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Research Article

Measuring Player Vulnerability in Roulette

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Abstract

This paper develops a measure of player vulnerability in games of chance where the player has control over betting strategy. The measure was specifically developed in a completely general form for the game of Roulette as played on electronic betting terminals, but can be applied to other games of chance. In the case of Roulette, the metric captures both the quantum of bet and, crucially, the specific type of bet. The generalised form of the measure accommodates any chosen bet that can be placed in Roulette. The paper gives the derivation of the measure, which is termed Vulnerability to Large Losses (VLL), and demonstrates the interpretation of VLL in a probabilistic context, indicating how it captures the notion of player vulnerability. The use of the VLL measure as a means of tracking and characterising the betting behaviour of individual gamblers is demonstrated. The VLL measure allows one to track the playing behaviour of a gambler over the course of an extended session of gambling and allows one to see how their playing style varies across time. It can then be used to directly interrogate a variety of propositions about gambling strategies or behaviour, and it is postulated that VLL has excellent potential to be used as a general metric to monitor player betting behaviour across time for a range of betting games.

ABBREVIATIONS

FOBT: Fixed Odds Betting Terminal; EGM: Electronic Gambling Machine; VLL: Vulnerability to Large Losses; HA: House Advantage; RTP: Return to Player

INTRODUCTION AND BACKGROUND

This paper emerged from research commissioned to answer a challenge posed in 2015 by the UK Government to a group of local councils who wished to secure a reduction in the maximum permitted stake on electronic gambling machines (EGMs) in betting shops, known as Fixed Odds Betting Terminals (FOBTs). Customers can play Roulette, amongst other games, on these machines for a maximum stake of £100 per 20-second spin. The councils proposed that this maximum permitted stake be drastically reduced. The responsible Government minister, however, rejected this proposal on the grounds of insufficient evidence to show that reducing the maximum stake would reduce gambling-related harm. He concluded with an appeal:

"Hence my call for data that supports the view, rightly or wrongly, that high stake machines contribute more to gambling-related harm [than low stake machines]...I find the question hard to answer in the absence of robust and good quality research."

We were asked to try to remedy this alleged lack of robust research and so to answer this call for data. To this end, and since FOBT gambling occurred primarily on the game of Roulette, we devised a customised research methodology to estimate the likely effect of reducing the maximum permitted stake on Roulette-based FOBTs on "protecting the vulnerable." This is the third objective of the UK Gambling Act of 2005 and a central objective of almost all gambling regulation everywhere.

A key part of the methodology we developed consisted of furnishing an account of vulnerability which would accord with the intentions of legislators, the findings of other researchers and with common sense. We concluded that what mainly concerned people when they were seeking to mitigate gambling-related harms was the likelihood that people would lose unaffordable amounts of money. In relation to maximum permitted stakes on EGMs the key question would then be how much would varying the stake make to players' vulnerability to large losses over relatively short periods of time.

This paper primarily focuses on how we explicated a concept of "vulnerability" in the context of Roulette-based FOBT gambling, which focuses not on who the "vulnerable" are but on what they are vulnerable to. We develop below a statistical metric which we term *Vulnerability to large losses* (VLL) which is a function of both size of stake and riskiness of betting strategy. As such, it makes possible the quantification of betting strategies from the perspective of vulnerability and of how changing rules relating to permitted betting strategies is likely to impact on the incurring of unaffordable losses. Moreover, VLL can be used to track player's betting behaviour over time, both from the perspective of quantum of bet and style of bet.

Measuring game variability and associated player loss

As mentioned above, this work grew out of a societal concern that gamblers playing FOBT machines were incurring unaffordable losses, a problem that has been recognized for some time in the case of EGMs; see, for example, Dowling [1]. Our focus in this paper is to measure an EGM player's vulnerability to losing large amounts and thus of particular interest are the potential swings in the player's monetary balance in the short-term. In the longer-term, if the player played a huge number of times, we know that the player could be expected to lose some fixed percentage of their monetary outlay (described by the euphemistically termed Return-to-Player (RTP) metric). This, of itself, could constitute a very unfavourable outcome for the player, but perhaps the outcome of particular potential harm is the probability of the player losing a large amount of money in the short-term when he/she is simply faced with a sequence of unfavourable outcomes.

EGM manufacturers usually use the gaming statistic, *Volatility,* to measure the variability of a player's percentage win/loss for some pre-specified number of plays for a unit bet.

Thus, for example, they might state the Volatility of player outcome for 10000 plays for a unit bet as, say, 8% with a House Advantage of, say, 10%. EGM manufacturers then often state 95% confidence intervals for 10 000 plays of £1 in the form:

10% ±1.96*8% which equates in monetary terms to a 95% confidence interval of (-£568, £2568)

That is, the casino could expect that if a player placed a £1 bet, 10 000 times, the casino would have a 95% chance of retaining between -£568 and £2568.

In the case of slot machines, players often play larger (than £1) bets. This does not affect the %volatility but simply increases the pound values in the above confidence interval, proportionately. The player can also play multiple lines (usually at £1 per line) on a slot machine; this raises the chance of the player winning (on at least one line), lowers the % volatility, but still increases the pound values in the confidence interval above, although the increase is less than proportional, see Barr and Durbach [2]. Generally, the higher the volatility of a game, the lower the percentage payback from the player's perspective [3]. Interestingly, these authors also argue that in the case of slots, a higher volatility tends to obscure a lower payback percentage.

EGM manufacturers use volatility as a standardised metric to compare and contrast the operation of different slot machines [4]. While the House Advantage of a machine is almost always regulated, the volatility of a machine is generally not regulated. Games with large bonuses which are generally won with low probability have high volatility and such games attract risk-loving players. EGM manufacturers quote the volatility for a unit bet, typically for 10 000 games and often publish 95% confidence intervals for House Advantage/Return-to-player (RTP).

The confidence intervals discussed above are structured to give the owners of EGMs an answer to the following question (assuming the machine is played 10 000 times at a £1 bet)

How much of that £10 000 handle can you expect to retain in the machine, and with what confidence limits?

Such figures are thus used to indicate to machine owners how many plays have to go through their machines to turn some pre-specified profit and with what level of certainty.

The game of Roulette is somewhat different to a standard slot machine in that the player has significant control over the kind of bet placed. A player at Roulette is faced with a multitude of possible bets and can choose any of these bets. Contrary to a slot machine, the notion of volatility is thus undefined for the game in general and can only be calculated for some specified bet. Two bets of particular interest in Roulette are the lowest-probability outcome bet (a single number bet) and the (almost) highest-probability outcome bet, ('even money' bet such as RED). Of course, the highest probability bet of all is a bet on ALL numbers which gives a loss of 2.73% with *no* uncertainty; this somewhat pathological case is not considered as it is rarely played.

MATERIALS AND METHODS

The specific case of roulette return and volatility

For illustrative purposes we first consider a £1 bet on RED in European Roulette. Wherever one places the bet, the statistical expectation of loss is 2.73%. If one repeats this process of betting £1, say 100 or 10 000 times, the statistical expectation of loss is still 2.73%, in the first case a loss of £2.73 and in the second £273. By statistical expectation we mean that if the process of making the bet of £1, 100 times is repeating infinitely, than the average loss across all the repetitions would be £2.73, even though it would be clear that in no *particular* repetition would the loss be exactly £2.73.

The Roulette table is structured so that players can play a range of different bets with different payoffs. The so-called House Advantage of 2.73% in European Roulette is true for any bet on the Roulette table, be it a single bet or a multiple (compound) bet comprising bets on many different numbers. In the illustrative case of betting £1 on each number (including zero) the player incurs a certain loss of £1 on *each and every* play. Although in each case, as mentioned, the expected payoff is the same, because these bets have different probabilities of winning and commensurately different payoffs which reflect these different probabilities, the variability of the payoffs is very different. Thus if one bets repeatedly on RED, the variability of payoffs over time and hence the variability of the player's balance would be much lower than if the player repeatedly bet on the number 8, since in the first case the chance of RED coming up is approximately 48.6% whereas in the case of the number 8, it is approximately 2.7%.

In the Roulette case, volatilities are routinely computed for specific bets, such as the two extreme cases mentioned above, however in this paper we extend this approach by developing an expression for the general case, ie a measure of volatility which is applicable to *any* bet placed in Roulette.

In the case of a bet on RED, it can easily be shown that the volatility is 99.964% (for 1 play) or 0.9996% (for 10 000 plays);

and in the case of a number bet the volatility is 583.78% (for 1 play) or 5.838% (for 10 000 plays).

In this paper, we are focussed on the actual potential quantum of money that a player may lose and thus are less interested in the volatility (a percentage-of-bet measure) and more interested in a metric which encapsulates the size of the bet. Moreover, since Roulette players often change bets from play to play we are primarily interested in a measure for one play.

We define a (generalized) Vulnerability to Large Loss (VLL) for one play as the standard deviation of a one-play Roulette bet. Note that this measure captures both the type of bet AND the quantum of bet.

RESULTS AND DISCUSSION

Establishing generalized VLL

Let us partition any compound bet in European Roulette into its equivalent "number bet" components, denoted by for the 37 different numbers each occurring with the same probability of 1/37. Hence, for example, a bet of £1 on RED constitutes a bet of £1/18 on each of the red numbers; a bet of £1 on the numbers 1-12 constitutes a bet of £1/12 on each of the numbers 1 through to 12.

Assume bets of $b_0, b_{1,} b_2, ..., b_{36}$ on the 37 numbers, and let the Gross Payout per unit of bet on each of the 37 equally likely numbers be w so a "win" yields a gain of $b_i(w-1),$ and a "loss". Therefore,

$$E(Gainperplay) = \sum_{i=0}^{36} b_i(w-1)p + \sum_{i=0}^{36} -b_i * (1-\text{pw})$$

Where p is 1/37 and w is 36, for each partitioned component bet, b_i

We need to consider the variance of this Gain per play. To do this, we define the *Gross* payout per play to be X and note that the variance of X will be equal to the Var (Gain per play) since for any set of the variance of is zero.

$$Var(X) = E(X^2) - (E(X))^2$$

$$E(X^2) = \sum_{I=0}^{36} b_i^2 w^2 p; and E(X) = \sum_{i=0}^{36} b_i wp \text{, so}$$

$$Var(X) = \left(\sum_{i=0}^{36} b_i^2 w^2 p - \left(\sum_{i=0}^{36} b_i wp \right)^2 \right) \text{; hence}$$

We define the square root of this quantity which is the standard deviation of the Gain per single play as Vulnerability to Large Losses (VLL):

$$VLL = \sqrt{\left(\sum_{i=0}^{36} b_i^2 w^2 p - \left(\sum_{i=0}^{36} b_i wp \right)^2 \right)} \text{, hence,}$$

For European Roulette, we obtain

$$VLL = \sqrt{\frac{36^2}{37} \left(\sum_{i=0}^{36} (b_i - \bar{b})^2 \right)}$$

Simplifying the general VLL formula for the European Roulette case gives:

Since VLL defined above is for one play, we may consider a series of Roulette plays to be a time series. In the section below we will consider how tracking gives us a handle on how Roulette players will change betting strategy as they alternatively build-up-winnings or attempt to chase loses.

We think the particular value of VLL is to track player behaviour and attitude to risk over time, as a player changes bets (both quantum of bet and type of bet) over time. However, we may compute a composite for a session of n independent plays as:

In Table 1 we demonstrate the calculation of VLL for several examples of individual play, where the quantum of bet and style of bet is changed at each play. In the table, each of six different bets are converted into equivalent "number" bets; thus the numbers in the table represent an equivalent bet (in £) made on each of the 37 Roulette numbers. From these figures, the VLL for each bet is easily computed using the formula discussed above.

Previous literature and discussion on measuring player vulnerability to large losses

There is a paucity of literature addressing the measurement of player vulnerability to large losses on gambling machines. Some authors have considered the problem and most have recognised the problem that RTP, by itself, is an inadequate measure of the risk faced by players. Moreover, messages around RTP may often be hard for players to understand in a slot machine context as it varies across machine and is confusing for players. Collins D [5] concluded that the RTP messages displayed by machines are often confusing for players and that other messages (including odds of winning any prize/ the jackpot. ; the volatility of the game ; average hourly loss rate ;the average cost of a gaming session) might be more useful.

RTP is somewhat easier to understand for Roulette as it is constant. However, it still remains an inadequate measure of player vulnerability and anyway does not directly factor in how vulnerability is related to the size of bet and style of play.

The actual size of bet is clearly another aspect of player vulnerability and is addressed by Parke A [6], who concludes that higher stakes, along with Return to Player and Game Speed contribute to a higher rate of loss. Moreover they argue that higher stakes also leads to impaired decision making ability and reduced self-control which exacerbates the rate of loss and hence gambling related harm.

Although he does not relate measured volatility to potential player harm, Edmunds [7], provide a useful comparative table of what they call "RTP volatility". This table gives 95% confidence intervals for percentage return-to-player (RTP) in terms of the number of games played for UK B3 and C machines as well as (B2) Roulette in 2 specific betting cases. In the case of Roulette they give figures for a bet on "Red" and a bet on a number (what they call a "Straight" bet). The table gives results for 10, 100, 1 000, 10 000, 100 000 and 1 000 000 games. This RTP volatility measure used by Edmunds is primarily directed to the supplier/ operator of gaming machines, who are particularly interested in the return that is expected from a particular machine and the confidence/risk associated with that return as a function of the number of games played.

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Table 1: Six bets (examples 1 to 6) translated into effective "number" bets and the associated VLL.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Example1	0	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0.083333	0	0	0	0	0	0
Example2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Example3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Example4	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Example5	0	0.05556	0	0.05556	0	0.05556	0	0.05556	0	0.05556	0	0	0.05556	0	0.05556	0	0.05556	0	0.05556
Example6	0	0	0.05556	1	0.05556	1	0.05556	1	0.05556	0	0.05556	0.05556	0	0.13889	0.08333	0.13889	0.08333	0.13889	0.08333

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	VLL
Example1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.404366**
Example2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**0**
Example3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5.83784**
Example4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**58.37838**
Example5	0.05556	0	0.05556	0	0.05556	0	0.05556	0	0.05556	0	0	0.05556	0	0.05556	0	0.05556	0	0.05556	**0.99963**
Example6	0.08333	0.13889	0.08333	0.13889	0.08333	0.13889	0	0.05556	0	0.05556	0	0	1.05556	0	1.05556	0	1.05556	0	**12.96385**

Example 1: A bet of £1 on 1st Twelve (1-12)
Example 2: A bet of £1 on each of the numbers 0 through to 36 (£37 bet in total).
Example 3: A bet of £1 on the number 1.
Example 4: A bet of £10 on the number 1.
Example 5: A bet of £1 on RED.
Example 6: A bet of £1 on BLACK, £1 on 2nd Twelve, £1 on the six numbers 3, 5, 7, 31, 33 and 35 (£8 bet in total)

Our measure of VLL is specifically targeted at measuring the vulnerability to the player for one play. The measure when applied to B2 Roulette is constructed in a generalised bet-setting; that is it can be calculated for any quantum and style of bet. This makes it quite different from volatility or any of the player vulnerability measures associated with RTP. As such, it is of particular use in tracking a player's behaviour across time when a player's quantum-of-bet and style of bet changes from play to play.

The probabilistic interpretation of VLL

One attractive feature of VLL is that it can be interpreted in a probabilistic context. This is best illustrated through the contrasting examples of a bet on RED compared to a bet on a particular number.

Consider, first, the case of betting on **RED**. Let us consider making the same £100 bet, 100 times.

We know the HA is 2.703% which equates to £270.3, and for this case we may compute VLL as £999.6

Assuming that the distribution of outcomes follows the Normal distribution (reasonable for 100 plays) and assuming a very large number of people made this bet on RED of £100, 100 times (£10 000 total bet), we may assume, through symmetry, that 50% would incur losses of at least £270.3 Moreover, since 66% of the distribution lies within one standard deviation of the mean we could state that 17% of them would be expected to incur losses in excess of £270.3 + £999.6 = £1 269.9. Similarly, we could state that 10% would be expected to incur losses in excess of £1 554.

For the case of betting on a **NUMBER** (£100 bet, 100 times), we apply similar logic and deduce that since HA is 2.703%, this equates to £270.3

For this case we may compute VLL as £5 837.8

Assuming Normality (reasonable for 100 plays) and if a very large number of people made this bet of £100, 100 times (£10 000 total bet), we may assume that 50% of the players would incur losses of at least £270.3 Moreover, since 66% of the distribution lies within one standard deviation of the mean we could state then 17% of them would be expected to incur losses in excess of £270.3 + £5 837.8 = £6 108.14. Similarly, we could state that 10% would be expected to incur losses in excess of £7 771.92.

VLL is proportional to bet size, so, for example in the case of a bet on RED of £10, repeated 100 times, all the figures above would be a factor of 10 smaller.

We could then conclude that in the case of RED, with a bet of £10, 100 times (£1 000 total bet), 17% of them would be expected to incur losses in excess of £27.03 + £99.96 = £126.99 and 10% would be expected to incur losses in excess of £155.4

We could then conclude that in the case of a NUMBER bet, with a bet of £10, repeated 100 times (£1 000 total bet), 17% of the players would be expected to incur losses in excess of £27.03 + £583.78 = £610.81 and 10% would be expected to incur losses in excess of £777.19

Tracking and characterizing individual patterns of play

We propose that the VLL measure is a useful way to track the betting behaviour of players over time, providing a means of quantifying how they adapt their play to changes in "fortune".

As outlined previously, the wider study which gave impetus to the development of this measure also afforded us the opportunity to explore the use of VLL to track individual patterns of play. The design of the study included focus groups in which a total of 58 regular gamblers played simulated FOBT Roulette and their play was recorded over a total of 3598 plays (separate bets). We demonstrate, below, the use of VLL to characterise betting behaviour using two case studies taken from the focus groups.

Consider the case of a player who does not normally play with a large VLL. Perhaps, as in the case of C6 in Figure 1, they would characterise themselves as someone who "never bets a total stake of more than £20". However, when they are in a position of having accumulated a substantial (relative to starting position) stock of money to play with, or "Money in Pocket", they are inclined to increase their stake per play and/or the inherent riskiness of their bet. When interrogated about this apparent anomaly during interview sessions post play, it emerged that the player did not regard the excess (over starting amount) of "Money in Pocket" as their "own" money so were more inclined to throw caution to the wind and bet with a large VLL. Group discussions in the focus groups indicated that this was not an uncommon gambling strategy.

Linda reflected a strategy more like that referred to as "chasing losses". As her "Money in Pocket" declined so her plays became increasingly risky as measured by VLL.

Not all players adjust their VLL according to their "Money in Pocket". Some players have a clear strategy and stick to it. In many of the cases observed in our simulation study it was not possible to link changes in strategy /behaviour to identifiable factors. It would be useful to compare in more detail how players describe their intended gambling strategy with what we observe of their VLL sequence. A post play analysis with the player themselves could then reveal which factors intervened to disrupt their intended strategy or modus operandi.

CONCLUSION

In this paper we have proposed a metric (VLL) to measure the vulnerability of a Roulette player or, more explicitly, the extent to which a bet they choose to play exposes them to losing large amounts of money. As the term "large" suggests, this measure is a relative one and can be used to make comparisons between bets or betting behaviour, rather than pronounce in some absolute sense as to the level of vulnerability. The larger the inherent riskiness of the type of bet (extent of coverage of the roulette table) and/or the larger the amount staked, the larger the VLL.

Although this measure is well known in Statistics as the standard deviation (in this case, of the pay out to the player) it has, to the best of our knowledge, not been shown how the standard deviation can be formulated in the general case for composite bets (involving any of the given betting options in Roulette). In this paper we show the derivation of the formula

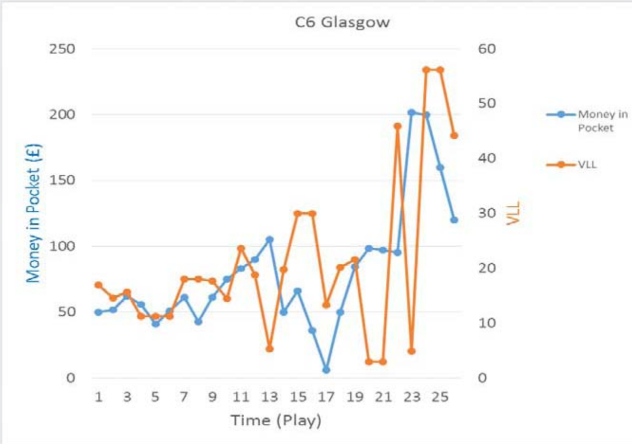

Figure 1 Change in VLL for C6 in Glasgow.

for VLL which is applicable to any bet which a player may choose to play. The examples shown demonstrate that VLL has the desirable properties of ranging from 0 (absolute certainty) to an extremely large number, as influenced by both the type of bet made and the amount staked.

We have also demonstrated the potential use of this measure in tracking and characterising the betting behaviour of gamblers. Our focus group interviews with gamblers indicated that some players struggle to articulate or possibly have little insight into their own betting behaviour. VLL (as captured through simulated gaming software) can provide a way to represent gambling behaviour over many plays and may be a useful mirror to reflect back gambling sessions to gamblers themselves. It may at least provide a point of departure from which to interrogate the strategies practiced and beliefs held by gamblers.

Another use for this measure is in demonstrating the potential effects of interventions being considered in future gambling policy. Gambling policy necessarily has to consider many facets of the effects of gambling on society, however a measure with an explicit focus on vulnerability would be beneficial in helping consider the many trade-offs that policy must inherently reflect.

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