SEEKING PSI IN THE CASINO

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ABSTRACT

Correlations and predictive modeling tests were used to explore the possibility that some fraction of the daily fluctuations in casino gambling payout percentages might be due to periodic variations in average psi abilities in the general population. The study was based upon examination of four years of daily gaming data from a Las Vegas casino.

Payout percentages were predicted to be positively correlated with lunar cycle and with gravitational tidal forces, and negatively correlated with the planetary geomagnetic field flux. Nearly significant correlations were observed for lunar cycle and geomagnetic field, and significant correlations were observed for tidal forces.

These results are consistent with previous research indicating that some environmental factors may be related to predictable variations in psi performance. Artificial neural network and abductive network techniques were used successfully to predict casino payout percentages based on seven daily environmental variables.

INTRODUCTION

When Parapsychologists Dream

When parapsychologists dream, they dream about thousands of highly motivated people participating in psi experiments, 24 hours per day, in dozens of laboratories, world-wide. They dream that these laboratories will be exquisitely sensitive to human needs and desires, yet maintain stringent controls, fraud-proof testing conditions, and obsessive attention to data collection and verification. Some parapsychologists even fantasize that people might pay for the opportunity to participate in these experiments.

This dream is a reality today in gambling casinos. Other than being profit-oriented, many gambling games are essentially identical to experiments conducted in psi laboratories.[1] Thus, if one accepts that precognition and psychokinesis are widely distributed human abilities,[2] then in principle they may also be present in the casino. That is, some percentage of gambling winnings may be psi-mediated.

For years, this has remained an untestable speculation because casinos, like most businesses, tightly control company information. It is difficult to gain access to daily profit/loss records from casinos, even for research purposes. This problem is compounded for research on possible psi-mediated effects, as casinos are dubious about promoting study of anything that may affect their profits. Fortunately, an executive at one Las Vegas casino[3] was interested in parapsychology and was kind enough to allow us to examine daily gaming data that allowed us to test the hypothesis of 'psi in the casino'.

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[1] This is not to say that casino operators and experimenters have the same goals, or that casino games and psi experiments are conducted under the same conditions. We discuss these differences later.

[2] As demonstrated by meta-analyses of decades of empirical data (e.g., Honorton & Ferrari, 1989; Radin & Nelson, 1989; Radin & Ferrari, 1991).

[3] Bernice Jaeger, Continental Hotel, Casino, and Resort, Las Vegas, NV.

Seeking Psi in the Casino

> Someone once asked me why women don't gamble as much as men do, and I gave the common-sensical reply that we don't have as much money. That was a true but incomplete answer. In fact, women's total instinct for gambling is satisfied by marriage. [Gloria Steinem]

To conduct a detailed search for psi in the casino, ideally we would like the daily win/loss data per player, per individual play, per game. We would like this data tracked for thousands of players over thousands of days, and we would like the empirically-determined chance payout percentages of the various casino games to compare against the observed payouts. While this level of detail is of interest to casinos, the technology to track gaming behavior this closely is still in the research and development stage.[4]

The data made available to us were daily figures called 'drop' and 'result' for the following five games: Roulette, Keno, Craps, Blackjack, and Slot machines. *Drop* is casino jargon referring to the amount of money dropped on the table, i.e. the amount of money bet on the game. *Result* is the amount of money paid out to the casino after the game is over. These figures allow us to calculate the daily *payout percentage,* i.e. the win/loss percentage from the gambler's point of view, per game. For example, let's say that on Monday the *drop* (players' bets) for all slot machines was $50,000 and the *result* (casino payout) was $30,000. This means the players won $20,000, and thus the payout percentage from the gamblers' perspective was $20,000/$50,000, or 40%. In other words, for each dollar played in a slot machine, on average the gambler's return was 40 cents.

While *drop* follows predictable weekly and seasonal cycles, daily payout percentages do not depend on the amount of money dropped (according to the null hypothesis), thus these daily values should be independent of any known periodicities and should follow the laws of chance. However, if psi were widely distributed in the population, and 'modulated' by external factors, then daily fluctuations might not be entirely random. The postulated nonrandomness might manifest in the form of correlations between psi and external factors.[5] What cycles or factors should we then examine?

Behavior, Psi and Geomagnetism

One factor is the planetary geomagnetic field (GMF). For decades, conventional wisdom about GMF and human physiology and behavior was that "biomagnetic effects on man are very small and are negligible as compared with other physical environmental stimuli" (Tromp, 1980, p. 124). This was based on the reasonable assumption that the energy absorbed by the body due to geomagnetic fluctuations was below the thermal limit, which means the effects were so minuscule that cellular functioning was not influenced or disrupted in any way, and so no physiological and certainly no behavioral effects were thought to be possible.

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[4] This data also raises privacy issues, which may make it difficult to obtain even if it were available.

[5] Of course, the Law of Large Numbers declares that even if there were occasional fluctuations in payout rates, over the long term casino winnings would still be predictably stable, and empirically they are very stable.

More recently, research suggests that electromagnetic and magnetic flux well below the thermal limit, but shaped with certain patterns and complex frequencies, do indeed affect biology ranging from single cells to human physiology and behavior (Weaver & Astumain, 1990). A small but growing literature suggests that some forms of human behavior are affected by variations in extremely weak, extremely low frequency (ELF) electromagnetic and geomagnetic fields (Wilson et al., 1990). That these fields affect human behavior is demonstrable, for example, in analyses of accidents: 362,000 industrial accidents and 21,000 traffic accidents have shown significant correlations with ELF variations (Tromp, 1980, pp.227-228), and numerous forms of unusual and abnormal human behavior have been correlated with GMF flux (Alonso, 1993; Braud & Dennis, 1989; Persinger, 1989a, b).

Of particular interest here is the budding literature in parapsychology suggesting that perceptual psi performance (i.e. ESP), both in the lab and spontaneously in the field, improves as GMF flux decreases (e.g., Gissurarson, 1992; Lewicki, Schaut & Persinger, 1987; Persinger, 1985; Persinger & Schaut, 1988; Spottiswoode, 1990; Radin, 1992, 1993; Wilkinson & Gauld, 1993). A few studies have suggested that active psi performance (i.e. PK) improves as GMF flux increases (e.g., Gearhart & Persinger, 1986).

If psi were operating in the casino, we might expect to find a correlation between casino payout percentages and levels of GMF. The direction of this correlation is difficult to specify in advance, because it is not clear whether gamblers would rely more on perceptual psi or active psi. However, because all casino game payouts can be influenced in principle by precognition, and because one of the more successful models of psi performance in micro-PK experiments suggests that effects observed in those experiments are actually due to precognition,[6] we predict that a possible GMF correlation with casino payout percentages would be negative.

Human Behavior and the Moon

> There is something haunting in the light of the moon; it has all the dispassionateness of a disembodied soul, and something of its inconceivable mystery.
>
> [Joseph Conrad (1857-1924)]

Another factor to explore is the lunar cycle. Because this factor has not been discussed in parapsychology as much as GMF relationships, we will discuss this in somewhat more detail, beginning with relationships between human behavior and the lunar cycle.

Researchers investigating moon-behavior relationships have most often compared lunar cycle against indices of abnormal and extreme behavior, e.g., homicide, suicide, criminal activity, disturbances in psychiatric settings, admissions to mental institutions, and telephone calls to 911 crisis centers. Researchers have also explored relationships with traffic accidents, fire alarms, ambulance runs, Dow-Jones averages, voting patterns, children's unruly behavior, and drug intoxication (for reviews, see Rotton & Kelly, 1985; Kelly, Rotton & Culver, 1985-86).

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[6] e.g., the 'Decision Augmentation Theory' suggests that most or all apparently influential effects on random number generators are better explained by precognition than force-like PK models (May et al., 1995).

Some of these studies found significant relationships (e.g., Geller & Shannon, 1976; Lieber & Sherin, 1972; Snoyman & Holdstock, 1980; Tasso & Miller, 1976; Templer & Veleber, 1980; Weiskott & Tipton, 1975), and others reported only small, inconsistent correlations (e.g., Chapman, 1961, Pokorny & Jackimczyk, 1974). For example, Frey, Rotton & Barry (1979) studied fourteen types of calls to police and fire departments over two years. They found that 6 out of 56 tests had significant "but very small" lunar effects, and concluded that those few effects were instances of Type I errors.[7]

Reviews of the literature have been generally negative. A meta-analysis published in 1985 concluded that lunar phase influences were "much ado about nothing", and the authors hoped that their report would be "much *adieu* about the full moon" (Rotton & Kelly, 1985, p.302). In a later report, they stated that after dividing the lunar cycle into four equal sections, activities usually termed lunacy accounted for 25.7% instead of the chance-expected 25%. They concluded that "we are not impressed by a difference that would require 74,477 cases to attain significance in a conventional (i.e. chi-square) analysis" (Kelly, Rotton & Culver, 1985-86, p.131).[8] A few years later, Martin, Kelly & Saklofske (1992) reviewed suicide and lunar cycles and concluded (p.794) that:–

> A consideration of the 20 studies examined here indicates that a knowledge of lunar phase does not offer the clinician any increase in ability to predict suicide and does not contribute to the theoretical understanding of suicide.

In sum, in spite of the fact that lunar myths and lore have endured for millennia, modern science remains skeptical. Contemporary popular articles range from the uncritically dismissive (*Berkeley Wellness Letter,* 1992) to the uncritically credulous (Grice, 1993).

Magic and the Moon

> It is the very error of the moon; She comes more near the earth than she was wont,
> And makes men mad. [Othello, Act V, Scene ii]

In spite of the lack of scientific consensus about lunar-behavioral effects, surveys continue to show that many people still believe in lunar-behavioral relationships. Thus, as with psi, it seems that human experience on this issue is at odds with conventional scientific wisdom. Parapsychologists have certainly learned the folly of ignoring human experience just because present scientific theories cannot adequately explain those experiences, thus it is worthwhile considering the historical links between the lunar cycle and magic. By magic, we mean the primeval origins of what we now call psi.

For millennia, primitive peoples associated the blazing, forthright sun with masculine and the cool, mysterious moon with feminine. The female monthly cycle, approximately the same duration as the synodic lunar cycle, was undoubtedly one of the reasons that many ancient moon deities were feminine, e.g., Ishtar of the Babylonians, Ix Chel of the Mayans, Hanwi of the Oglala Souix, Artemis of the Greeks, and Zirna of the Etruscans (Guiley, 1991).

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[7] We might point out that, ignoring the problem of non-orthogonality among the variables they studied, the cumulative probability of obtaining up to 6 significant correlations at $p < 0.05$ out of 56 tests is unlikely (binomial $p = 0.02$).

[8] In a city with a population of 1 million, this 0.7% increase may not sound like much, but in practical terms during 'adverse' lunar phases there would be hundreds of additional crisis calls per day.

Of particular importance for the present study is the observation that religious ceremonies and magical rituals were often timed to precisely match phases of the lunar month (Radin, 1957), and the traditional calendars of many cultures are based on lunar cycles, including the Islamic, Hebrew, Chinese, and Mayan calendars. To this day, popular holidays like Easter and Passover are still timed according to the lunar cycle. The moon also figured prominently in medieval talismans, good luck charms, and magic. The 'witching hour' was midnight under a full moon, because that is when magical forces were supposed to be most powerful (Guiley, 1991). Based on secrets from the Cabala, lunar charms were often used to enhance fertility, start new ventures, and enhance psychic powers ("Magical Arts", 1990, p. 37).

Along with religious and ceremonial practices, for centuries it was common knowledge that human and animal behavior were affected by the moon. Pliny the Elder, a Roman naturalist from the first century, wrote that "we may certainly conjecture that the moon is not unjustly regarded as the star of our life . . . The blood of man is increased or diminished in proportion to the quantity of her light" (Guiley, 1991, p. 100). Nearly two thousand years later, modern medical researchers have reported that post-operative bleeding peaks around the time of the full moon (Guiley, 1991, p. 113).

From medieval times, it was considered dangerous to sleep in the moonlight or even to gaze at the moon. The 18th-century French psychiatrist, Daquin (Oliven, 1943, p. 720), wrote in his book on mental disorders: "It is a well established fact that insanity is a disease of the mind upon which the moon exercises an unquestionable influence." Sir William Hale, chief justice of England, wrote in the 1600s that "the moon hath a great influence in all diseases of the brain . . . especially dementia" (Guiley, 1991, p. 142). Two hundred years later, in writing England's Lunacy Act of 1882, Sir William Blackstone, the great English lawyer, defined "A lunatic, or *non compos mentis,* is one who hath . . . lost the use of his reason and who hath lucid intervals, sometimes enjoying his senses and sometimes not, and that frequently depending upon the changes of the moon" (Oliven, 1943, p. 720).

Dipsomania, or periodical alcoholism, was mentioned in the early psychiatric literature, and was often associated with lunar cycles (Oliver, 1943, p. 720). In light of legal treatments of lunacy, it is interesting to note that the nefarious 'Son of Sam', a serial killer in New York City in the 1970s, killed five of his eight victims on nights when the moon was either full or new (Guiley, 1991, p. 148). Public fascination with 'creatures of the night', including vampires and werewolves, continues to the present day, suggesting that this age-old folklore will remain in the forefront of our imagination for generations to come (Spence, 1960). Contemporary surveys confirm that many people still believe that strange behavior peaks around the time of the full moon (Abel, 1976; Lieber, 1978; "Moon Madness", 1981).

Experimental Psi and the Moon

One published experiment was found which suggested that psi performance varies with lunar cycle. Puharich (1973) proposed that psi performance should be related to gravity. To test his prediction, it was necessary to conduct an experiment under changing gravitational conditions. One way to do this is to

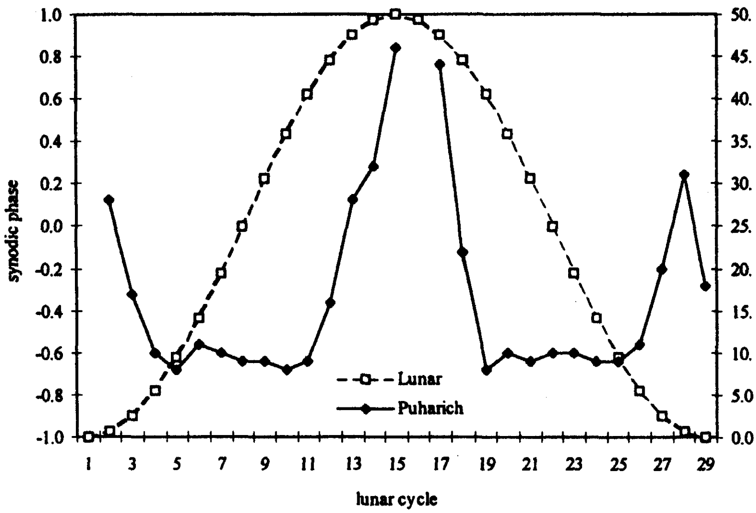

Figure 1. Outcome of Puharich's (1973) telepathy test. The left ordinate is synodic lunar phase, where +1 is full moon and –1 is new moon. The right ordinate is the score in a telepathy test, where a higher score was better. One day was skipped in Puharich's experiment.

conduct an experiment every day over the synodic lunar cycle, because the sun-moon system predictably changes the gravitational forces (i.e. tidal forces) felt on Earth. Puharich's predictions for a telepathy test, coincidentally in accordance with expectations from magical folklore, was that perceptual psi would increase around the full moon, decrease at the half-moons, then rise again around the new moon. The experimental results confirmed Puharich's prediction (1973, pp.281-289), as illustrated in Figure 1. Thus, in the present analysis, we explored whether a gravitational effect might be related to casino payout percentages.

Lunar-Solar-GMF Relationship

An alternative explanation for Puharich's result, rather than being a gravitational effect *per se,* might be a complex relationship between the lunar cycle and GMF. Fluctuations in GMF have been linked to numerous periodic factors, including long-term 'secular variations' related to structures in the Earth's core, and shorter term 'external variations', including solar activity, a daily cycle, and of primary interest here, the synodic lunar cycle (Becker, 1990; Roney-Dougal, 1991; Playfair & Hill, 1978; Tromp, 1980, p.123).

A flurry of studies in the 1960s, published mainly in the geophysics literature, suggested that there was a lunar-GMF correlation (e.g., Bell & Defouw, 1964; Bigg, 1963). Later analyses demonstrated that these apparent correlations were probably due to fluctuations in the solar 'wind' (Bell & Defouw, 1966; Michel, Dessler & Walters, 1964; Rassback & Dessler, 1966). It turns out that there is a close coincidence between the length of the lunar synodic month (29.53 days) and the rotational period of the sun, so what originally appeared to be a lunar-GMF association might have been confounded by solar effects. However, later analyses showed that the moon passes through the Earth's magnetosphere around the time of the full moon, leading to new speculations about lunar-GMF relationships. For example, Fraser-Smith (1982) found evidence of a lunar-GMF relationship during total lunar eclipses in data recorded after 1932, but not before (from 1870 to 1932).

To confuse the situation further, while the gross geophysical relationships are not yet clarified, biological systems seem to be exquisitely sensitive to minute energetic effects that might otherwise seem to be negligible. For example, the marine mollusk responds differently to geomagnetic fields according to the phase of the moon (Kohmann & Willows, 1987), and both humans and rats display different thresholds for convulsions according to changes in magnetic fields and the position of the moon during solar eclipses (Keshavan et al., 1981). Thus, we took a purely empirical approach to the question of a lunar-GMF relationship and simply examined this relationship for the four years covered by the casino data, and then examined the same relationships for 10 years of GMF data recorded in the 1980s.

Table 1

Variables used in this study

Variable	*Daily Data*
	CASINO GAMES
Roulette	drop, result, payout percentage
Keno	drop, result, payout percentage
Blackjack	drop, result, payout percentage
Craps	drop, result, payout percentage
Slots	drop, result, payout percentage
COMBO	average payout percentage for the above five games
	WEATHER
Maxtemp	maximum outdoor temperature
Humidity	outdoor humidity
Baro	barometric pressure
	GEOPHYSICS
GMF	natural log of the mean geomagnetic planetary A-index
SSN	sunspot number
Flux	10.7-cm solar radio flux

METHOD

Data

Table 1 lists the variables used in this analysis. The data covers daily values for the four years from 1991 through 1994, inclusive. Some data were missing, e.g., all casino data for the month of June, 1991, and five other individual days. In addition, slot machine data were available usually every other day due to recording practices in the casino. Thus, for all games excepting slot machines, out of a total of 1,461 actual days from 1991 to 1994, there were a total of 1,426 actual datapoints (i.e. 1,461 – 30 – 5). For the slot machines, there were a total of 748 days of data.

In Table 1, the phrase 'payout percentage' refers to the payout percentage from the gambler's point of view, i.e. *p% = (drop–result)/drop*. The value of *drop* is always positive, reflecting the fact that real money is dropped on the table or in the slot machine, but *result* can be positive or negative. If *result* is positive, it means there is money remaining on the table after the day is done, the casino earned a profit, and *p%* ranges from 0% to 100%. If *result* is negative, it means the casino lost money to the gamblers, and *p%* will be greater than 100%. In this dataset, daily payout percentages on the various games ranged from about 5% to over 400%. The large payout percentages represented times when one or more gamblers hit jackpots or they had an unusual run of luck.

To reduce the effects of random daily variations, each data series listed in Table 1 was smoothed using a 7-day moving average transformation; this is a common practice in time-series analysis. This transform helped fill in the occasional missing datapoint and the every-other-day nature of the slot machine data. (But it also introduced autocorrelations, the consequences of which we address later). No smoothing was possible for the one month of missing data for June 1991, so that block of data was left blank. After experimenting with numerous smoothing algorithms and finding that they all provided essentially the same end-results, the simplest method was employed:–

$$V_{is} = \sum_{n=i-3}^{n=i+3} V_n / 7$$

where V_{is} is the smoothed value V for day i. This algorithm required us to drop three data points at the beginning and end of each daily data series.

The term COMBO in Table 1 is the variable of primary interest. This is the combined average of daily percentage payouts for the five casino games. By using smoothed averages to fill in occasional missing data points, COMBO included average casino data for nearly every casino game for every day.[9] Figure 2 shows the overall averages for the casino games and COMBO, with one-standard-error bars.

Analyses

This study was interested in examining four correlations:–

- lunar cycle vs. COMBO, predicted to be *positive* based on magical lore and Puharich's (1973) experimental results,
- Gravity vs. COMBO, predicted to be *positive* based on Puharich's (1973) experiment,
- GMF vs. COMBO, predicted to be *negative* based on previous literature suggesting better perceptual psi on days of lower GMF, and
- GMF vs. lunar cycle, predicted to be *negative* based on the speculation that GMF and lunar cycle provide opposite predictions for psi performance.

[9] Later we address the effect on COMBO of having fewer datapoints and a lower average payout percentage for Slots as compared with the other games.

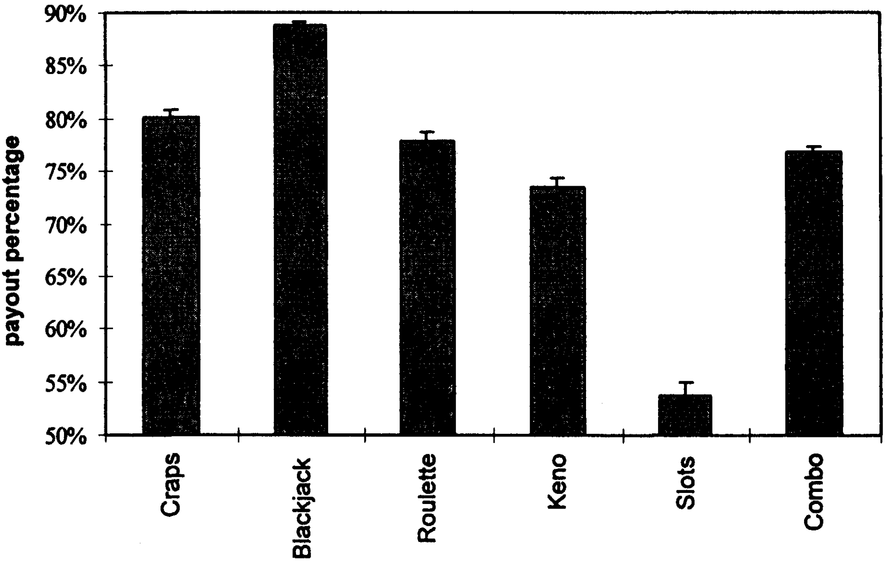

Figure 2. Payout percentage mean and standard errors for the casino games.

For the lunar cycle, first we determined the days of the full moon from 1991 through 1994. Then we defined the full moon as 'O', assigned the 14 days before and after the full moon the values 1 through 14, and created a new array using the formula:–

$$moon = \cos [\pi (day/14)]$$

In this formula, *moon* is the coded value for the lunar cycle, and *day* was the number of days from the full moon. This transformation turned the full moon value into '1', the new moon into '–1', and the remaining 27 days into a (co)sine wave, which represented the waxing and waning of the lunar cycle.

To form a curve used to represent gravitational cycles, following Puharich's description of expected fluctuations in gravity we used the absolute value of the lunar sine curve and adjusted the magnitude of the left and right tails of the curve to be half the peak value of the center of the curve. That is, a curve (see Figure 5) was created using the scheme:

$$gravity = | \cos [\pi (day/14)] | \text{ for days 0 to 7, inclusive, and}$$

$$gravity = 0.5 \times | \cos [\pi (day/14)] | \text{ for days} > 7$$

It is important to point out that all of these planned correlations were conducted *with respect to the lunar cycle* by using a superposed epoch analysis centered on the full moon. That is, for the variables COMBO and GMF we determined the average of all daily values falling on the day of the full moon, one day after the full moon, one day before, two days after, and so on, until we determined daily averages for each of the 29 days. Because the database contained nearly four years of daily data, these averages were based on 49 to 50 lunar cycles, which provided good mean estimates for each variable over each day of the synodic cycle. The same method was used to correlate COMBO and GMF against the estimated gravity curve described above.

Monte-Carlo Simulation

The data used in these correlations are smoothed twice: once by a moving average transformation that smoothed the daily raw data, and then again when averaged by the superposed epoch analysis based on the day of the lunar cycle. Double-smoothing helps reduce random noise due to daily and monthly variations, but the two methods also decrease the variation between the individual datapoints (introduced by the moving average transform), and therefore increase the standard deviation of correlation of each data series. This in turn inflates the t score and the associated probabilities.

To estimate the actual standard deviation given this dataset and the application of these two smoothing transforms, we employed a Monte-Carlo technique. As an example, consider the correlation between, say, the variables COMBO and the lunar cycle (see Figure 4). A standard linear correlation between these variables results in $r = 0.74$, which, if all of the elements comprising the variables were independent, would be associated with t (27df) = 5.79, $p = 3.65 \times 10^{-6}$. However, because COMBO was subjected to two transforms, this t score is an overestimate of the true statistical significance of this correlation.

A random sampling procedure was applied to the 1,426 elements of the variable COMBO to create a new 'pseudo-COMBO' array consisting of the set of original COMBO elements in randomized order. Using this new pseudo-COMBO, correlations between lunar phase and four types of data were determined: (1) for daily data, (2) for 7-day smoothed data, (3) for an epoch analysis with respect to lunar cycle using daily data, and (4) for an epoch analysis with respect to lunar cycle using smoothed data. This process was repeated 100 times with newly randomized pseudo-COMBO arrays to form empirically determined means and standard deviations of the correlations resulting from the four types of transforms.

The Monte-Carlo results for the lunar vs. pseudo-COMBO correlations shown in Figure 3 indicate, as expected, that the chance mean correlations were essentially zero, regardless of the transform, suggesting that no systematic mean-shift biases were introduced by any of the data transformations. In addition, we see that the standard deviations of the correlations increased, as expected, as we go from the original raw data, to a 7-day moving average of the raw data, to a superposed epoch analysis of the raw data, and then to a superposed epoch analysis based upon the 7-day moving average.

The advantage of using the latter analysis, even given the rather large standard deviations introduced by the combination of epoch and smoothing transforms, is that the resulting correlation is visually more informative. That is, while the correlations obtained under various data transforms are more or less the same in terms of statistical significance, the correlations based on the unsmoothed data are smaller and difficult to visualize graphically. Because data visualization is an important component in exploratory data analysis, in the following graphs we only show the superposed, smoothed epoch analysis.

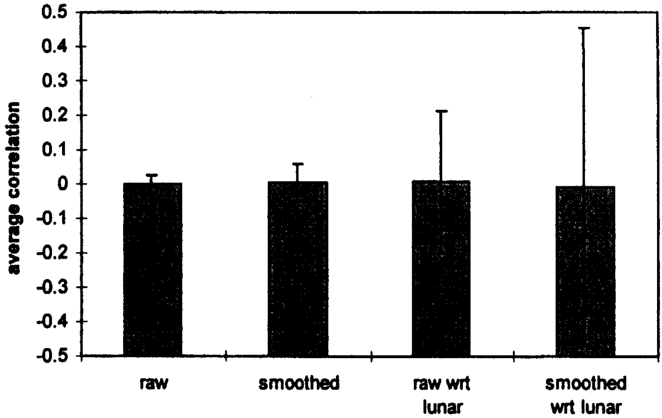

Figure 3. Results of Monte Carlo simulation, showing average correlations of pseudo-COMBO data and standard deviations for the original 'raw' data, for a 7-day moving average, for the raw data with respect to lunar cycle, and for smoothed data with respect to lunar cycle.

RESULTS

> I always find that statistics are hard to swallow and impossible to digest. The only one I can ever remember is that if all the people who go to sleep in church were laid end to end they would be a lot more comfortable.
>
> [Mrs. Robert A. Taft, wife of American President]

Planned Analyses

The lunar cycle vs. COMBO correlation was predicted to be positive. Table 2 shows that depending on the type of smoothing transforms employed, the correlations range from a small and nearly significant positive correlation for raw data to a much larger but less significant correlation for data subjected to a smoothed epoch analysis. Figure 4 shows that for the latter correlation COMBO peaks with a payout percentage of about 78.5% on the day of the full moon, dropping to a low of about 76.5% near the new moon. This suggests that by gambling on or near days of the full moon, and by not gambling on or near

Table 2

*Results of lunar cycle vs. COMBO correlations, with z scores based on comparison of the observed correlations (**observed r**) with chance (i.e. Monte-Carlo-determined) mean correlations (**chance r**) and associated standard deviations of the chance correlations (**chance sd$_r$**); $z = (\text{observed } r - \text{chance } r) / (\text{chance } sd_r)$*

data	transform	observed r	chance r	chance sd$_r$	z	p
daily data	unsmoothed	0.048	0.003	0.028	1.575	0.058
daily data	smoothed	0.097	0.008	0.069	1.282	0.100
lunar epoch	unsmoothed	0.378	-0.003	0.244	1.559	0.059
lunar epoch	smoothed	0.744	0.046	0.479	1.459	0.072

days of the new moon, over the long term it may be possible to boost one's payout percentage by about 2%.[10]

The gravity (tidal) curve vs. COMBO correlation was predicted to be positive. Table 3 shows that each of the four transforms results in a significant positive correlation. Figure 5 shows the relationship for the smoothed epoch analysis. The GMF vs. COMBO correlation was predicted to be negative; Figure 6 shows a close-to-significant negative relationship for the smoothed epoch analysis, $r = -0.66$, $p = 0.07$. The GMF vs. lunar correlation was also predicted to be negative, which was confirmed, but again not significantly so, with the smoothed epoch analysis resulting in $r = -0.36$, $p = 0.20$.

Table 3

Results of gravity cycle vs. COMBO correlations, with z scores based on comparison of the observed correlations with chance mean correlations and associated standard deviations of the chance correlations; z = (observed r – chance r) / (chance sd_r)

data	transform	observed r	chance r	chance sd_r	z	p
daily data	unsmoothed	0.075	0.003	0.024	2.940	0.002
daily data	smoothed	0.121	0.008	0.047	2.430	0.008
lunar epoch	unsmoothed	0.542	0.020	0.175	2.988	0.001
lunar epoch	smoothed	0.880	0.043	0.369	2.269	0.012

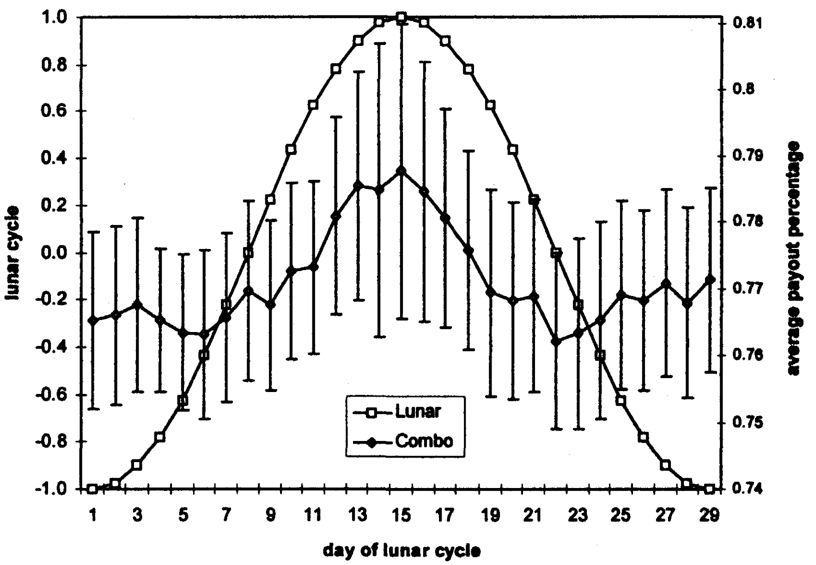

Figure 4. Lunar-COMBO correlation, p = 0.072, for data subjected to smoothed epoch analysis.

[10] Of course, all this really means is that we will lose a little slower than usual, because the empirical payout percentage is still less than 100%. Casinos have nothing to worry about.

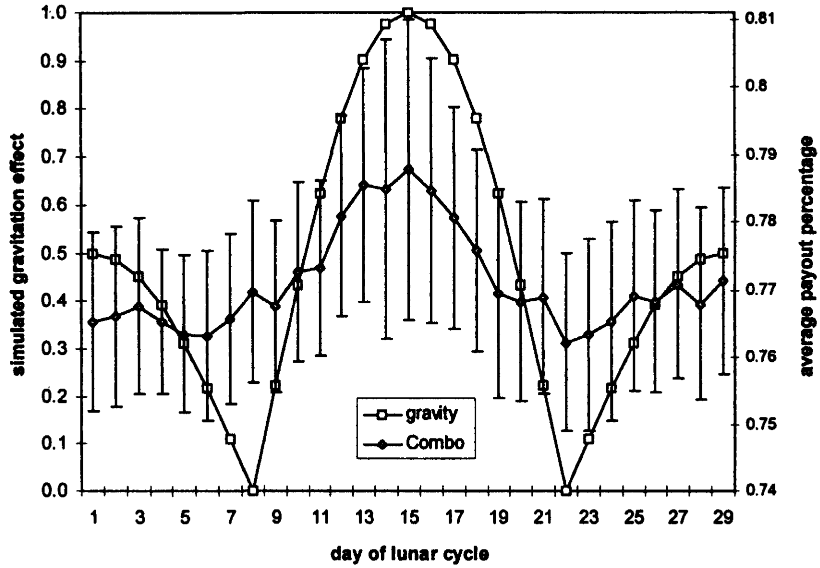

Figure 5. Gravity-COMBO correlation, p = 0.012, for data subjected to smoothed epoch analysis.

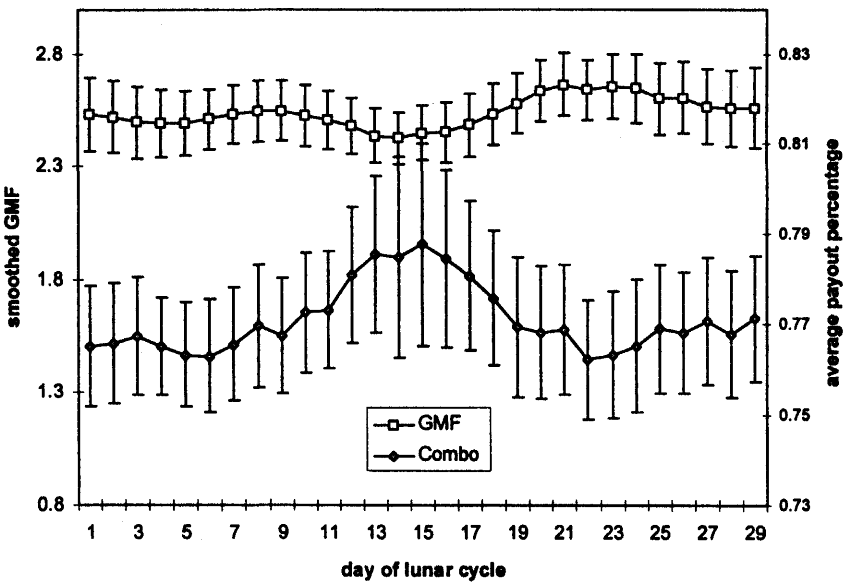

Figure 6. GMF COMBO relationship, r = –0.66, adjusted t = 1.52, p = 0.07 (one-tail). The left ordinate is the natural log of the smoothed daily Ap index with respect to lunar cycle; the right ordinate is the smoothed daily average payout percentage with respect to lunar cycle.

Slots Analysis

As mentioned earlier, because the average Slots payout percentage was significantly smaller than the payout percentages for the other games (as shown in Figure 2), and because Slots data were available only for every other day, it is possible—since COMBO is an average of all casino data combined—that the disparities in payout percentages conspired to cause an artifactual inflation of the correlations observed in Figures 4, 5 and 6. This might occur if, for example, there were strong periodicities in Slots data due to weekly cycles that happened to match the lunar cycle. To examine this possibility, we began by calculating the correlations for the original COMBO variable both including and excluding Slots data.

Table 4 shows that the correlations involving lunar and gravity vs. COMBO with Slots data *included* were larger than the same correlations calculated with Slots data *excluded*. This suggests that the Slots data did contribute some lunar-related factor to the overall combined correlation. To investigate this further, the distribution of Slots payout percentages by day of the week was examined to see if there were any unexpected deviations, followed by examination of the correlation of Slots data alone vs. lunar cycle.

Table 4

Lunar cycle and gravitational tidal correlations versus COMBO, with Slots data included and excluded

	lunar with slots	lunar without slots	gravity with slots	gravity without slots
r	0.74	0.44	0.88	0.77

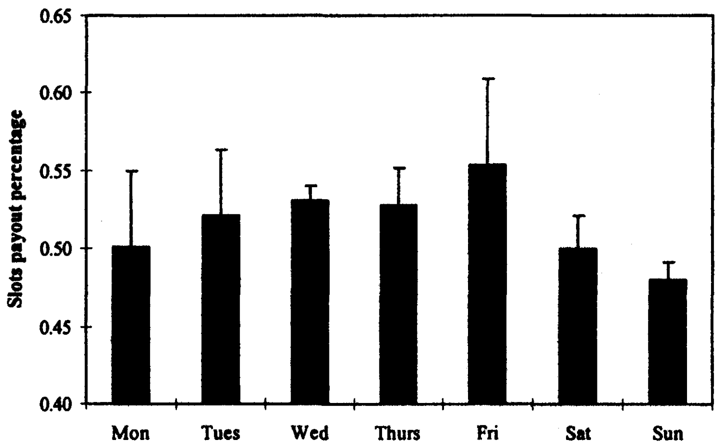

Figure 7. Daily distribution of Slots payout percentages.

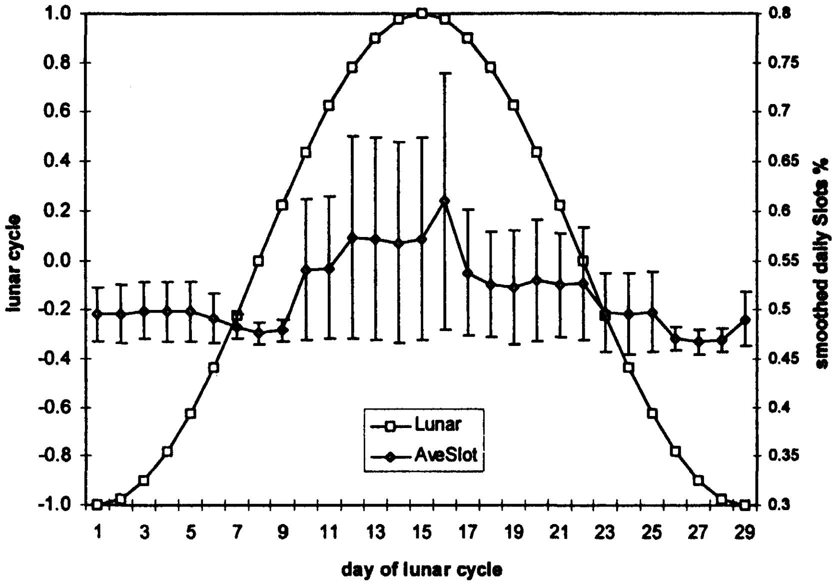

Figure 8. Smoothed Slots payout percentages by lunar cycle, with one-standard-error bars.

The distribution of average Slots payout percentages over the course of a week (Figure 7) showed no unusual deviations, but Slots by lunar cycle (Figure 8) revealed that the largest payouts occurred around the time of the full moon. The standard errors of those larger payouts indicate that the averages were probably due to only a few jackpots rather than to systematically higher

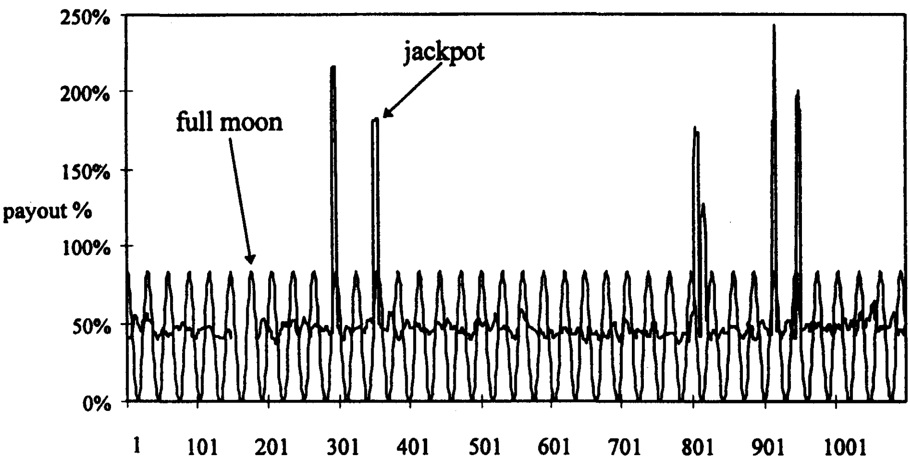

Figure 9. Lunar cycle and Slots jackpots. The ordinate is the payout percentage, the abscissa is the number of consecutive days. The sine wave shows the synodic lunar cycle.

payout rates. This is confirmed by an examination of the time-course of smoothed Slots payout rates (see Figure 9), which shows that of the six major jackpots recorded over the course of the four year database,[11] four occurred within one day of the full moon. If we consider this as four 'hits' in six events, where the probability of each event is $p = 3/29$, then the odds of seeing up to four 'hits' occur where they did by chance is less than 1 in 16,000. Further study with new data will be required to decide if this reflects a genuine lunar-slots relationship or if it is simply a coincidence.

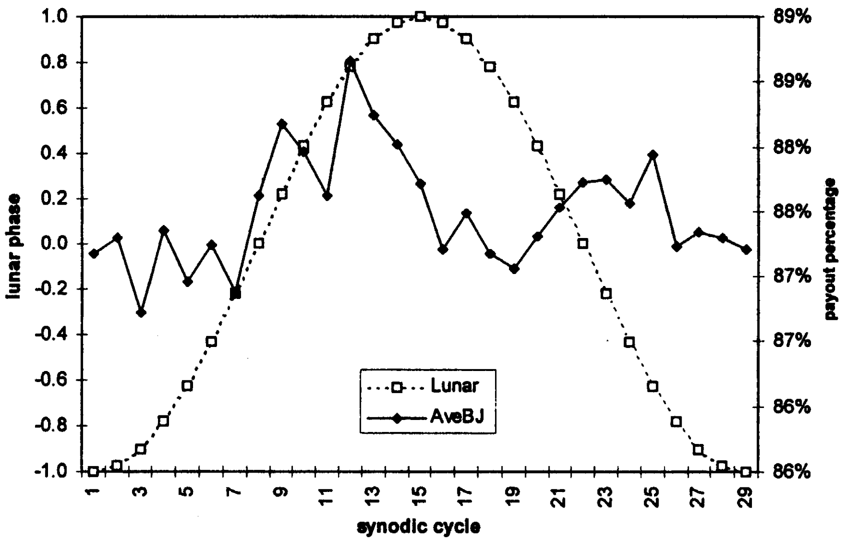

Figure 10. Average payout rates for blackjack.

Analysis of Other Casino Games

To see whether the results found for COMBO could be attributed entirely to slots data, we examined the results of each of the other games separately. In Figure 10, we see that the peak payout rate for blackjack occurred, on average, three days before the full moon. Figure 11 shows that the peak for craps occurred three days after the full moon;[12] Figure 12 shows the peak for roulette at one day after the full moon; Figure 13 shows the peak for keno at one day before the full moon.

The odds against chance that up to three of five casino games would independently show peak payout rates within one day of the full moon (i.e. slots, keno and roulette) is just over 2,000 to 1. Thus, the overall results seen in Figure 4 do not appear to be due to the slots alone, suggesting that the lunar-payout relationship may be generalizable.

[11] The last few lunar cycles are not shown in Figure 10 because no jackpots occurred during those months.

[12] Day 29 for craps had virtually the same payout rate.

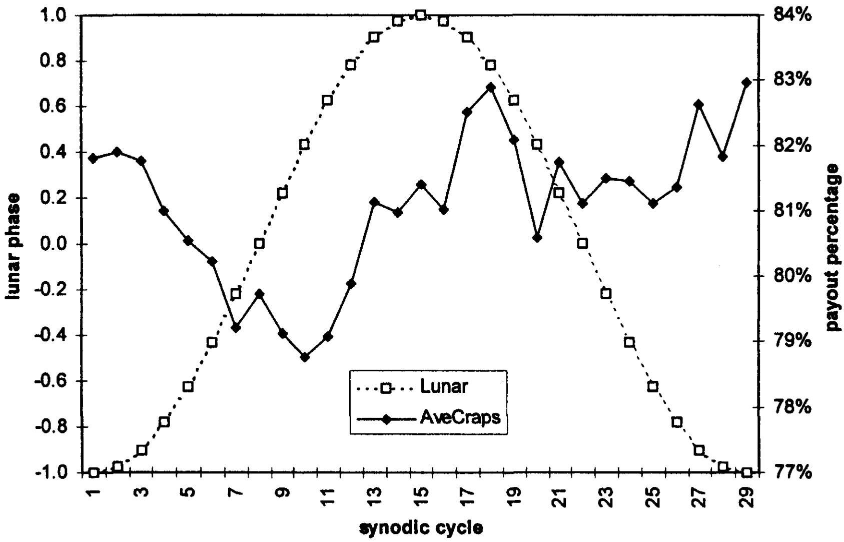

Figure 11. Average payout rates for craps.

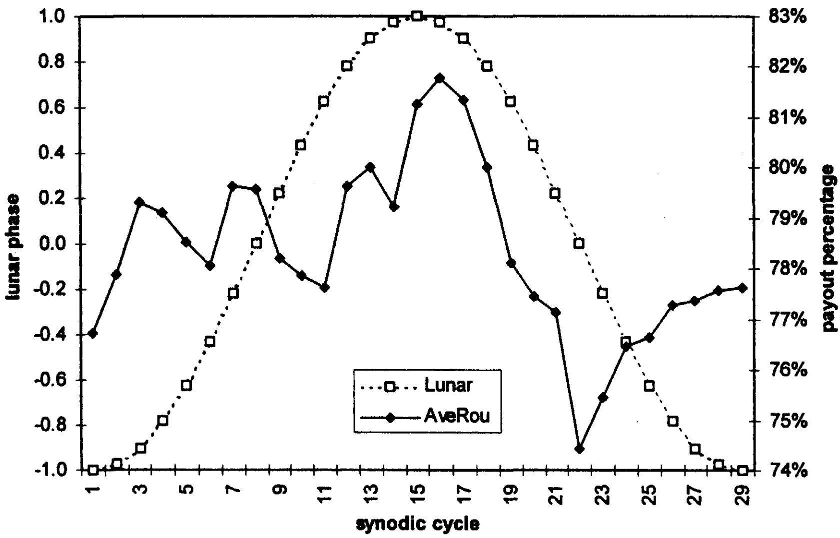

Figure 12. Average payout rates for roulette.

Confirming Analyses

To confirm the observation of a negative correlation between lunar cycle and GMF observed for the four years 1991 to 1994 ($r = -0.36$, $p = 0.20$), the same relationship was examined for the decade 1980 to 1989. Figure 14 shows that the negative relationship maintained over more than 120 lunar cycles.

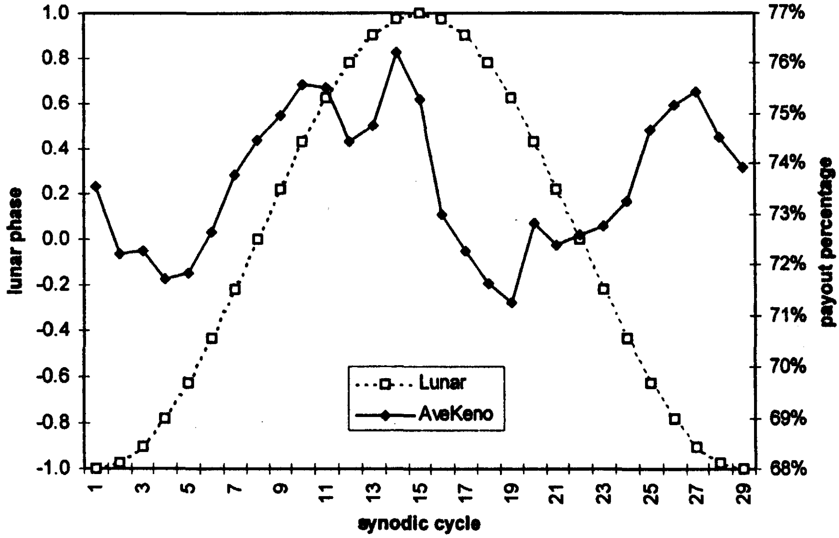

Figure 13. Average payout rates for keno.

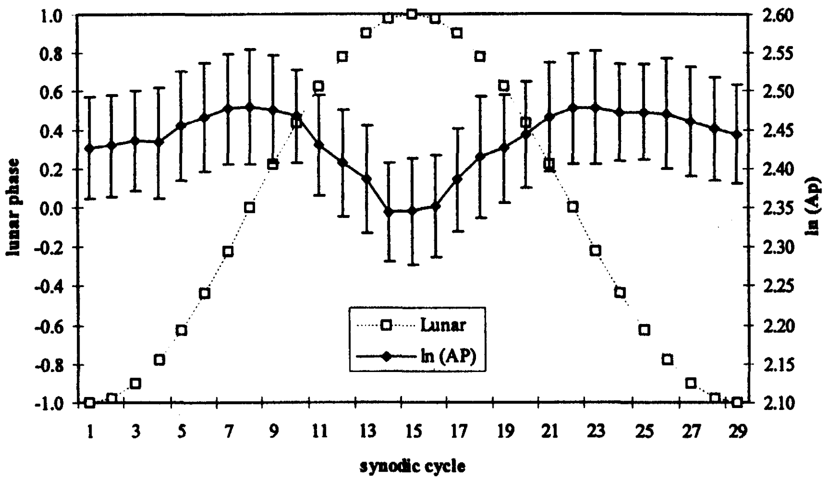

Figure 14. Graph of lunar cycle and GMF for 1980 to 1989; plus and minus one standard error; the right ordinate is smoothed daily average GMF with respect to lunar cycle, the left is the phase of the lunar cycle.

To further study the possibility of lunar effects in both GMF and casino payout percentages, a bivariate co-spectral analysis, analogous to a cross-correlation analysis but in the frequency domain, was used to examine the daily (unsmoothed) GMF and daily (unsmoothed) casino payout percentages.

Results (Figure 15) show that the highest spectral peak corresponds to a cycle of about 9 days, but the second-highest peak, at log period 3.39 days, corresponds to 29.67 days. The frequency resolution of this spectral analysis is about 1 day, thus this analysis confirms that a lunar period (29.53 days) may be common to both daily GMF and to casino payouts.

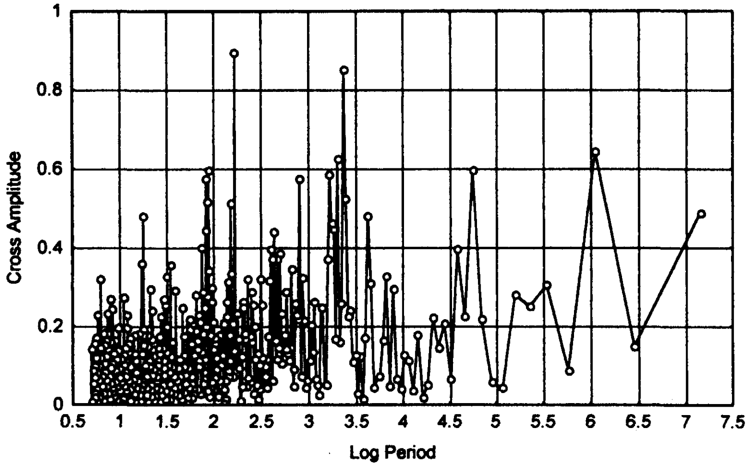

Figure 15. Bivariate cross-spectral analysis of raw daily values (unsmoothed) for GMF and casino payout percentage. The ordinate, cross-amplitude, is the product of the GMF and payout percentage spectral frequencies.

Discussion

The Skeptical View

It is often assumed that gamblers want to win. Surely they focus as much intention on their games as any highly motivated subject in a laboratory psi experiment. Thus, goes the skeptical argument, if we believe the meta-analyses suggesting that psi is widely distributed in the population, then the casinos should be going broke. And lo!, because casinos are exceptionally profitable, ipso facto our reasoning must be flawed, and psi must not be real.

One response is to refer to the empirically determined payout percentages, as shown in Figure 2. These percentages show why casinos do not need to worry about the presence of genuine psychics. While the odds for some optimally-played games (like craps) are theoretically close to 1 to 1, in practice no one plays optimally all the time. The best payout rates in real-life data are only about 88%. With these house advantages, the best psychics in the world would have to play consistently well, with very high-level psychic functioning, to win any substantial amounts.

Another problem with the standard skeptical view is that it ignores the fact that casinos are specifically designed for entertainment, not for optimal psychic functioning. Casinos are loud and visually distracting; they provide free alcohol, scantily-clad attendants, and dense cigarette smoke. Such a setting is hardly conducive to first-class psi, which is often associated with meditative states and high mental focus.

In addition, the common assumption that gamblers uniformly want to win is questionable. Any clinical psychologist will confirm that people do not always do what it is in their best interest to do. For example, in a purely rational world, far fewer people would be smoking cigarettes. And even a casual study of gambling behavior reveals it to have a strong self-destructive element. So the skeptical assumption that psychics would be breaking the bank in casinos carries hidden assumptions that natural psychics are better integrated psychologically than the general population, and that they are highly motivated by money. Both assumptions may be wrong.

Speculations

> There are two great pleasures in gambling: that of winning and that of losing.
>
> [French proverb]

It is intriguing to note that modern findings about lunar cycle and psi (Puharich, 1973; Radin & Rebman, 1994), lunar cycle and abnormal behavior (e.g., Lieber, 1978), and GMF fluctuations vs. psi and abnormal behavior (e.g., Persinger, 1985), seem to corroborate ancient mythology and folklore about the effects of the moon on human behavior (Guiley, 1991).

The common links among these factors—moon, tidal factors, GMF, abnormal behavior, psi—are not well understood. Some researchers suggest that the pineal gland may play a role, because it is sensitive to geomagnetism and, as the suspected, vestigial 'third eye', it may have a connection with psychic lore about clairvoyance and the 'sixth sense' (Becker, 1990; Roney-Dougal, 1991; Wilson et al., 1990). Others have noted that local static magnetism and GMF seem to have played a role in producing altered states of consciousness at ancient sacred sites (Devereux, 1990). For example, Devereux (1990), citing Pepper & Wilcock (1977, p.207), indicates that in ancient times magnetism, magic, and the stars were closely linked:–

> Magnetism . . . constitutes an art of healing, not through a substance but by a power, a power borrowed 'from the stars and nowhere else', says Paracelsus, the sixteenth-century alchemist. . . . People had something magnetic in them, he maintained, without which they could not exist and through which they were linked to the sun and the stars.

The eventual explanations for how the moon, GMF, gravity and psi fit together will probably be exceedingly complex. There are so many interrelationships among terrestrial and extraterrestrial factors, and between behavioral and environmental factors, that unraveling them sufficiently to produce viable explanatory models and then persuasive predictable power will require a detailed, multidisciplinary effort and years of intensive research.

Predicting Casino Payouts with a Neural Network

In the meantime, we can explore rudimentary models and test their predictive power. In the first model we tested, the predictor variables were (from Table 1) the seven smoothed daily values for GMF, sunspot number, 10 cm radio flux, lunar phase, maximum temperature, barometric pressure, and humidity. These variables were used to try to predict COMBO.

Two tests were conducted, using two different types of modeling techniques. For the first test, a conventional backpropagation artificial neural network was employed.[13] This model had 7 input nodes (the seven predictors mentioned above), 10 hidden nodes, and 1 output node (COMBO). Conceptually, each input/output pair was a row in a spreadsheet. The rows consisted of the daily data, and the columns corresponded to individual variables such as GMF, sunspot number, etc.

The data used for training and testing the network were daily values, i.e. not the superposed epoch analyzed data. The network was trained on 80% of the data, or 1,134 data items, and tested on 20%, or 284 items.[14] Before the network observed any data, the rows of the entire dataset were randomly scrambled so the day-to-day chronological order between data items was destroyed, but the inter-relationships *within* a given row (i.e. the columns) were not changed. This is a common practice used when training neural networks. It helps the network avoid learning any time-dependent relationships in the data, and was particularly important in this study because of the 7-day smoothing algorithm applied to the data. The scrambling also helps the network develop a model that generalizes to new, time-independent data.[15]

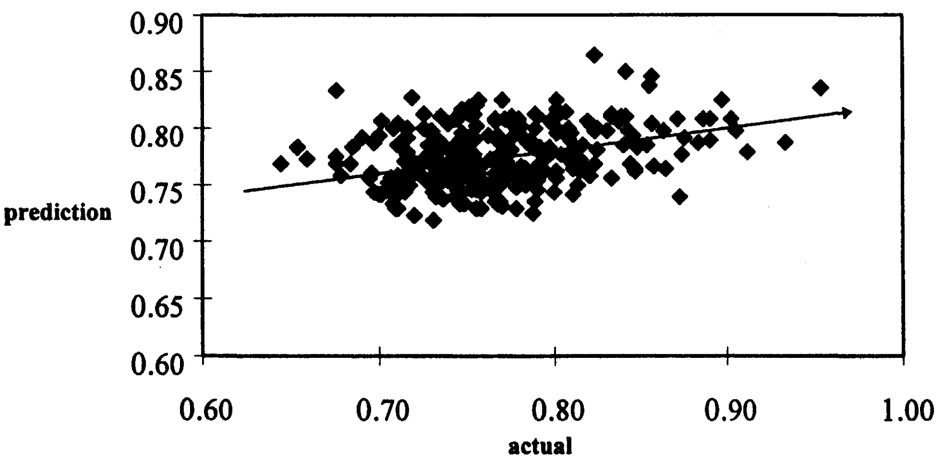

Figure 16. Correlation between neural network's predictions of casino payout rates and actual payout rates; N = 284, r = 0.32, t = 5.74, 282 df, p << 0.001.

[13] *Brainmaker Professional 3.1,* neural network software from California Scientific Software (Lawrence & Lawrence, 1992).

[14] The 80% training, 20% testing split was a default assigned by the neural network software. The number of samples employed in this test corresponds to the 1,426 datapoints minus a few data items dropped due to the use of the 7-day smoothing transform. The testing set was used only to test the predictive power of the trained network.

[15] Of course, time-based information can be critically important, but the present study was interested in whether simultaneous environmental relationships might be used to predict casino payout rates.

As a control, we took the original dataset and maintained the order of the rows (i.e. the daily data), but scrambled the items *within the columns* (i.e. the values of the individual variables). This scrambling should result in a network that cannot learn anything because the (hypothesized) meaningful relationships between the seven inputs and one output were destroyed.

The networks were trained (repeatedly presented with example data items) until the error rates between the actual and predicted outputs fell below 5% for all items in the training dataset. Results of the final tests are shown in Figures 16 and 17. Without attempting to analyze what the networks learned,[16] it is clear that when presented with actual data, the network successfully learned to associate the seven environmental inputs with COMBO, that is, it learned that certain configurations of geophysical and local environmental conditions resulted in different casino payout percentages, and *it was able to successfully demonstrate* its knowledge on new data it had not 'seen' before. When the meaningful relationships were scrambled in the control test, the network was no longer able to learn.

Predicting Casino Payouts with an Abductive Network

An abductive network is similar to a neural network, except instead of being a network of extremely simple, neuron-like nodes, it is a network of mathematical equations.[17] For some problems and datasets, this form of modelling provides better results than a neural network. The same datasets and variables prepared for the neural network test were used in this analysis, except that the net was trained on 75% of the data (1063 samples)[18] and tested

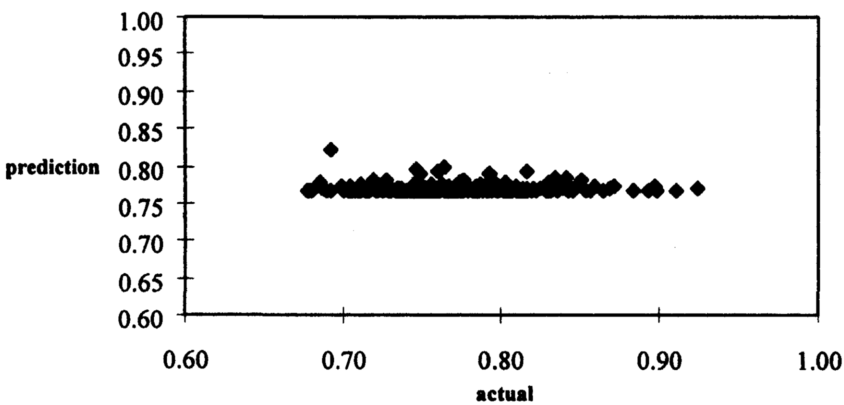

Figure 17. Correlation between neural network's predictions of casino payout rates and actual payout rates for the scrambled data; *r* = *–0.012, t = –0.200, 282 df, p = 0.841. The variance in the control output shown here is restricted because the neural network defaults to a 'best-guess' output when it cannot learn meaningful relationships between the inputs and output.*

[16] Because this is a difficult problem far beyond the scope of this study.

[17] An abductive network called AIM, from AbTech Corp., Charlottesville, VA, was used for this test.

[18] This training, testing split was the default assigned by the software.

on 25% (355 samples). The results, shown in Figures 18 and 19, indicate that the abductive model was somewhat more successful than the backpropagation neural network in learning relationships between environmental variables and casino payout percentages.

These two modeling tests show that there are meaningful relationships between fluctuations in the environment and winnings in the casino. By inference, assuming that gaming odds are uniform and that payout percentages are not subject to seasonal or other variations, these analyses provide evidence for psi in the casino.

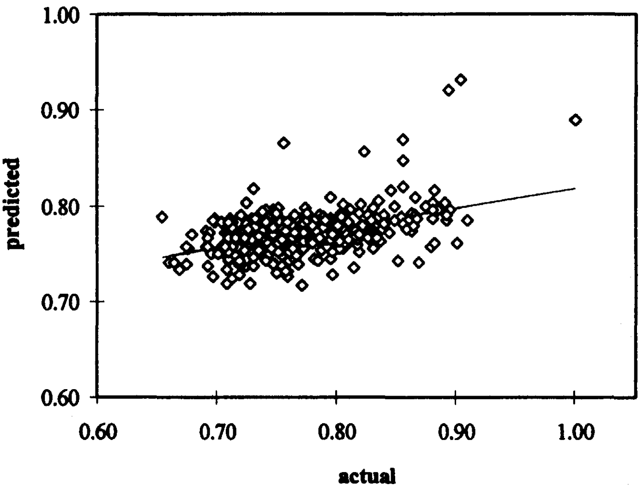

Figure 18. Correlation between abductive network's predictions of casino payout rates and actual payout rates; r = 0.450, t = 9.460, 353 df, p << 0.001.

CONCLUSION

> The moon is a white strange world, great, white, soft-seeming globe in the night sky, and what she actually communicates to me across space I shall never fully know. But the moon that pulls the tides, and the moon that controls the menstrual periods of women, and the moon that touches the lunatics, she is not the mere dead lump of the astronomist. [D. H. Lawrence (1885-1930)]

Correlations and predictive modeling tests were used to explore the possibility that daily fluctuations in casino payout percentages might be due, at least in part, to 'psi in the casino'. Casino games are strictly controlled and closely monitored by both casinos and gaming control boards, thus it is unlikely that payout percentages are systematically manipulated or biased. This makes casino data suitable for testing hypotheses about payout fluctuations.

In this study, involving four years of data from a Las Vegas casino, daily payout percentages were shown to significantly correlate with gravitational tidal forces, and nearly significantly correlate with lunar cycle and GMF. Both lunar cycle and geomagnetic flux have been linked in previous research to

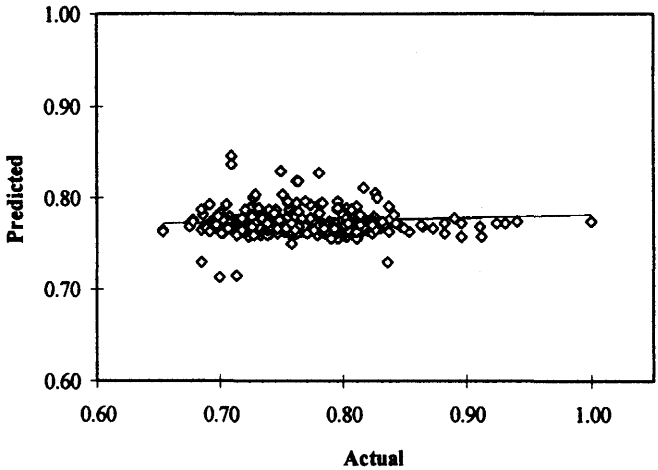

Figure 19. Correlation between abductive network's predictions of casino payout rates and actual payout rates for scrambled data; $r = 0.0346$, $t = 0.583$, *353 do*, $p = 0.561$.

changes in psi performance, and now gravitational tides show interesting effects as well.

There is an alternative to the hypothesis that environmental variables affect psi per se. Fluctuations in the environment probably affect the functioning of the human nervous system (Tromp, 1980), including some aspects of cognitive functioning (Persinger & Levesque, 1983; Snoyman & Holdstock, 1980; Rotton & Frey, 1985). During GMF quiet periods, when this aspect of the environment is presumably not adversely affecting the nervous system, what we see as higher casino payout rates may actually be chance-expected values, and during periods of environmental disturbances, when the nervous system is stressed and our ability to concentrate is reduced, what we observe as lower casino payout rates may instead be lower-than-chance levels. This is because gamblers' attention and vigilance are presumably not as high; they may tend to be distracted from the games more easily (especially games like blackjack and craps where playing strategies can influence the payout percentages), and hence they tend to lose more.

Countering this alternative is the observed distribution of Slots payout percentages. Slot jackpots are relatively rare, and yet four of six jackpots in four years occurred close to the day of the full moon. So perhaps there is indeed something remarkable about the full moon. Perhaps it acts as a cosmic clock (which is coincidentally in sync with fluctuations in solar wind), or perhaps it acts as a modulator of global GMF and tidal forces.

Whatever the ultimate explanation, the present exploratory analysis has just scratched the surface of what may be a set of complex relationships among environmental factors and psi performance in casino games. While the absolute magnitude of the effect observed here is small, on average one can apparently gain about a 2% advantage by gambling on the full moon and not gambling on the new moon. This means most players will lose a little slower than usual.

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