Slot machine structural characteristics: Distorted player views of payback percentages

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Abstract

This paper presents a sample three-reel three-coin slot machine game with a bonus for three coins, and a true payback percentage of 85.6% when one or two coins are wagered and 92.5% when three coins are wagered. The player sees the winning or losing combination of three symbols on the payline as well as (a) the physical reels as they scroll by and (b) what is just above and just below the payline at the end of play. An analysis of this game shows that observing the physical reels and what is just above and just below the payline indicates that the slot machine would lose money, and thus the player would make money, as the game would have a payback percentage in the range of 192%–486% if this reflected reality. The paper concludes by discussing the results of the analysis in terms of gaming regulations and problem gambling.
Keywords: slot machine, probability, randomness, virtual reels, gaming regulations, problem gambling

Introduction

The payback percentage of a slot machine is determined by a computer program inside the slot machine. The underlying algorithms that the computer uses to create a slot machine game have been described by Turner and Horbay (2004) in their paper directed toward counsellors who treat and researchers who study problem gambling. The algorithms are also documented in articles in other disciplines, such as the gaming industry papers by Locke (2001) and Wilson (2003, 2004a, 2004b, 2004c, 2004d, 2004e, 2004f) and by a senior executive from an independent gaming lab (Maida, 1997). The algorithms are based on a recently expired patent (Telnaes, 1984).

The payback percentage of a slot machine game cannot be determined by examining (a) the symbols on the physical reels in the slot machine or (b) what is displayed just above or just below the payline in the payline window at the end of a play. The purpose of this paper is to use a sample slot machine game to determine the difference between the true payback percentage, as determined by the computer, and the payback percentage as indicated (a) on the physical reels and (b) by what is displayed just above or just below the payline in the payline window at the end of a play.

The difference between the true payback percentage and the payback percentage as indicated on the physical reels will be termed the physical reel distortion factor (PRDF). The difference between the true payback percentage and what the player sees just above

and just below the payline in the payline window will be referred to as the payline window distortion factor above/below (PWDFa and PWDFb, respectively).

The paper is written to help problem gambling researchers better understand how slot machines can be random and yet guarantee that the physical reel distortion and the payline window distortions do exist.

To do this analysis, a slot machine pay table is needed. The manufacturers of slot machines and the jurisdictions in which they are located do not make the pay tables publicly available. Thus, a sample slot machine pay table detailed by Wilson's seven articles in *Slot Tech Magazine* is used (Wilson, 2003, 2004a, 2004b, 2004c, 2004d, 2004e, 2004f). It is a three-reel three-coin slot machine with a bonus for the maximum bet of three coins. Although there are many different slot machine games available on the market, Wilson chose to document a simple three-reel three-coin machine to keep the calculations "simple and easy" (Wilson, 2003, p. 12).

Using the sample slot machine from Wilson, the first section of this paper shows the calculations that determine the payback percentage based on the physical reels, while the second section shows the true payback percentage as determined by the computer. In the third section, an analysis is done on the difference between the true payback percentage and what appears just above and just below the payline in the payline window. The fourth section discusses the distortions as they relate to gaming regulations and problem gambling.

PRDF

Until the mid-1980s, the true payback percentage on a slot machine could be calculated using the physical reels. Older, mechanical slot machines were built so that each symbol on each reel had an equal chance of occurring on the payline. The reels commonly had 22 stops, so the total number of reel combinations on the payline in a three-reel mechanical slot machine was 10,648 ($22 \times 22 \times 22$).

When computers were introduced into slot machines, the computer randomly controlled the outcome with an equivalent number of combinations as the mechanical slot machines had, so that a slot machine with 22 stops per reel would continue to have 10,648 reel combinations on the payline. The technique the computer used for doing this was patented by Saxton (1978) and used a straightforward mapping of random numbers to the 22 stops.

In this section, the payback percentage of a sample slot machine game is calculated using the physical reels as though the physical reels represented the odds as they did in the older, mechanical slot machines.

The game Wilson designed is a three-coin, three-reel slot machine with 22 stopping positions per reel and a bonus for the jackpot on a maximum bet of three coins. On each reel, half of the stops are blank and half are symbols. The layout of the three physical reels is shown in Table 1. Note that in this slot machine the layout of all three physical reels is the same. This is found among some slot machines, but in others the layouts of the three physical reels are different from one another. The calculations and descriptions in this paper apply equally to slot machines in which all three physical reels are the same and slot machines in which the physical reels are different from one another, so the PRDF and the PWDF calculations will be the same in both instances.

Table 1

Layout of the 22 symbols on the physical reels

#	Symbol
1	Double Bar
2	–
3	Single 7
4	–
5	Double Bar
6	–
7	Double 7
8	–
9	Triple Bar
10	–
11	Single 7
12	–
13	Single Bar
14	–
15	Single 7
16	–
17	Single Bar
18	–
19	Double 7
20	–
21	Triple Bar
22	–

For this sample slot machine, the pay table in Table 2 contains the pay glass information—the winning combinations and what they pay. Table 2 shows, for example, that three double 7 symbols on the payline pays 500 credits if one coin is wagered, 1,000

Table 2

Pay table (using the 22 stops on the physical reels)

	Pays per coin			Occurrences			Hits	Credits		
				Per reel						
	1	2	3	1	2	3		1 Coin	2 Coins	3 Coins
3 Double 7s	500	1,000	6,000	2	2	2	8	4,000	8,000	48,000
3 Single 7s	200	400	600	3	3	3	27	5,400	10,800	16,200
Any 3 7s	75	150	225	5	5	5	90	6,750	13,500	20,250
3 Triple Bar	40	80	120	2	2	2	8	320	640	960
3 Double Bar	20	40	60	2	2	2	8	160	320	480
3 Single Bar	10	20	30	2	2	2	8	80	160	240
Any 3 Bars	5	10	15	6	6	6	192	960	1,920	2,880
Any 3 Symbols	2	4	6	11	11	11	990	1,980	3,960	5,940
Total reel combinations				22	22	22	10,648			
Total wagered over the 10,648 reel combinations								10,648	21,296	31,944
Payback over the 10,648 reel combinations								19,650	39,300	94,950
Payback percentage								184.5%	184.5%	297.2%

credits if two coins are wagered, and a bonus jackpot of 6,000 credits if three coins are wagered. Three double 7 symbols is the only winning combination with a bonus for the third coin. All other winning combinations are linear payouts, with two and three coins paying two and three times as much as one coin would.

Calculating the odds using the physical reels

Table 2 shows what the pay table for this slot machine would be if the physical reels were used to determine the true odds. The calculations for the top three winning combinations will be discussed here.

There are eight combinations of three double 7 symbols on the payline because there are two double 7 symbols on each reel (2 × 2 × 2). Thus, the chance of getting any combination of three double 7 symbols is 8 out of 10,648, the total number of reel combinations. There are three single 7 symbols on each reel, thus there are 27 combinations of three single 7 symbols on the payline (3 × 3 × 3) out of 10,648 total reel combinations.

Any three 7s is a winning combination. There are five 7s on each reel (two double 7 symbols and three single 7 symbols), giving 125 reel combinations of any three 7s (5 × 5 × 5) out of 10,648 total reel combinations. However, slot machines pay only the highest amount for any combination of 7s, so we have to subtract from the 125 combinations the eight occurrences of three double 7 symbols on the payline and the 27 occurrences of

three single 7 symbols on the payline, leaving 90 combinations (out of 10,648 total reel combinations) that would pay for any three 7s (125 – 8 – 27).

Payback percentage using the physical reels

The payback percentage is the average amount that is paid on each play. For example, a payback percentage of 90.0% means that, on average, the slot machine pays out 90.0% of the amount that was wagered. Table 2 shows the calculation of the payback percentage as if physical reels were used to determine the payback percentage. With 22 stops, the total number of reel combinations is 10,648 (22 × 22 × 22). For one coin wagered, the payback over these 10,648 reel combinations is 19,650 credits, yielding a payback percentage of 185% (19,650/10,648). The payback percentage for two coins is also 185% (39,300/21,296). For three coins, the total wagered over the 10,648 combinations is 31,944 (10,648 × 3) and the payout is 94,950, yielding a payback percentage of 297% (94,950/31,944). If the physical reels accurately reflected the outcome, the casino would lose money on this slot machine, and players, on average, would make money.

But slot machines make money. Gross gaming profits in Ontario for 2004 are reported in the Ontario Lottery and Gaming Corporation's annual report and fact sheets (OLGC 2006a, 2006b) and the *Canadian Gaming News* (Sack 2005a, 2005b). Using the data from OLGC and Sack's data for eight gaming facilities, we can calculate that the average annual gross profit per slot machine at these eight gaming facilities is $198,828 (with a range from $80,300 to $350,765), yielding an annual gross profit of $1,179,845,352 from the 5,934 slot machines in these eight facilities.

A summary of this section

This section has shown that the physical reels on a sample slot machine would indicate that the player makes, on average, 185% or 297% of his or her wager and thus the machine loses money. However, slot machines make money, so this cannot be true.

The next section details how virtual reel mapping determines the true payback percentage. This information is complementary to and expands upon the description of virtual reel mapping in Turner and Horbay (2004). Virtual reel mapping is used to determine the outcome, and the physical reels are just used as displays to inform the player whether he or she has won or lost.

Table 3

Layout of the 64 symbols on the virtual reels

#	Reel 1	Reel 2	Reel 3	#	Reel 1	Reel 2	Reel 3
1	1) DoubleBar	1) DoubleBar	1) DoubleBar	33	13) SingleBar	13) SingleBar	13) SingleBar
2	1) DoubleBar	1) DoubleBar	1) DoubleBar	34	13) SingleBar	13) SingleBar	13) SingleBar
3	1) DoubleBar	2) –	1) DoubleBar	35	13) SingleBar	13) SingleBar	13) SingleBar
4	2) –	2) –	2) –	36	13) SingleBar	13) SingleBar	13) SingleBar
5	2) –	3)Single 7	3)Single 7	37	13) SingleBar	14) –	13) SingleBar
6	3) Single 7	4) –	4) –	38	13) SingleBar	14) –	13) SingleBar
7	4) –	4) –	4) –	39	14)–	15) Single 7	14) –
8	4) –	5) DoubleBar	5) DoubleBar	40	14)–	16) –	14) –
9	5) DoubleBar	5) DoubleBar	5) DoubleBar	41	15) Single 7	16) –	15) Single 7
10	5) DoubleBar	5) DoubleBar	5) DoubleBar	42	16) –	17) SingleBar	16) –
11	5) DoubleBar	5) DoubleBar	5) DoubleBar	43	16) –	17) SingleBar	16) –
12	5) DoubleBar	5) DoubleBar	5) DoubleBar	44	17) SingleBar	17) SingleBar	17) SingleBar
13	5) DoubleBar	5) DoubleBar	5) DoubleBar	45	17) SingleBar	17) SingleBar	17) SingleBar
14	5) DoubleBar	5) DoubleBar	6) –	46	17) SingleBar	17) SingleBar	17) SingleBar
15	5) DoubleBar	6) –	6) –	47	17) SingleBar	17) SingleBar	17) SingleBar
16	6) –	6) –	6) –	48	17) SingleBar	18) –	17) SingleBar
17	6) –	6) –	7) Single 7	49	17) SingleBar	18) –	17) SingleBar
18	6) –	6) –	7) Single 7	50	17) SingleBar	18) –	17) SingleBar
19	6) –	7) Double 7	8)–	51	17) SingleBar	18) –	17) SingleBar
20	7) Double 7	8)–	8)–	52	18) –	19) Double 7	18)–
21	8) –	8) –	8) –	53	18) –	20) –	18)–
22	8) –	8) –	9) TripleBar	54	18) –	20) –	18)–
23	8) –	8) –	9) TripleBar	55	18) –	20) –	18)–
24	8) –	9) Triple Bar	9) TripleBar	56	19) Double 7	20) –	18)–
25	9) TripleBar	9) Triple Bar	9) TripleBar	57	20) –	21) TripleBar	19) Double 7
26	9) TripleBar	9) Triple Bar	9) TripleBar	58	20) –	21) TripleBar	20)–
27	9) TripleBar	10) –	10) –	59	20) –	21) TripleBar	20)–
28	10) –	10) –	10) –	60	20) –	21) TripleBar	20)–
29	10) –	11) Single 7	11) Double 7	61	21) TripleBar	21) TripleBar	20)–
30	11) Single 7	12) –	11) Double 7	62	21) TripleBar	21) TripleBar	20)–
31	12) –	12) –	12) –	63	21) TripleBar	21) TripleBar	21) TripleBar
32	12) –	13) SingleBar	12) –	64	22) –	22) –	22) –

Virtual reel mapping

The main point of this section is to show what the actual pay table is for this sample slot machine, so that we can compare the true payback percentage with the fact that the

physical reels would indicate that the player, on average, makes money on this sample slot machine.

A now-expired US patent, called the Telnaes patent (Telnaes, 1984), provides the foundational algorithm for how modern slot machines use a computer to determine the outcome and then display the result using the physical reels on the slot machine. In the background of the invention section of his patent, Telnaes states, "it is important to make a machine that is perceived to present greater chances of payoff than it actually has within the legal limitations that games of chance must operate." Before its expiry, the Telnaes patent was owned by the slot machine manufacturer International Game Technology (Wilson, 2004a, p. 19) and was licensed to other manufacturers. In his patent, Telnaes did not use the term "virtual reel mapping," but this is the term used now to describe his algorithm.

Maida (1997, p. 45) describes the Telnaes patent as follows:

> This method alters the odds of hitting any particular combination. The virtual reel may have any range of numbers from one to infinity. (As a practical manner, numbers greater than 512 have not been attempted.) Each number of the range is "mapped" to a range of 1 to 22—the number of symbols on the physical reel.
>
> The random-number generator chooses one number for each reel and then "maps" it to the physical reel. The reel spins to that position, and the machine evaluates the ending stop positions to determine whether a win or a loss has occurred.
>
> This method dominates the technology currently used in industry: more than 80% of spinning-reel slot machines use this algorithm.

In his articles, Wilson first describes in detail the concept of virtual reel mapping (2004a). In his subsequent papers, Wilson documents many aspects of slot machines using a sample slot machine game that he made up (2004b, 2004c, 2004d, 2004e, 2004f). Wilson's sample slot machine game has 64 virtual stops per reel (Table 3). Since the physical reel has only 22 stops, the virtual reel has to be mapped to the physical reel, with the game designers choosing the mapping. In Table 3, column one is the number of the virtual stop. Column two shows for reel 1 the physical stop position and the symbol at that stop position. For example, on reel 1, physical stop 1 is the double bar, physical stop 2 is a blank, physical stop 3 is a single 7, and so on until physical stop 22, which is a blank.

Looking at reel 1 in Table 3, we see that virtual stops 1 to 3 are mapped to physical stop 1, virtual stops 4 and 5 are mapped to physical stop 2, virtual stop 6 is mapped to physical stop 3, and so on until all 64 virtual stops are mapped to all 22 physical stops. Reels 2 and 3 each have their own mapping, as shown in Table 3. It was noted earlier that the three

physical reels on our sample slot machine are identical, but Table 3 shows that the virtual reels underlying them are not identical.

A comparison of the virtual reels and the physical reels is shown in Table 4. On all three physical reels the highest-paying symbol, double 7, occurs 9% of the time (2 out of 22), whereas on virtual reels one and two double 7s occur 3% of the time (2 out of 64) and on virtual reel three double 7s occur 4.7% of the time (3 out of 64). Thus, for reel 1, comparing the virtual stops with the physical stops shows that double 7 occurs 291% more often on the physical reel than on the virtual reel (2 out of 22 (9%) versus 2 out of 64 (3%)).

Conversely, we see that lower-paying symbols occur on the virtual reels more often than they appear on the physical reels. The lowest-paying symbol is single bar. It occurs 9% of the time on each of the three physical reels (2 out of 22), whereas it appears 22% of the time on virtual reel 1 (14 out of 64). Thus, for reel 1 the single bar occurs on the virtual reel only 42% of the times that it occurs on the physical reel (2 out of 22 (9%) versus 14 out of 64 (22%)).

Table 4

Comparison of virtual reels and physical reels

Symbol	Virtual reels			All three physical reels	Distortion		
	Reel 1	Reel 2	Reel 3		Reel 1	Reel 2	Reel 3
–	29	29	28	11	110%	110%	114%
Double 7	2	2	3	2	291%	291%	194%
Single 7	3	3	4	3	291%	291%	218%
Triple Bar	6	10	6	2	97%	58%	97%
Double Bar	10	9	9	2	58%	65%	65%
Single Bar	14	11	14	2	42%	53%	42%
Total Stops	64	64	64	22			

To determine the true payback percentage for this game, we must do the same calculations that were done in Table 2 in the PRDF section, but instead of using the 22 stops on the physical reels in the calculations we use the 64 stops on the virtual reels. The calculations and results for the virtual reels are shown in Table 5.

Table 5

Pay table (using the virtual reels)

	Pays per coin			Occurrences			Hits	Credits		
				Per reel						
	1	2	3	1	2	3		1 Coin	2 Coins	3 Coins
3 Double 7s	500	1,000	6,000	2	2	3	12	6,000	12,000	72,000
3 Single 7s	200	400	600	3	3	4	36	7,200	14,400	21,600
Any 3 7s	75	150	225	5	5	7	127	9,525	19,050	28,575
3 Triple Bar	40	80	120	6	10	6	360	14,400	28,800	43,200
3 Double Bar	20	40	60	10	9	9	810	16,200	32,400	48,600
3 Single Bar	10	20	30	14	11	14	2,156	21,560	43,120	64,680
Any 3 Bars	5	10	15	30	30	29	22,774	113,870	227,740	341,610
Any 3 Symbols	2	4	6	35	35	36	17,825	35,650	71,300	106,950
Total reel combinations				64	64	64	262,144			
Total wagered over the 262,144 reel combinations								262,144	524,288	786,432
Payback over the 262,144 reel combinations								224,405	448,810	727,215
Payback percentage								85.6%	85.6%	92.5%

Table 5 shows that the true payback percentage for this slot machine is 85.6% if one or two coins are played and 92.5% if three coins are played. Our results are the same as Wilson's (2004c), as we are discussing his slot machine game. This is within the regulated payback percentage range for slot machines in many jurisdictions in North America. The 92.5% payout means that, on average, for each play the casino makes 7.5%—what is called the hold (100% – 92.5%). Stated from the player's perspective, the player loses, on average, 7.5% of his or her bet on each play.

Summary of this section

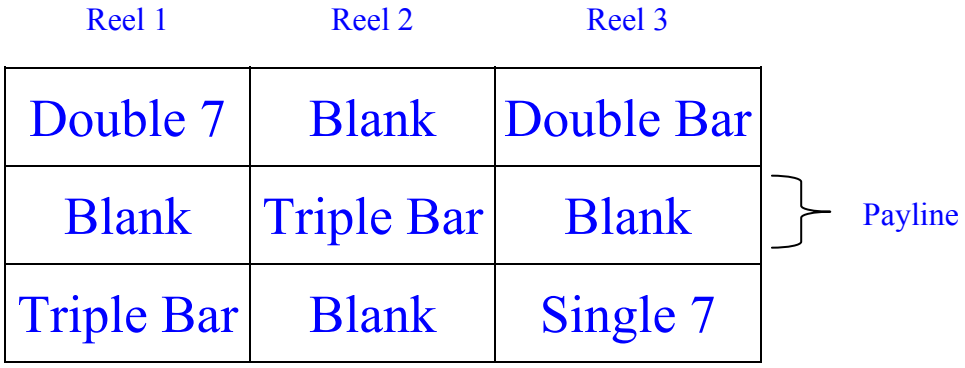
Many variations of slot machine games are on the market (thousands have been approved in North America), so it is impossible to say anything about a particular slot machine without having access to its pay table. However, earlier it was shown that, using the physical reels with one or two coins, the sample slot machine would pay out, on average, 1.85 credits for every credit that was wagered, and, for a maximum bet of three coins, it would pay out, on average, 2.97 credits for every credit wagered. The true odds show that it pays out on average 0.856 credits for every credit wagered with one or two coins and 0.925 credits when three coins are wagered. This means that the payback percentage indicated using the physical reels is more than two and three times higher than the true payback percentage (i.e., 185%/85.6% equals 2.16 and 297%/92.5% equals 3.21).

PWDF

This section discusses the difference between the true payback percentage and what the player sees just above or just below the payline in the payline window. The issue is first discussed and then the sample slot machine from Wilson (2004b, 2004c, 2004d, 2004e, 2004f) is used in an analysis of the difference between the payback percentages.

When a player plays a slot machine, he or she either wins or loses on each play, and the results are displayed on the payline. This section concerns itself with what three symbols are displayed in the payline window just above and just below the payline. Figure 1 shows a sample of a payline window on a slot machine. On the payline are the symbols or blanks (in this case, blank on reel 1, triple bar on reel 2, and blank on reel 3). Also typical, as can be seen in Figure 1, is that above and below the payline the player can see one or two symbols on each reel for a total of three to five symbols on each reel (i.e., one symbol on the payline, one or two symbols above the payline, and one or two symbols below the payline). This total area of view is called the payline window. What we are seeing in Figure 1 is physical stops 19 to 21 on reel 1, physical stops 8 to 10 on reel 2, and physical stops 1 to 3 on reel 3.

Figure 1. Sample payline window.



Manufacturers can design the game so that the symbols just above and just below the payline are unequally distributed so that (a) higher-paying symbols appear more often just above or just below the payline than they would by chance and, conversely, (b) lower-paying symbols appear less often than they would by chance. We can see how this is done by examining in more detail the virtual reel in Table 3. For this discussion we will assume that we can see three symbols in the payline window for each reel—one symbol on the payline, one above the payline, and one below the payline—although this is a design that can vary from machine to machine. The overall issues of how and why the

PWDFs are designed into games are similar for all games that include a PWDF regardless of how many symbols can be seen in the payline window. The results of the mathematical analysis will vary but the overall issues are the same.

In Table 3 we see that on reel 1 the virtual stops 16 to 19 are blanks and are all mapped to the physical stop 6. Virtual stop 20 is a double 7 and is mapped to physical stop 7. Virtual stops 21 to 24 are blanks and are all mapped to physical stop 8. Only two double 7 symbols are on reel 1. The other is at virtual stop 56. It is also similarly surrounded by eight blanks on the virtual reel (i.e., virtual stops 52 to 55 and 57 to 60).

We know from Table 3 that double 7 occurs on the payline two times (i.e., virtual stops 20 and 56) out of a possible 64; this is a 3.1% chance of occurring. We can see in Table 6 that because of the mapping of the virtual reel, double 7 will appear just above the payline 8 out of 64 times (12.5%) because the double 7 in virtual stop 20 (i.e., physical stop 7) will occur just above the payline every time virtual stops 21 to 24 (i.e., physical stop 8) appear on the payline and the double 7 in virtual stop 56 (i.e., physical stop 19) will appear just above the payline every time virtual stops 57 to 60 (i.e., physical stop 20) appear on the payline.

Table 6 shows for each symbol on reel 1 the number of times it will appear just above the payline. It is important to note in Table 6 that column one is showing the virtual stop that is on the payline, whereas column two is showing what is just above the payline. We see from the table that on reel 1, when virtual stops 1 to 3 are on the payline, then a blank will be just above the payline; when virtual stops 4 and 5 are on the payline, the double bar will be just above the payline; and so on to see what is just above the payline when each of the 64 stops is on the payline. Table 6 can be cross-referenced to Table 3, as column one in both tables is referring to the virtual stops. The difference between the two tables is that columns two to four in Table 3 are referring to what is on the payline, which is shown in the articles by Wilson (2004b, 2004c, 2004d, 2004e, 2004f), whereas Table 6 is unique to this paper, and column two in Table 6 is referring to what is just above the payline.

For higher-paying symbols, such as double 7, the number of times the symbols appear just above the payline is greater than it would be by chance alone, whereas for the lower-paying symbols, such as single bar, the chances of that symbol appearing just above the payline are lower than they would be by chance alone.

Table 7 shows the results of an analysis to determine the payback percentage for the three symbols occurring just above the payline as if those symbols were used to determine the game outcome. Observing the three symbols just above the payline would indicate that the slot machine has a payback percentage of 193.0% on one and two coins and a payback percentage of 485.9% on three coins.

Table 6

Layout of the 64 symbols just above the payline on Reel 1

#	Reel 1		#	Reel 1
1	1) –		33	13) –
2	1) –		34	13) –
3	1) –		35	13) –
4	2) DoubleBar		36	13) –
5	2) DoubleBar		37	13) –
6	3) –		38	13) –
7	4) Single 7		39	14) SingleBar
8	4) Single 7		40	14) SingleBar
9	5) –		41	15) –
10	5) –		42	16) Single 7
11	5) –		43	16) Single 7
12	5) –		44	17) –
13	5) –		45	17) –
14	5) –		46	17) –
15	5) –		47	17) –
16	6) DoubleBar		48	17) –
17	6) DoubleBar		49	17) –
18	6) DoubleBar		50	17) –
19	6) DoubleBar		51	17) –
20	7) –		52	18) SingleBar
21	8) Double 7		53	18) SingleBar
22	8) Double 7		54	18) SingleBar
23	8) Double 7		55	18) SingleBar
24	8) Double 7		56	19) –
25	9) –		57	20) Double 7
26	9) –		58	20) Double 7
27	9) –		59	20) Double 7
28	10) TripleBar		60	20) Double 7
29	10) TripleBar		61	21) –
30	11) –		62	21) –
31	12) Single 7		63	21) –
32	12) Single 7		64	22) TripleBar

Table 7

Pay table (symbols just above the payline)

	Pays per coin			Occurrences			Hits	Credits		
				Per reel						
	1	2	3	1	2	3		1 Coin	2 Coins	3 Coins
3 Double 7s	500	1,000	6,000	8	8	8	512	256,000	512,000	3,072,000
3 Single 7s	200	400	600	6	6	6	216	43,200	86,400	129,600
Any 3 7s	75	150	225	14	14	14	2,016	151,200	302,400	453,600
3 Triple Bar	40	80	120	3	3	3	27	1,080	2,160	3,240
3 Double Bar	20	40	60	6	6	4	144	2,880	5,760	8,640
3 Single Bar	10	20	30	6	6	7	252	2,520	5,040	7,560
Any 3 Bars	5	10	15	15	15	14	2,727	13,635	27,270	40,905
Any 3 Symbols	2	4	6	29	29	28	17,654	35,308	70,616	105,924
Total reel combinations				64	64	64	262,144			
Total wagered over the 262,144 reel combinations								262,144	524,288	786,432
Payback over the 262,144 reel combinations								505,823	1,011,646	3,821,469
Payback percentage								193.0%	193.0%	485.9%

A detailed analysis is not shown here for just below the payline, but those calculations have been done and the results are that observing the three symbols just below the payline would indicate that the slot machine has a payback percentage of 191.5% on one and two coins and a payback percentage of 484.5% on three coins.

Summary of this section

As discussed earlier, observing the physical reels does not reveal to the player anything about the actual odds, as the odds are designed into the virtual reel mapping. What this section has shown is that not only does virtual reel mapping obscure the odds, but also the mapping itself intentionally increases the probability that the winning combinations will appear disproportionately higher just above and just below the payline.

The following section will discuss the PRDF and PWDFs relative to gaming regulations and problem gambling.

Discussion of gaming regulations and problem gambling

Table 8 includes a summary of the distortions that have been presented in separate sections in this paper. The slot player can see the physical reels as they scroll by but cannot see the virtual reels. The player cannot see the algorithm that is used to determine

Table 8

Summary of payback percentages

Method used to calculate the odds	Payback percentage		
	1 Coin	2 Coins	3 Coins
True odds as determined by the computer	85.6%	85.6%	92.5%
PRDF	184.5%	184.5%	297.2%
PWDFa	193.0%	193.0%	485.9%
PWDFb	191.5%	191.5%	484.5%

the result, so the player has no way of knowing that the results just above and just below the payline are intentionally distorted so that in nonwinning plays the higher-paying symbols appear more often than they would by chance alone. Conversely, the lower-paying symbols appear less often than they would by chance alone.

Gaming regulations

Games such as the one described in this paper have been approved by regulators and independent gaming labs and are widely used in jurisdictions in North America. The main Nevada Gaming Regulation (Nevada Gaming Commission, 2006) that relates to PRDFs and PWDFs is Regulation 14, which states in part in section 14.040:

> [2](b) For gaming devices that are representative of live gambling games, the mathematical probability of a symbol or other element appearing in a game outcome must be equal to the mathematical probability of that symbol or element occurring in the live gambling game. For other gaming devices, the mathematical probability of a symbol appearing in a position in any game outcome must be constant.
> 3. Must display an accurate representation of the game outcome. After selection of the game outcome, the gaming device must not make a variable secondary decision which affects the result shown to the player.

It is important to note that Regulation 14.040 (2b and 3) is referring to gaming devices in general and is not specific to slot machines. It is the responsibility of regulators to interpret the regulations for any given gaming device. For slot machines, the regulators must be aware of the distortions described in this paper, as the design of the distortions is in the par sheets, and the regulators have decided that these distortions are acceptable within Regulation 14.040 (2b and 3).

Thus the regulators are interpreting the regulations to mean that games that include the PRDFs and PWDFs do meet the requirement in 14.040(3) that the game "Must display an accurate representation of the game outcome."

An issue that arises is whether slot machines that have distortions as described in this paper should be legal. This paper does not address this issue directly. Rather, the intent of this paper is to document the distortions, and the corresponding regulations, so that problem gambling researchers may study such distortions to determine if slot machines with such distortions increase the likelihood of problem gambling and should be banned by (a) modifying and/or (b) reinterpreting the existing regulations.

Problem gambling

Some gamblers may gamble without ever having a gambling problem, while others may develop a gambling problem. The Ontario Problem Gambling Research Centre's (OPGRC) problem gambling framework can be used to explain or contextualize a dynamic environment in which gamblers may move between low risk and high risk and also move between the presence of gambling problems and not (OPGRC, 2006). The OPGRC framework aligns the entire population in a continuum defined by risks and problems. It shows that all gamblers have direct and indirect risk factors and any given gamblers may or may not have a gambling problem at any given time. An important aspect of the framework is that it expresses risk and prevalence as percentages on a continuum. Any individual gambler has a probability of experiencing a problem, and that probability increases as the number of risk factors increases.

The OPGRC framework encapsulates the Pathways Model (Blaszczynski, 2000; Blaszczynski & Nower, 2002), which stresses that a large number of factors are important to be able to predict whether a gambler will develop a problem. The larger the number of risk factors that exist for an individual, the higher is the probability that the individual will develop a problem.

The OPGRC framework separates direct risk into (a) risk practices and (b) risk cognitions. Risk practices include items such as regularly spending more time and money gambling than intended, whereas risk cognitions are "serious misunderstandings about the nature of probability and randomness" (OPGRC, 2006). According to the OPGRC framework, risk cognitions "are thoughts and beliefs held by gamblers that support the adoption and maintenance of risk practices" (OPGRC, 2006). Although not stated specifically in the OPGRC framework, we believe that various EGM structural characteristics, such as near misses, function as indirect risk factors and may lead to faulty risk cognitions.

One aspect that deserves attention is what characteristics of a game's design increase risk cognitions. Griffiths (1993, 1995, 1999) uses the term "structural characteristics" to refer to the characteristics of gambling technologies. Structural characteristics of slot machines

include colour, sounds, and speed. Cornish (1978) states that structural characteristics of a particular gambling activity are responsible for reinforcement, may satisfy gambler's needs, and may actually facilitate excessive gambling. Griffith (1995, p. 196) elaborates on Cornish:

> By identifying the particular structural characteristics it may be possible to see how (a) needs are identified; (b) information about gambling is presented (or perhaps misrepresented), and (c) cognitions are influenced and distorted. Showing the existence of such relationships has great practical importance. Not only could potentially "dangerous" forms of gambling be identified, but effective and selective legislation could be formulated.

A slot machine structural characteristic that has been given attention by problem gambling researchers is the "near miss," which *Webster's Third New International Dictionary* (1993) broadly defines as "something that falls just short of success" and Griffiths defines as "failures that are close to being successful" (1995, p. 23). In discussing the frequent occurrence of higher-paying symbols above and below the payline in his sample game described in this paper, Wilson said, "With this design the 7's will be either on the pay line or slightly above or below it most of the time. While this gives the illusion that the 7's have almost lined up on the pay line, it's the virtual reel that tells the truth." (Wilson, 2004a, p. 21). Although Wilson does not use the term "near miss," it is clear from the two definitions above and the quote from Wilson that the frequent occurrence of higher-paying symbols just above and just below the payline produces "failures that are close to being successful" (i.e., near misses).

Several studies have investigated slot machine near misses. Strickland and Grote (1967) and Reid (1986) studied near misses on the payline. The results of their controlled experiments showed that near misses on the payline led to significantly longer playing times. Cote, Caron, Aubert, and Ladouceur (2003) use the term "near win" rather than near miss, and the results of their study of near wins on the payline show that "near wins can be added to the list of factors that may motivate people to gambling" (p. 433). In a controlled experiment reported by Kassinove and Schare (2001), the near miss had a statistically significant effect on the number of games played (which they termed persistence). No studies have been published that have specifically examined PWDF (a & b) and PRDF distortions.

Currently, electronic gambling machines make up a large percentage of gaming industry profits. Studies also show that among gamblers seeking treatment, use of electronic gambling machines tends to be the most common form of gambling (Rush, Moxam Shaw, & Urbanoski, 2002; Becoña, Labrador, Echeburúa, & Ochoa, 1995; Wiebe & Cox, 2001).

Problem gamblers often exhibit misunderstandings about their chances of winning (Wagenaar, 1988; Gaboury & Ladouceur, 1989). The results of the current study suggest that the machines themselves may be a source of some of their erroneous beliefs. Further laboratory and field research is needed, focusing on the extent to which PWDF (a & b) and PRDF may contribute to problematic gambling.

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