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The maximum rewards at the minimum price: Reinforcement rates and payback percentages in multi-line slot machines

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Abstract

Past research has shown that gamblers frequently use the *mini-max* strategy in multi-line slot machines, whereby the player places the minimum bet on the maximum number of lines. Through a detailed analysis and explanation of the design of multi-line slot machine games, we show that when using the mini-max strategy, the payback percentage remains unchanged, yet the reinforcement rate is significantly increased. This increase in reinforcement rate is mainly due to spins in which the amount won is less than the amount wagered, which we call *losses disguised as wins*. We have verified these conclusions by playing an actual slot machine game for 10,000 spins and recording the results. We believe that the high reinforcement rate that results from playing multiple lines on games of this type contributes to their potential addictiveness. We provide three theories for why

players use the mini-max strategy and suggest further areas of research.

Introduction

Modern video slot machines are sophisticated computer games. So-called line games typically have five animated reels that the player "spins" in hopes of winning prizes that are awarded when identical symbols land on the spaces of horizontally arranged paylines. On many of these electronic gaming machines (EGMs), the player can typically wager one to five credits on multiple paylines (typically 9, 15, 20, or more paylines). Haw (2008b, 2009) showed how the rate of operant reinforcement increased as the number of wagered paylines increased on a popular slot machine game in Australia. In this paper, we extend Haw's work on reinforcement rates in multi-line games by using a simple theoretical slot machine game to demonstrate how games of this type are designed. Furthermore, we show how the frequency of prizes increases dramatically as the number of played lines increases and how most of these apparent wins are *losses disguised as wins* (LDWs; Dixon, Harrigan, Sandhu, Collins, & Fugelsang, 2010), in which the prize is less than the amount wagered. We then discuss reinforcement rates in terms of the pathways model of problem and pathological gambling (Blaszczynski & Nower, 2002) and the commonly used *mini-max* strategy, whereby players wager the minimum number of credits on the maximum number of lines (Livingstone, Woolley, Zazryn, Bakacs, & Shami, 2008).

Haw (2009) used the term "multiplier potential" to describe the fact that the total wager on a spin is the product of the denomination of the machine, the number of lines wagered, and the number of credits wagered on each line. He determined that the denomination of the machine and the maximum number of lines were the two most important determinants of the average amount wagered. He stated that "from a behaviourist perspective, these two characteristics represent the operant link between the gambler and the reinforcer and may play a role in understanding gambling as an elicited, contingency-shaped behaviour" (Haw, 2009, p. 1). This hypothesis follows logically from the pathways model of problem and pathological gambling, in which Blaszczynski and Nower (2002) proposed "a process commonly applicable to all gamblers" with

> the influence of classical and operant conditioning leading to increased participation and the development of habitual patterns of gambling, and cognitive process resulting in faulty beliefs related to personal skill and probability of winning. (p. 491)

In an experimental test of the effect of wager size on player behavior, Sharpe, Walker, Coughlan, Enersen, and Blaszczynski (2005) modified existing slot machines to have lower denomination bill acceptors, slower reel spins, and a lower maximum wager. Lowering the maximum bet level from $10 to $1 was accomplished by reducing the multiplier potential of the game. Their results showed that “the reduction in maximum bet levels was the only modification likely to be effective as a harm minimization strategy” (p. 503).

In a field study, Livingstone et al. (2008) interviewed 180 Australian EGM players about their gaming strategies and found that “many participants said their most common pattern was to bet minimum credits on maximum lines (mini-max)” (p. 104). This finding has been supported experimentally by Dixon, MacLin, and Daugherty (2006), who found that 83% of participants preferred a machine with frequent small payouts over a machine with larger but less frequent payouts. This phenomenon is somewhat peculiar when considered in light of the fact that the *payback percentage* of any EGM game does not vary with the number of lines bet.

The payback percentage is the average proportion of money that is bet on an EGM that is returned to players in the form of prizes. The payback percentage is always less than 100% and the remaining amount (the *hold*) is the profit taken by the casino. In this paper, we use a simple theoretical slot machine game to show that, despite having more frequent wins and nominally larger wins when playing multiple lines, the payback percentage remains constant irrespective of the number of lines played and the number of credits wagered per line. We will show that there is no monetary advantage conferred by adopting the mini-max strategy. We will then discuss the different schedules of reinforcement that are created when players adopt the mini-max strategy versus other strategies. We conclude by arguing that players adopt the mini-max strategy in order to maximize the frequency of reinforcement while minimizing the amount that they risk per spin. As Livingstone et al. (2008) concluded, “[EGM players] consistently preferred games where there were frequent wins, with the occurrence of wins seeming more important in problem gambler discourse than the size of those wins” (p. 115). Indeed, studies have shown that player behavior does not change with payback percentage, but is related to reinforcement rate (Haw 2008a; Weatherly & Brandt, 2004). Likewise, B. F. Skinner (1953) wrote in his classic treatise, “Slot machines, roulette wheels, dice cages, horse races, and so on pay off on a schedule of variable-ratio reinforcement. Each device has its own auxiliary reinforcements, but the schedule is the important characteristic” (p. 104). We contend that players’ ability to influence the variable reinforcement schedule[1] of the game, by adjusting the number of lines played and hence the frequency of prizes, may be a key mechanism in the development of problematic gambling behavior.

Money Storm: A Typical Multi-line Slot Machine Game

To illustrate the features of a typical multi-line EGM, we will briefly describe the slot machine game “Money Storm” (Interactive Game Technologies, Reno, NV, USA), shown schematically in Figure 1a. The game shown enables players to play up to a maximum of 20 lines and the player can wager one to five credits on each payline, with each credit having a value of 2 cents. Thus, the minimum wager is one credit (one credit wagered on one payline) and the maximum wager is 100 credits (five credits wagered on each of 20 paylines). In Figure 1b, the player has used the mini-max strategy. The player has wagered the *mini*(mum) number of credits (1 credit) on the *maxi*(mum) number of lines (20). Thus on each spin, the player has wagered a total of 40 cents. Figure 2 contains schematic depictions of each of the 20 paylines. In addition to line wins, this game also has scatter wins and bonus rounds. In this game, a win equal to twice the amount wagered on a payline is given whenever the Money Storm logo falls on the first space of that payline. In the instance illustrated in Figure 1b, the Money Storm logo is in the first space on 9 of the 20 paylines, and so the player has been awarded a total of 18 credits (i.e., two credits won on each of the nine winning paylines). Thus, the player has wagered 40 cents and “won” 36 cents (a loss disguised as a win). At the conclusion of the spin, the game highlights all of the line wins (Figure 1b) and then cycles through each of the wins individually (as in Figure 1a). These visual displays are presented with celebratory music whenever a prize is awarded on at least one payline, even if the total amount awarded on all of the paylines is less than the total amount wagered on the spin. In this instance, the loss of 4 cents was celebrated as a win. These exciting audiovisual events are present only on spins with a prize awarded on at least one payline; outcomes where the players lose their entire spin wager (40 cents in this case) are delivered in stark silence.

The Payback Percentage Is Constant: Example of a Simplified Multi-line Slot Machine Game

Money Storm is a very complex game with five reels, 20 paylines, and an elaborate paytable, making it difficult to illustrate the relations between the mini-max strategy, the frequency of rewarded outcomes, and the fact that despite playing more lines, the payback percentage remains the same. To help explain the concepts of how multi-line slot machines work, we will first examine a simplified slot machine game that we have designed for illustrative purposes, and then we will revisit Money Storm.

Paytable.

Figure 3 shows the paytable for a simple hypothetical three-reel slot machine game that we designed. This game pays prizes for getting three identical symbols on a payline. With one coin wagered, three apples on a payline pays two credits, three bananas on a payline pays four credits, and three cherries on a payline pays 25 credits. With two credits wagered per payline, the wins are doubled to four credits for three apples, eight credits for three bananas, and 50 credits for three cherries.

Paylines.

Our simplified game allows players to bet on up to five paylines. These are shown in Figure 4. The player can wager on one to five paylines (in slot machine jargon, the player is said to "buy a line"). Players must buy lines in order from 1 to 5. If the player chooses to buy one line, the player is wagering on only payline number 1. If the player buys three lines, the wager is on lines 1, 2, and 3; and if the player buys five lines, the wager is on lines 1, 2, 3, 4, and 5. The total credits wagered on a spin are the product of the number of lines wagered multiplied by the wager per line. Thus the minimum wager is one credit (i.e., wagering one credit on one line) and the maximum wager is 10 credits (i.e., wagering two credits on each of the five lines). Consider the following example. If the player had bought only one line, the result in Figure 5a would be a loss because there are not three identical symbols on the first payline (i.e., the middle horizontal row of symbols). However, if the player had wagered on all five lines, there would have been a win of 25 credits on line 3, which contains three cherries (the top row of 5a) and a win of four credits on line 5 (the B's that align in a ˆ shape in Figure 5a), which contains three bananas. The result in Figure 5b has a win of two credits for three apples on line 5. Again, the player would not win anything in this scenario if they were wagering on one line.

Reels.

Harrigan and Dixon (2009) showed two modern five-reel multi-line slot machine games that have been approved for use in Ontario, Canada. The number of symbols per reel was 47, 46, 48, 50, and 50 in one game (Lucky Larry's Lobstermania) and 35, 35, 35, 35, and 35 in the other (Money Storm). In this simplified example, the number of symbols on the video reels is limited to three on the first reel, three on the second reel, and four on the third reel. The reels are designed as an array in a data structure called a *circular linked list*. We will use the third reel, shown in Figure 6, to explain how the circular linked lists work.

- The third reel contains four symbols: apple, banana, apple, and cherry. Each has a stopping position (S1, S2, S3, S4) associated with it.
- A random number between 1 and 4 is generated for the reel.
- If the random number generated is 1, then the apple in stopping position 1 is displayed on the middle horizontal line (i.e., payline # 1), the cherry is displayed above the payline (i.e., payline #3), and the banana is displayed below the payline (i.e., payline # 2).
- If the random number is 2, then the banana in stopping position 2 is displayed on payline #1, the apple in stopping position 1 is displayed above the payline, and the apple in stopping position 3 is displayed below the payline.

- If the random number is 3, then the apple in stopping position 3 is displayed on the payline, with the banana above the payline and the cherry below the payline.
- If the random number generated is 4, then the cherry is displayed on the payline, the apple in stopping position 3 is displayed above the payline, and the apple in stopping position 1 is displayed below the payline.

For the outcome depicted in Figure 5a, the random numbers were 1 for reel 1, 1 for reel 2, and 1 for reel 3. For Figure 5b, the random numbers were 3 for reel 1, 2 for reel 2, and 2 for reel 3.

Random Number Generator.

When the game is idle, the random number generator (RNG) in the slot machine is continuously generating random numbers. As in all three reel EGMs, when the player presses spin, the last three random numbers are used to determine the stopping position of the three reels. On five reel games, it is the last five random numbers that determine the outcome. At the instant the spin button is pressed, the slot machine has determined the outcome, but the player does not know the outcome yet. The animated reels then appear to spin for approximately 5 seconds, and the three symbols corresponding to the three random numbers land on the center payline.

Our simple slot machine game needs three random numbers for each spin: one between 1 and 3 for reel 1, another between 1 and 3 for reel 2, and one between 1 and 4 for reel 3. The RNGs generate large numbers, typically in the range of zero to four billion (thus making it virtually impossible to determine the next numbers to be generated by the algorithm). To get a number between 1 and 3, the large random number is divided by the number of symbols on the corresponding reel and then 1 is added to the remainder. For example, assume that the last three random numbers generated by the RNG were 326,789 for the first reel; 4,102,198 for the second reel; and 957,162 for the third reel.

The three reel positions would be calculated follows:

- 326,789 divided by 3 results in 108,929 with a remainder of 2. One is then added to the remainder to produce the random number “3” for reel 1. The cherry will appear on payline 1 for the first reel.
- 4,102,198 divided by 3 results in 1,367,399 with a remainder of 1. One is then added to the remainder to produce the random number “2” for reel 2. The apple will appear on payline 1 for the second reel.
- 957,162 divided by 4 results in 239,290 with a remainder of 1. One is then added to the remainder to produce the random number “2” for reel 3. The banana will appear on payline 1 for the third reel.

Thus, in this example, the reels stop in positions 3, 2, and 2, which is the outcome shown in Figure 5b.

All Possible Outcomes.

Given that the number of symbols per reel is three on the first reel, three on the second reel, and four on the third reel, the total number of possible outcomes is 36 (calculated as the product of the number of symbols per reel, or 3 × 3 × 4, which equals 36). The total number of combinations is referred to as the game's *cycle*, and so this simple game has a cycle of 36. Each outcome has an equal probability of occurring on any given spin, and so each outcome will occur with approximately equal frequency over the lifetime of this slot machine. We can therefore calculate the likelihood of each possible outcome by examining the cycle. Today's five-reel games with 30 to 50 symbols per reel have cycles of hundreds of millions. The reason that we designed this simplified game is so that we could show all possible outcomes, although, as will be shown, the effects concerning the number of reinforced spins and payback percentage generalize across cycle sizes. Figure 7 shows all 36 possible outcomes for the game. The outcome in the upper left corner shows the outcome when the random numbers are 1, 1, and 1. This outcome has a win of 25 credits on the third payline and a win of four credits on the fifth payline. The outcome to the right of that is the outcome when the random numbers were 1, 1, and 2. This outcome is a loss. Each of the remaining possible outcomes in Figure 7 shows the random numbers and any winning lines.

Table 1 shows the corresponding mathematics associated with the same 36 outcomes depicted in Figure 7. Row 1 in Table 1 corresponds to outcome 1 in Figure 7, row 2 in Table 1 corresponds to outcome 2 in Figure 7, and so on. The first five columns in Table 1 are for each of the five individual lines. Table 1 shows that on payline 1 there are four wins, in outcomes 5, 7, 14, and 36. Payline 2 has wins on outcomes 9, 19, 26, and 28. For each payline, over the cycle of 36 spins, there are 32 losses and 4 regular wins (wins greater than the spin wager), resulting in a hit frequency of 11% (4 divided by 36 equals 0.11) for each payline.

When wagering one credit per line, the total wager per line over the cycle is 36 credits. Table 1 shows that the total won on each individual line over the cycle is 33 credits (2 + 2 + 4 + 25), and each payline has a payback percentage of 91.7% (33 divided by 36 equals 0.917), which approximates a typical payback percentage on slot machines in North America. In operant conditioning terminology, the *reinforcement rate* per line is RR9.0 as there are four spins with winning outcomes in the cycle of 36 spins (36 divided by 4 equals 9). In other words, a player may expect to win something on the first payline at an average of one in nine spins. Note that the winning amounts and total wagered would be doubled if the wager were two credits per line, while the hit frequency, payback percentage, and reinforcement rate would remain *unchanged*. The total monetary loss by players would, however, be doubled over the course of the cycle.

The five columns on the right-hand side of Table 1 show the winning amounts for all possible choices of buying one to five lines. The total in each row for these five columns is calculated from the five individual payline columns on the left. For example, when wagering one credit per line, the following possibilities exist for outcome 1 (amounts would be doubled if the player wagered two credits per line):

1. Buy one line resulting in a loss (i.e., a net loss of one credit)
2. Buy two lines resulting in a loss (i.e., a net loss of two credits)

3. Buy three lines resulting in a win of 25 on line 3 (i.e., a net win of 22 credits)
4. Buy four lines resulting in a win of 25 on line 3 (i.e., a net win of 21 credits)
5. Buy five lines resulting in a win of 25 on line 3 and a win of 4 on line 5 (i.e., a net win of 24 credits)

It is important to note that the same outcome can be a regular loss or a win, depending on the number of lines wagered. For example, in the preceding example, the outcome is a regular loss when the player buys one or two lines, but is a win when the player buys three, four, or five lines.

Reinforcement Rate.

Regardless of the number of lines that are bought, the number of spins in the cycle is 36. Table 1 shows that as the number of lines bought increases from one to five, the number of regular losses (spins where the person loses all of their spin wager) decreases from 32 to 18. This is because the player has bought more opportunities to receive a prize on any given spin. We use the term *hit* to refer to a spin on which the player is *rewarded* by being paid something, even if it is less than the amount wagered (i.e., both wins and LDWs). In modern slot machines, both wins and LDWs are "celebrated" by the machine with "winning" sounds and flashing lights or animations. As shown in Table 1, the number of hits increases as the number of lines wagered increases. These hits can be broken down by the number of wins in which the prize is greater than or equal to the wager and the number of LDWs in which the award is less than the amount wagered. When wagering on one or two paylines, there are no LDWs, but the number of LDWs increases significantly as the number of bought lines increases. When all five lines are bought, there are 13 LDWs and only five wins. The hit frequency (i.e., spins with celebratory audiovisual feedback indicating a win) will be 18 hits of 36 spins (i.e., 50%), but the number of spins in which the player actually wins more than wagered will be five of 36 (i.e., 13.9%). In other words, 13 of the 36 spins (i.e., 36.1%) accompanied by celebratory audiovisual signals of reward will actually be net losses for the player. Furthermore, 13 of 18 hits (i.e., 72.2%) accompanied by celebratory audiovisual signals and rewards are net losses.

Table 1 shows the reinforcement rates (the average number of spins between reinforcements) over the cycle of 36 spins. Each individual line has a reinforcement rate of 9.0 because for each line there are four possible wins of the cycle of 36 (36 divided by 4 equals 9.0). Importantly, when the player buys all five lines, the reinforcement rate increases from once every nine spins (when playing only one line) to once every two spins (when playing all five lines). It is very likely that this more than 4-fold increase in the reinforcement rate affects the experience of players. Of course, each outcome is selected randomly from the cycle of possible outcomes, but if a gambler were to play this game long enough to ensure a representative sample of outcomes from the cycle, and wager on all five paylines, a hit would occur on approximately half of the spins. As we will see when we revisit the Money Storm game, these game characteristics are similar to those of real EGMs.

Payback Percentage.

The five columns on the left of Table 1 show that each of the five individual lines has a payback percentage of 91.7%. The five columns on the right show that the payback percentage remains unchanged at 91.7% regardless of the number of lines bought. In essence, when a player has bought five lines, the player is playing five games. That is, the player has five possible ways of winning, each with a payback percentage of 91.7%, and thus the payback percentage when buying all five lines is also 91.7%. In payback percentage terms, there is *no advantage* to playing multiple paylines over playing a single payline. One spin with wagers placed on all five lines is mathematically equivalent to making five spins on five different slot machines simultaneously and placing a wager on one line for each machine.

The hold (the casino's profit) is the opposite of the payback percentage and together they always add to 100%. Our game with a payback percentage of 91.7% has a hold of 8.3%, meaning that 8.3% of all the wagers placed on all the lines throughout the lifetime of our simplified slot machine game will be lost. With a hold of 8.3%, the loss per cycle can be calculated as 8.3% times the total wager. Table 1 shows that as the number of lines bought increases, the average amount lost per spin in the cycle increases correspondingly. Thus, when five lines are bought, the loss per cycle is 5 times the loss when one line is bought, and so the casino's profit is 5 times greater.

The capability of modern EGMs to enable players to wager on more than one line and to vary the amount that they wager on these lines affords what researchers call *gambling strategies*. Often, players choose to adopt what Livingstone et al. (2008) have called the mini-max strategy, placing the minimum bet on the maximum number of lines. As we have shown, the payback percentage remains the same no matter how many lines are selected. Our example also shows that the higher the average wager (the more credits per line and the more lines wagered on), the higher the average loss. Paradoxically, the preferred mini-max strategy used by most EGM players is actually a poor strategy if the goal of playing the game is to avoid losing money. As we have shown, what significantly distinguishes single-line play from multi-line play (as in the mini-max strategy) is that playing maximum lines is likely to result in some form of reinforcement (win or LDW). In our game, reinforcement rates range from once every nine spins to every other spin. The amount won over time will be equivalent, but the machine will dole out the payback in smaller and more regular increments if all lines are wagered, whereas betting on only one or a few lines would result in a long series of losses interspersed with infrequent large wins. The regularity of outcomes with multi-line betting may seem more predictable to players and convey a comforting sense of control over the game.

Money Storm Revisited

For our simple slot machine game, we have shown the result for each of the 36 spins in the cycle. Although the concepts remain unchanged, each EGM found in a casino will have a different cycle size and different number of lines that can be “bought,” and so each game will vary in payback percentage, hit frequency, and reinforcement rate. To provide an example table of results for an actual slot machine game, we played 5,000 spins on Money Storm while wagering on one line and 5,000 spins while wagering on 20 lines and recorded the results. These results are shown in Table 2. The payback percentage was the same in both instances. With one line wagered, the hit frequency was 15.4% and the reinforcement rate was once every 6.5 spins. While wagering on 20 lines, however, the hit frequency was 47.88% and the reinforcement rate was once every 2.1 spins.

Why do Players Use the Mini-Max Strategy?

According to Livingstone et al., players of multi-line EGMs overwhelmingly often choose the mini-max strategy whereby they wager the minimum number of credits on the maximum number of lines. Given that the payback percentage is unchangeable, why do players use the mini-max strategy? Because this strategy does not affect their odds of gaining money, it cannot be because mini-max is an optimal strategy for monetary gain. Indeed, it is a good strategy for *losing* money because playing more lines increases the overall bet size. We suggest that there may be three explanations for why players would select this strategy. Each explanation is framed in terms of the pathways model of problem and pathological gambling and in particular on the classical and operant conditioning aspect of the model in which the player's exposure to reinforcers gives rise to excitement and arousal that may ultimately contribute to an illusion of control and other irrational beliefs that support further gambling.

One possible reason for using the mini-max strategy is that players enjoy being rewarded (i.e., a win or an LDW) over not being rewarded (i.e., a regular loss). By increasing the number of lines wagered, they can experience an increased frequency of operant reinforcement. As Haw (2009) noted, the capacity for players to change the number of lines wagered and thereby effectively change the reinforcement schedule may be “the operant link between the gambler and the reinforcer.” Indeed, players may be able to consciously distinguish regular wins from LDWs, although similar audiovisual feedback is given at the conclusion of regular wins and LDWs but not at the conclusion of regular losses. In terms of Pavlovian conditioning, regular wins are powerful unconditioned stimuli that are experienced intermittently. The sights and sounds that accompany regular wins can easily become classically conditioned to the hedonic experience of winning money. When LDWs occur, there is brief exposure to these conditioned stimuli that may be sufficient for players to feel the affective experience of reward. At an emotional level, the difference between LDWs and regular wins may become blurred and the hit frequency (which includes both LDWs and wins) effectively becomes the rate of operant behavioral reinforcement. These motivational processes almost certainly involve unconscious elements of the limbic system and dopaminergic reward centers of the brain that are well-known for the roles they play in addictive behavior (Zack & Poulos, 2009). Of critical importance for the issue of addictive gambling is the fact that repeated activation of reward pathways may cause neuroadaptation of these motivational systems. According to a biological-psychological perspective, such adaptation is the final common pathway underlying the transition from recreational enjoyment or "liking," to pathological craving or "wanting" (Koob, 2009; Robinson & Berridge, 2000). If the active ingredient in EGMs is the reinforcement schedule and programming EGMs to feature large numbers of playable lines inherently leads to artificially high reinforcement rates, then programming games with these features is analogous to producing cigarettes with extra nicotine and elevated potential for addiction of consumers. The individual characteristics of some people may make them more responsive to this manipulation and place them at greater risk for pathological gambling (MacLaren, Fugelsang, Harrigan, & Dixon, 2011; Milosevic & Ledgerwood, 2010). One exciting area of future research may focus on the mechanisms through which individual differences in motivation and personality may interact with game features and reinforcement schedules to impact the likelihood of transitioning to a cycle of addictive behavior.

A second explanation for why players use the mini-max strategy is that by allowing the player to select the number of bought lines, the player is given some control over the game. They can essentially adjust the Money Storm game from a 15.4% hit frequency to a 47.8% hit frequency, resulting in a major change in the playing experience. The player does in fact control the lines played and so it is in essence *real* control over the game. However, a player's impression that they may have uncovered a winning strategy by playing the maximum number of lines is somewhat misleading. This line of mentation could be invoked to support a wider belief system involving illusory control generally, as well as other cognitive distortions that are believed to play a critical role in continued gambling according to the pathways model (Blaszczynski & Nower, 2002). A third possibility further involves *cognitive regret* and the effects of players' choices on operant reinforcement. A player who buys only one line is very likely to see outcomes in which winning combinations occur on unbought lines and to experience cognitive regret for not buying these lines. On subsequent spins, a player experiencing this regret or frustration could change his or her wagering strategy to cover all lines and thereby obtain any potential wins. As Livingstone et al. (2008) concluded, this “effect is likely to entrench the operant conditioning effects associated with the random ratio schedules of EGM reinforcement, whilst ingraining in the gambler the need for comprehensive ‘coverage’ of possible game outcomes” (p. 117). As players reduce the apparent opportunity cost of missing out on possible wins, they also increase the frequency of LDWs and upwardly adjust the reinforcement schedule of the game. The real cost of this comprehensive coverage is that larger amounts of money are expended with no increase in payback percentage.

Conclusions

Previous research has shown that gamblers frequently use the mini-max strategy in multi-line slot machines. Through a detailed analysis and explanation of the design of multi-line slot machine games, we have shown that when gamblers use the mini-max strategy, the payback percentage remains unchanged but the reinforcement rate is significantly increased. We believe this increase in reinforcement rate, which is mainly due to LDWs, may underlie the addictiveness of multi-line slot machine games.

As illustrated in this paper, the payback percentage is completely independent of the number of lines wagered or the amount wagered per line. The player's choices do not affect the payback percentage in any way, but they do cause tangible changes in reinforcement rate. If the active ingredient that reinforces slot machine play is the subjective experience of reward, then betting on all paylines gives the player a potent way of upwardly titrating their “dose” of frequent rewards. An intriguing question for future research may center on game popularity and the ways in which experienced gamblers may “forage” a casino in search of games with the most rewarding reinforcement schedules and how they may strategically play these games to optimize their subjective experience of reward while prolonging the amount of time they can spend gambling before their money is depleted.

Notes

[1]The term “reinforcement schedule” does not imply that specific outcomes of a game are predetermined or ordered in any predictable way, but that the average frequency of wins that occur across a large number of spins can be increased or decreased by the design of the game and the options chosen by players.

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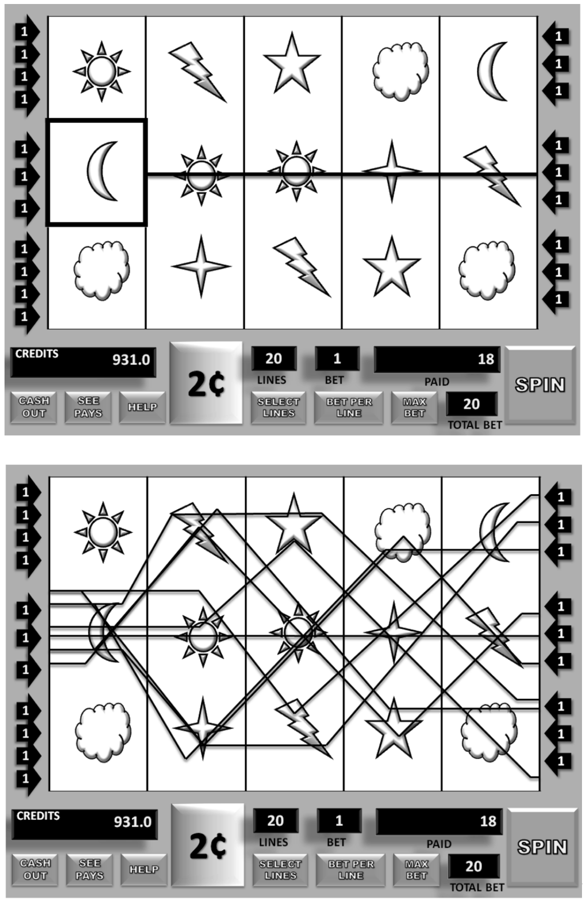
Figures



a)

b)

Figure 1.

Screenshots resembling the Money Storm game showing a line win (a) and wins on 9 of 20 lines (b).

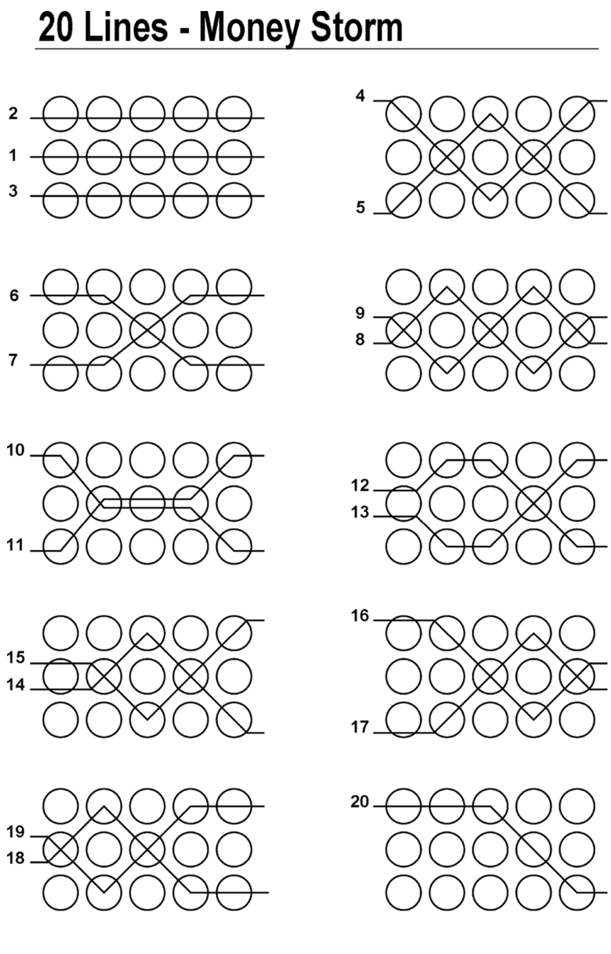


Figure 2.

Schematic of the 20 lines in the Money Storm game

	Reel 1	Reel 2	Reel 3		Credits Wagered 1	2
Example 1	A	A	A		2	4
Example 2	B	B	B		4	8
Example 3	C	C	C		25	50

Note. A = apple, B= banana, C= cherry.

Figure 3.

Paytable for our simplified slot machine game. With one credit wagered, three apples (A) pays two credits, three bananas (B) pays four, and three cherries (C) pays 25.

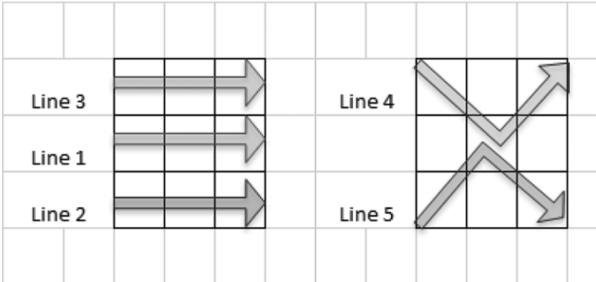


Figure 4.

The five paylines in our simplified slot machine game

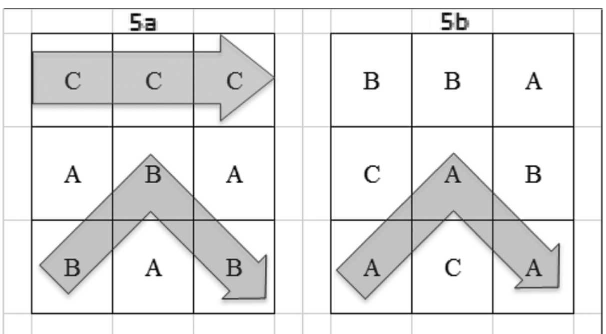


Figure 5.

Sample outcomes for two spins on our simplified slot machine game

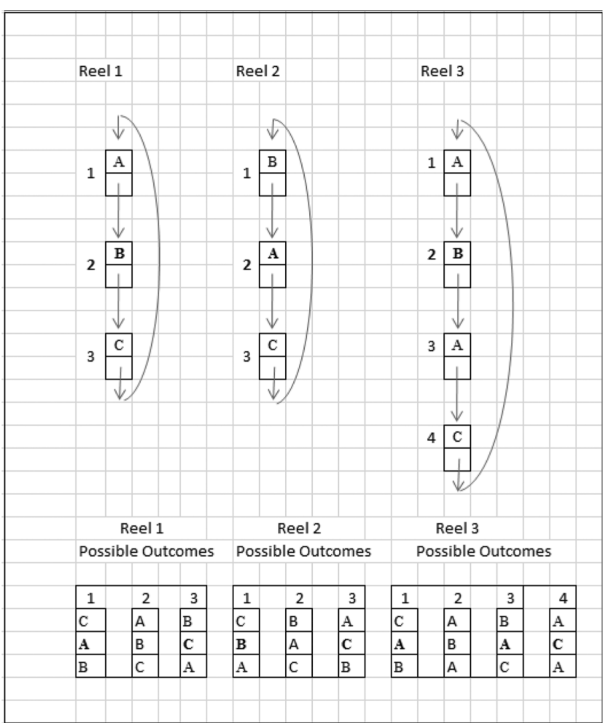
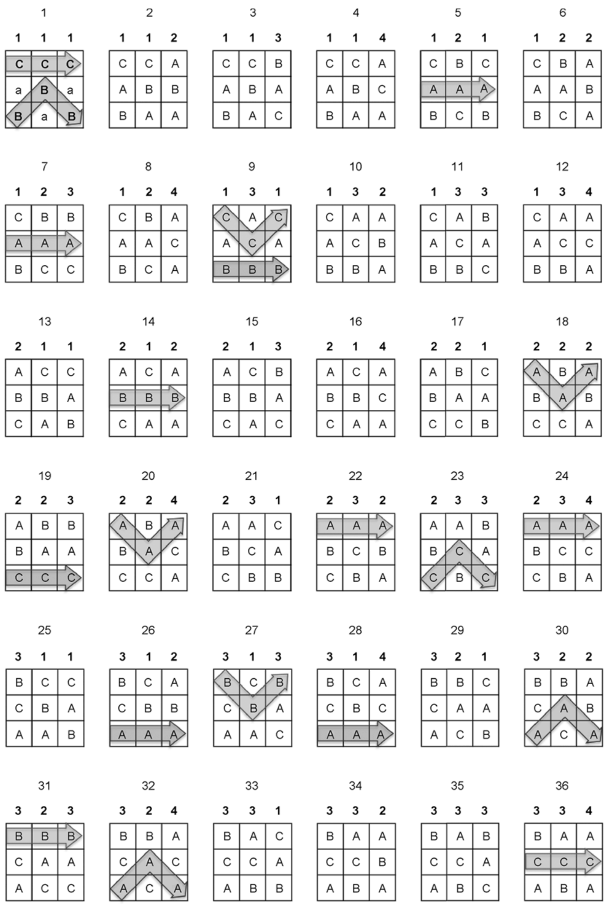


Figure 6.

Circular linked lists for the three reels of our simplified slot machine game.



Note. Arrows indicate lines that involve a payout.

Figure 7.

All 36 possible outcomes in our simplified slot machine game.

Tables

Table 1.

All 36 possible outcomes in our simplified slot machine game

	Five individual paylines					"Buy" one to five paylines				
Outcomes	1	2	3	4	5	1	1–2	1–3	1–4	1–5
1			25		4			25	25	29
2										
3										
4										
5	2					2	2	2	2	2
6										
7	2					2	2	2	2	2
8										
9		4		25			4	4	29	29
10										
11										
12										
13										
14	4					4	4	4	4	4
15										
16										
17										
18				2					2	2
19		25					25	25	25	25
20				2					2	2
21										
22			2					2	2	2
23					25					25
24			2					2	2	2
25										
26		2					2	2	2	2
27				4					4	4
28		2					2	2	2	2
29										
30					2					2
31			4					4	4	4
32					2					2
33										
34										
35										
36	25					25	25	25	25	25
Regular losses	32	32	32	32	32	32	28	24	21	18
Regular wins	4	4	4	4	4	4	8	6	7	5
LDWs hits	0	0	0	0	0	0	0	6	8	13
Total hits	4	4	4	4	4	4	8	12	15	18
Spins	36	36	36	36	36	36	36	36	36	36
Hit frequency	0.11	0.11	0.11	0.11	0.11	0.11	0.22	0.33	0.42	0.50
Credits won	33	33	33	33	33	33	66	99	132	165
Credits wagered	36	36	36	36	36	36	72	108	144	180
Payback %	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
Reinforcement	9.0	9.0	9.0	9.0	9.0	9.0	4.5	3.0	2.4	2.0
Loss per cycle	4	4	4	4	4	4	8	12	16	20

Table 2.

5,000 spins on Money Storm when wagering on one line and 20 lines

Outcomes	1 line	20 lines
Regular losses	4,229	2,608
Winning hits	771	909
LDW hits	0	1,483
Total hits	771	2,392
Spins	5,000	5,000
Hit frequency	15.4%	47.8%
Credits won	4,525	90,504
Credits wagered	5,000	100,000
P %	90.5	90.5
Reinforcement rate	6.5	2.1
Loss (in credits)	475	9,496

Note. LDW = losses disguised as wins.

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