arousal, and the wins in the bonus mode also lead to further (operant) reward. In sum, the bonus round is indeed, in the words of the gambler, "a very good place to be" – it is operantly and classically rewarding. We note that it is unlikely that gamblers would habituate to the extra arousal associated with the bonus mode because the bonus mode lasts only a relatively short period of time and because entering the bonus round occurs only intermittently. From a reinforcement schedule point of view, gamblers know that the bonus mode is a very good (and arousing) place to be, yet they experience the bonus mode only on a random-ratio schedule. This multi-level reinforcement schedule (of wins and the less frequent, but more rewarding, bonus mode) is of potential concern for problem gambling. Recall that only those who are *repeatedly* exposed to the bonus mode will experience the classical conditioning that enables the animated fisherman to become a conditioned stimulus. Hence, only those who are repeatedly exposed to the bonus mode will experience the two

(operant plus classical) triggers of arousal associated with the bonus mode. Thus the very nature of the bonus mode may have preferential effects on problem (as opposed to novice) gamblers.

Near misses

Speculation has also been put forth that near misses are misinterpreted by problem gamblers as a form of win in which "the player is not constantly losing but constantly nearly winning" (Parke and Griffiths, 2004, p. 407). Our analysis shows how clustering techniques and starving certain reels of winning symbols preferentially elevate the instances of near misses. If, indeed, problem gamblers interpret near misses as wins, then one might surmise that they experience rewarding arousal to these near misses. If so, this would change the nature of reinforcement for problem and non-problem gamblers. To whit, problem gamblers would receive rewarding arousal on more spins than would non-problem gamblers. It may also be the case that the relatively big wins associated with hand-pays and the gamblers responses to near misses are not orthogonal in their contributions to problem gambling. We speculate that the highly arousing hand-pays may sensitize the anomalous responses to near misses. Concretely, a near miss involving the symbols that were associated with a recent hand-pay win may prove to be more arousing (and rewarding) than the same near miss occurring before a hand-pay win. Although at present this is mere speculation, we are currently conducting empirical investigations to better understand the relations among big wins and near misses, and their relation to problem gambling.

Illusion of control

Walker's sociocognitive theory of gambling involvement (Walker, 1992, p. 147) states that some potentially heavy gamblers maintain and increase their involvement in gambling by engaging in irrational thinking. The irrational thinking is characterized by three well-known psychological processes, one of which is the illusion of control – a perception that there is more skill in the game than is objectively the case. Langer (1975) defines skill as a situation in which there is a causal link between behaviour and outcome. She conducted six experiments showing that when a person is allowed to make choices in a random event, a perceived skill factor is introduced for the person and thus fosters an illusion of control. In one experiment, Langer allowed half of the subjects to choose their raffle ticket, whereas the other half were not given a choice (choice was the skill factor). Later, the subjects were asked to sell back their ticket or trade it for a ticket in a different raffle that had better odds. People who were able to choose their tickets valued their tickets as being worth significantly more than did those people who did not get to choose their tickets, although both groups clearly understood that the outcome of the raffle was random.

With respect to our analysis of the four games, there are multiple points at which players can make choices, including pressing the stop button to speed up game play and making several choices in bonus mode. The stop spin does not affect the game outcome, but using the button on the video slots provides the gambler with an illusion of control, as it

gives the player the impression that the stop spin button is somehow a factor in determining the stopping position of the reels (Ladouceur & Sévigny, 2005). When the Lobster Buoy Bonus feature is triggered in *Lobstermania*, the player chooses between three lobster traps to enter the feature (see Figure 2A). Then, within the feature, the player has to choose several of nine buoys (see Figure 2C). The result of both choices is random, with the result determined by a lookup table (shown in Table 8). However, the fact that the player consciously chooses some of the buoys and not others provides a situation conducive to an illusion of control, similar to the Langer lottery example described earlier.

Myths and irrational thinking: Multiple versions of the same game

Ontario approves multiple versions of the same game, with the payback percentage being the most notable difference between different versions. One slot machine may be running one version of a game, whereas another identical-looking slot machine, in the same or a different Ontario gambling facility, may be running a version of the same game with a different payback percentage. Importantly, this is concealed from the player – the games look identical and are played in the same way – because three lobsters in a row wins in both games. The player's experience varies significantly from game to game because, on average, the player loses four times more money per spin on an 85% version compared with a 96.2% version, which means that for a given bankroll, the player can gamble four times longer on the 96.2% version.

Gamblers commonly believe that some slot machines are "hot or loose" (i.e., ready to payout), whereas others are "cold." Indeed Turner and Horbay (2004) cite this belief as one of the common myths held by gamblers, namely, that "some machines are set to be loose." Turner and Horbay acknowledge that "machines do indeed vary in payback percentage and hit frequency" but state that the odds are not typically posted and it "would be impossible to determine which machines were actually set to pay out more." However, given the wide variation in payback percentage (85% vs. 98%) of the different versions of the games approved in Ontario, it is not beyond the realm of possibility that an experienced player could discriminate between a loose machine (i.e., a 98% version) and a machine with a much lower payback percentage (i.e., an 85% version). Indeed Haw (2008) showed in a laboratory setting that a subset of his participants were sensitive to payback percentage – after sampling two machines for 40 spins each, 80% of this subsample chose to gamble on the machine with the higher payback percentage.

If there really are instances of loose and tight machines (as predetermined by the payback schedules), and experienced gamblers can (eventually) tell the difference between them, this may feed into the gamblers self-attribution of "gambling skill." One nefarious consequence of this self-attribution is that problem gamblers may develop a faith in their skill and apply this skill to choosing things such as the bonus buoys in the bonus mode. They win, and despite the fact that their choices are irrelevant (the lookup table determines what they win), they will likely attribute their winning to their skill level. Such mentations will likely generalize to other situations where perceived skill is applied to other chance outcomes (hot vs. cold blackjack tables, dealers, etc.). The bottom line is

that having visually identical machines with different payback percentages may start gamblers down the road of seeing their winning as evidence of ability – a situation that may make it harder for them to realize that with enough plays, everyone loses, regardless of a particular machine's payback percentage.

Our analyses of the PAR Sheets have implications not only for research, but also for policy and clinical interventions in problem gambling. Consider a person who gambles twice per week and always plays the same machine. Given that it is legal to have a range of payback percentages in Ontario, and given that payback percentage can be easily changed by the owners through the machine settings options, it is theoretically possible for this person to gamble on a machine with a high payback percentage early in the week and on one with a low-payback later in the week. One questions the fairness of this practice from the consumer's perspective.

Furthermore, a number of problem gambling prevention campaigns cite that mistaken beliefs about the odds of winning at gambling constitute a key risk factor for developing problem gambling. Information-based treatment approaches often will try to teach gamblers that outcomes on slot machines are random and that if gamblers play any machine long enough, they will ultimately lose. Although this is true, it is also true that players are more likely to experience more wins on a high payback percentage machine than on a low payback percentage machine. Problem gamblers may focus on this latter information, and, to their detriment, fail to focus on the fact that if you play any machine long enough, you will invariably lose. Thus, having identical-looking machines with different payback percentages may serve to muddy the waters in the minds of problem gamblers when it comes to the messages they are receiving from information-based intervention strategies and may even serve to undermine these campaigns.

Conclusions

In this research, we have used information provided in PAR Sheets to learn more about the structural characteristics of slot machine games. Where such information was lacking (e.g., the bonus mode of *Lucky Larry's Lobstermania*) we either played or observed others playing slot machines in a real gambling venue to gain a further understanding of these slot machines. In particular, the PAR Sheets show detailed information about the overall design of slot machine games and provide specific information about the frequency of wins, losses, and near misses. The analysis provides a number of intriguing findings. These include the following: (a) With a bankroll of $100.00 and making the maximum wager, one has an 89% chance of encountering a hand-pay of at least $125.00 (assuming one continues to play until the bankroll is depleted); (b) a substantial number of wins are actually losses. For gamblers placing the maximum bet on 15 lines of a nickel machine, 35% of their signalled wins will be less than their wager per spin; (c) the myth that there are loose and tight slot machines is actually true and could contribute to the evolution of gamblers' "systems" and other faulty cognitions; (d) bonus modes are highly salient environments associated with wins that are in the view of the gambler a very good place to be. Because entering these arousing and highly rewarding bonus environments is

rare, only those who gamble frequently will become classically conditioned to these environments and experience the combined effects of operant and classical conditioning – a situation that could preferentially target problem gamblers.

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References

Blaszczynski, A. (2000). Pathways to pathological gambling: Identifying typologies. *Journal of Gambling Issues, 1*. Retrieved from http://www.camh.net/egambling/issue1/feature/index.html

Blaszczynski, A., & Nower, L. (2002). A pathways model of problem and pathological gambling. *Addiction, 97,* 487-499.

Brisman, A. (1999). *American Mensa guide to casino gambling: Winning ways.* New York: Sterling Publishing.

Coventry, K.R., & Constable, B. (1999). Physiological arousal and sensation seeking in female fruit machine players. *Addiction, 94,* 425-430.

Coventry, K.R., & Hudson, J. (2001). Gender differences, physiological arousal and the role of winning in fruit machine gamblers. *Addiction, 96,* 871-879.

Delfabbro, P. H., & Winefield, A. H. (1999). Poker-machine gambling: An analysis of within session characteristics. *British Journal of Psychology. 90,* 425-439.

Freedom of Information and Protection of Privacy Act, R.S.O. 1990, Chapter F.31 (2007). Retrieved Oct 12, 2007, from http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90f31_e.htm

Griffiths, M. (1993). Fruit machine gambling: The importance of structural characteristics. *Behavioral Science, 9,* 101-120.

Griffiths, M. (1994). The role of cognitive bias and skill in fruit machine gambling. *British Journal of Psychology, 85,* 351-369.

Griffiths, M. (1995). *Adolescent gambling.* London: Routledge.

Griffiths, M. (1999). Gambling technologies: Prospects for problem gambling. *Behavioral Science, 15,* 265-283.

Harrigan, K.A. (2007). Slot machine structural characteristics: Distorted player views of payback percentages. *Journal of Gambling Issues, 20.* 215-234.

Harrigan, K.A. (2008). Slot machine structural characteristics: Creating near misses using high symbol award ratios. *International Journal of Mental Health and Addiction, 6,* 353-368.

Harrigan, K.A. (2009). Slot machines: Pursuing responsible gaming practices for virtual reels and near misses. *International Journal of Mental Health and Addiction,* 7(1), 68-83.

Haw, J. (2008). The relationship between reinforcement and gaming machine choice. *Journal of Gambling Studies, 24,* 55-61.

Ladouceur. R., & Sévigny, S. (2005). Structural characteristics of video lotteries: Effects of a stopping device on the illusion of control and gambling persistence. *Journal of Gambling Studies, 21,* 117-131.

Langer, E. (1975). The illusion of control. *Journal of Personality and Social Psychology, 32,* 311-318.

Locke, K. (2001, August). Above PAR. *Slot Tech Magazine,* 4-8.

Parke, J., & Griffiths, M. (2004). Gambling addiction and the evolution of the "near miss." *Addiction Research and Theory, 12,* 407-411.

Parke, J., & Griffiths, M. (2006). The psychology of the fruit machine: The role of structural characteristics (revisited). *International Journal of Mental Health and Addiction, 4,* 151-179.

Skinner, B.F. (1953). *Science and human behavior.* New York: Macmillan.

Turner, N., & Horbay, R. (2004). How do slot machines and other electronic gambling machines really work? *Journal of Gambling Issues, 11*. Retrieved from http://www.camh.net/egambling/issue11/jgi_11_turner_horbay.html

Walker, M. (1992). *The psychology of gambling.* New York: Pergamon Press.

Williams, R., & Wood, R. (2004). *Final report to the Ontario Problem Gambling Research Centre: The demographic sources of Ontario gaming revenue.* Retrieved February 26, 2008, from http://www.gamblingresearch.org/contentdetail.sz?cid=198&pageid=1042&r=s

Wilson, J. (2003, December). Slot machine volatility index. *Slot Tech Magazine,* 10-17.

Wilson, J. (2004a, January). Virtual reels? Physical reels? Just the real truth. *Slot Tech Magazine,* 18-22.

Wilson, J. (2004b, February). PAR excellence: Improve your edge. *Slot Tech Magazine,* 16-23.

Wilson, J. (2004c, March). PAR excellance: Part 2. *Slot Tech Magazine*, 16-21.

Wilson, J. (2004d, April). PAR excellance: Part 3. *Slot Tech Magazine*, 20-26.

Wilson, J. (2004e, May). PAR excellence – Improving you game – Part IV. *Slot Tech Magazine*, 21-24.

Wilson, J. (2004f, June). PAR excellance: Part V: The end is here! *Slot Tech Magazine*, 24-29.

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