# SOLAR-PERIODIC FULL MOON EFFECT IN THE FOURMILAB RETROPSYCHOKINESIS PROJECT EXPERIMENT DATA: AN EXPLORATORY STUDY

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**ABSTRACT: Radin and Rebman (1998) claimed evidence of psychokinesis effects in casino payout rates depending on lunar phases. They found the peak effect in the full-moon interval. This paper reports on an experimental data evaluation of 199,632 retroPK experiment trials, covering eight years. The hypothesis of a full moon effect is tested with the large database of the Fourmilab RetroPsychoKinesis Project. An earlier test of these findings by the author, published in 2000, supported the full moon hypothesis. In additional tests with new data, published in 2002, the observed effect changed its sign and disappeared. Some researchers, including the author, suggested in the past an anomalous experimenter effect and assumed the consequences of the model of pragmatic information to be the real cause of these effects.[1] But a new evaluation of the data revealed a significant retroPK solar-periodic relationship which indicates that actually physical parameters are responsible for the change of the full-moon effect in the mentioned intervals. The hypothesis is suggested that the moon's interaction with earth's magnetosphere during the moon's passage through the magnetotail in full-moon times might modulate retroPK performance.**

The lore about the moon's effect on the animal and human behavior has existed for centuries. The full moon seems to be connected with a higher accident rate. The notions of "full moon madness," "lunacy," and "lunatic" imply a relationship of altered states of consciousness with lunar influences. The tales of werewolves and moon magic bring the moon into connection with anomalous phenomena. In the Holy Bible, people pray to the Lord that the moon shall not "smite you by night" (Ps. 121:6, Revised Standard Version). The full moon is also associated with important spiritual events: Passover and Easter are always at Saturday and Sunday after the full moon of the vernal equinox. The time of a solar and lunar eclipse is considered to be a time of extreme spiritual importance and of successful prayer: "The *sun shall be turned to darkness*, and the *moon to blood*,

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1 This was also mentioned in the first submitted draft of this paper. But an anonymous reviewer commented on the presented results with the words: "As written, the paper con-clues that there is 'no there there' except perhaps a remarkably potent experimenter retroPK effect. But a brief glance at the figures tells a different story, one I think the author should flesh out as a valuable contribution." As the consequence of this statement, a reanalysis of the data was done with respect to dependence on physical parameters, giving this paper its present look.

before the day of the Lord comes, the great and manifest day. And it shall be that *whoever calls on the name of the Lord shall be saved.*" (Acts 2:20-21; Joel 2:31-32) Is this only superstitious belief or does the lore about the effects of the moon have a grain of truth? Does the moon affect the results of our thinking, wishing, and praying?

In the 1960s, Andrija Puharich observed during telepathy experiments an increase in the strength of effects at the time of full moon and new moon (Puharich, 1973). In the 1970s, Stanley Krippner and colleagues noticed increased psi abilities at the time of full moon. They wrote:

> The data of 80 night time sessions involving ESP in dreams suggest a significant relationship with the lunar cycle. It is hoped that other investigators will inspect their data to see whether similar patterns emerge or, better yet, design experiments to probe this association more thoroughly. (Krippner, Becker, Cavallo, & Washburn, 1972, p. 18)

In the 1990s Radin and Rebman mentioned that psychokinesis effects also arise in everyday life and they sought to test such effects particularly in the casino: "Thus, if one accepts that precognition and psychokinesis are widely distributed human abilities, then, in principle, they may also be present in the casino" (Radin & Rebman, 1998, p. 193). In 1998, they claimed, based on analyses of data from Las Vegas casinos, that the payout rate (the quotient of income and payout rate) varies over a period of time and is correlated with some environmental variables. They found that the peak effect occurred within 1 day of the full moon. They supposed that "some environmental factors may be related to predictable variations in psi performance" (p. 193). One of these environmental factors is the influence of the geomagnetic field: Scores in free response anomalous cognition experiments are negatively correlated with geomagnetic fluctuations (Spottiswoode, 1990). Another one is the tidal effect, the moon's gravitational influence on the earth.

Casino data are hard to get. But for those who are interested in examining the anomalies claimed by Radin and Rebman there is another possibility. Because they reduce the anomalies observed in the casino payout rates to psychokinesis and/or precognition (Radin, 1997, p. 175), this opens the opportunity for the direct use of psychokinesis (PK) or retropsychokinesis data for testing the findings of the Radin and Rebman study. For this test the only public PK database in the World Wide Web was used and analyzed: the quite extensive database of the Fourmilab RetroPsychoKinesis Project.

A first attempt of the author to replicate the findings of Radin and Rebman with the Fourmilab retroPK data seemed to confirm a positive, significant effect in the full moon interval (Etzold, 2000). In the summer of 2000 the situation changed rapidly. A significant and strong negative effect in the full moon interval canceled the entire accumulated positive deviation. The replication with the new data failed (Etzold, 2002a). The reason for the unsuccessful replication will be considered in this study.

Many serious studies on lunar effects in human behavior and experience have failed to find any significant effects (Bördlein, 2002; Culver, Rotton, & Kelly, 1988; Guiard, 2002; Wunder & Schardtmüller, 2002). Is Radin's and Rebman's study now the great exception? All of the aforementioned studies showed defects that make it difficult to test the claim of a lunar effect. Krippner and his colleagues analyzed the data of 80 nighttime sessions, 2.7 lunar cycles if these sessions were executed day by day. This is a very small time interval to make a general statement about a lunar effect. A defect of the Radin and Rebman study might be the fact that it represents only one pilot study without any consistent replication. The large error bars in Figure 4 of the Radin and Rebman study (1998, p. 204) more likely indicate a nonsignificant deviation (Boller, 2002). In another publication, Radin demonstrates a replication with new data from lottery payout rates. However, this replication shows the lowest payout rate exactly at the time of the full moon, which Radin explained with increased geomagnetic field values at this time (Radin, 1997, p. 187). In contrast to that, other studies associate high PK effects such as poltergeists or retarding the hemolysis of red blood cells with high geomagnetic field activity (Braud & Dennis, 1989; Gearhart & Persinger, 1986; Palmer, Baumann, & Simmonds, 2005). The hypotheses here are based on Radin and Rebman's observation that low geomagnetic field activity is associated with high positive retroPK effects whereas high geomagnetic field activity might be associated with high negative retroPK effects.

## The Fourmilab RetroPsychoKinesis Project

John Walker oversees the ongoing Fourmilab RetroPsychoKinesis Project, which was founded by Matthew R. Watkins in 1996. It deals with an automated remote retroPK experiment that tests mental influences on prerecorded random data. Data are derived from a hardware random number generator (RNG) based on radioactive decay.[2] The participants are encouraged to shift the mean deviation of the RNG only by wishing, wanting, and praying in a predetermined direction. For this purpose, a sequence of random data is transferred to their computers via the World Wide Web and displayed on the screen in animated form. A visual display shows the deviation of the current cumulative score from chance (in terms of standard deviations), which can be displayed in three

2 http://www.fourmilab.ch/hotbits/

different forms: clock, pendulum, and bell curve or "experiment" for a rudimentary numerical report of results. An acoustic signal can be set to sound when the last peak value reached has been exceeded. At the end of each experiment, the final score of the mean shift deviation is calculated and indicated. The participants can select from "for-the-record" runs, "practice," and "demo" experiments, and they can select the direction of their intent. Note that there is a default setting for a particular target direction ("right" for clockwise and the bell curve and "high amplitude" for the swinging pendulum). Three quarters of the test persons used this default setting, which corresponds to a positive deviation as consistent with the participant's intent from the expected mean result in the random data. Each result, including the total of random data used for every for-the-record and practice experiment, is registered on the Fourmilab server in a log file. The demo experiment results use computer-generated pseudorandom data. They are not registered.

The title RetroPsychoKinesis suggests a backwardly oriented causation, that is, an influence of events in the past from the future. But keeping in mind that the retroPK data had already been generated and saved before the test person requested the random data for an experiment, we cannot exclude the interpretation of the observed phenomena as a result of precognition or anomalous cognition. For example, I can choose the goal of an experiment (e.g., left or right), but if I feel intuitively what might be the correct decision, I do not need to try to influence the REG via psychokinetic efforts in order to get a confirming result.

A summary of the total retroPK for-the-record results and the control run results is updated daily, so everybody may monitor on the web what is going on.[3] No results are provided in the summary for the practice runs, but individual users can see their practice runs in reports of their own experiments.

*Data Generation and Standard Analysis With Fourmilab*

For one retroPK for-the-record experiment, 1,024 random bits are requested from Fourmilab's RNG, the "HotBits" server. The theoretical mean value is fixed at 512 hits; the theoretical standard deviation is 16 bits. The empirical standard deviation computed here for the entire control run database was 15.948 bits. The internal clock of the Fourmilab server is set to Coordinated Universal Time (UTC). A check of the correct server time, taken from a retroPK experiment time stamp that was started exactly at 12:01 Central European Summer Time (CEST) = 10:01 UTC of the time of the Physikalisch-Technische Bundesanstalt's atomic clocks,[4] revealed no time difference.

3 http://www.fourmilab.ch/rpkp/experiments/summary/
4 http://www.ptb.de/en/zeit/uhrzeit.html

However, no "fresh" random bits are supplied. The Fourmilab server maintains an inventory of 8,388,606 random bits (1,048,576 bytes) that is periodically refilled from the HotBits generator, which itself maintains an inventory of 2,097,152 bits (262,144 bytes). Between the generation of the random bits and their use in experiments there is an unknown delay. From the first retroPK experiment on January 11, 1997 up to this analysis, 199,632 for-the-record experiments and 202,958 practice runs were counted in total. They are registered under 19,030 "participants," that is, different e-mail addresses or keywords. Since December 26, 1997 control experiments have been running, one run every hour, totaling 60,163 as of this writing. It is probably one of the largest parapsychological field experiments in the world.

The first registered retroPK run is dated January 11, 1997, 17:33 UTC, and the last retroPK result evaluated here is dated October 8, 2005, 12:45 UTC. Analysis of the retroPK for-the-record experiments included only those labeled as "Record" in the raw data file with no other additions. The experiment database includes a total of 9 runs with incorrect bit counts resulting from errors in the experiment software that have since been corrected. The results of these erroneous runs have been left in the database but are ignored when analyzing it.

An analysis showed that many runs were done with the same date and time stamp, usually 2%, in the retroPK for-the-record experiments and practice runs. These are runs of users who click to start an experiment and, when there is no immediate reply due to internet congestion between their machine and the Fourmilab server, click again. Beside those runs, two large clusters of approximately 1,000 runs were visible in the graph, which led to the suggestion that "fakers" started record experiments, aborted the experiments prematurely and started the next runs, and so on. If the effect observed depends only on failures in internet connections, we might get the same distribution of "failed runs" in the for-the-record experiments as in the practice runs. Approximately 10,000 such experiments with the same date and time stamp in clusters (out of a total of 199,632 for the record experiments) were counted, especially in August 1999, July and August 2001, and January 2004. Such "faker" clusters are completely absent in the practice runs. The total of 14,769 results yielded a $z$ score of 1.31, but they showed no visible full moon effect. These data were kept in the database. In the worst case they increased the random noise in the results, especially in the first evaluation period.

Two time intervals were found in which the HotBits generator was down and no retroPK experiments could be run: from April 28 through June 28, 2002, and from January 1 through January 16, 2003. The daily distribution of the retroPK for-the-record experiment data showed that more than half of all experiments were done in sessions between 18:00 and 5:00 UTC. An overall summary for the total of 199,632 for-the-record experiments of retroPK data in the evaluation period of January 1997 through October 2005 showed a bit score of 5,830 less than the expected mean bit score and yielded a nonsignificant *z* score of -0.82.[5] This negative result does not support the retroPK hypothesis. Remarkable in the RetroPsychoKinesis Experiment Summary are the "short-runner" results: 7,232 test persons (or unique identities) did only one experiment and 3,376 did only two runs, and these short-runner groups produced a bit score of -7,739, which amounts to $z = -4.10$.

There might be two interpretations of these results. One is that weakly motivated and perhaps skeptical persons might have stopped this experiment when their first retroPK score was negative. Therefore they did not climb higher in the table of the "Runs by Subjects Histogram," and their negative score remained in the short-runner group. This could result in an "early stopping" bias. These short-runners might be persons with low motivation for doing the experiments or persons who mistyped their identity (e-mail address or user name) in the experiment's log-in form.

Another possible interpretation is that the significant total result of the short-runners might be a retroactive influence of the data that reflects their unconscious negative attitude toward the experiment. In this case the highly significant result would support the hypothesis that human beings are in fact able to retroactively influence the data. For a clear decision it might be necessary to collect more data about human behavior regarding "beginner's unluck" to test whether an early stopping bias is responsible for the effects observed here.

In the evaluation period, 60,163 control runs were counted, each with 1,024 "trials." The total bit sum of "hits" was 30,805,822, and the theoretical mean was 30,803,456. The standard deviation was 5,550.086, and the deviation from expectation was 2,366. An overall $z = 0.426$ was computed for the control run database. This might indicate that the HotBits random event generator is working well insofar as we only compute summed bit scores of the experiment data. But a test for randomness of the random data revealed that the Fourmilab HotBits server perhaps does not always generate genuine random data.

The HotBits server uses interval timing for generating the output of random bits in connection with a clock, which counts exactly 1,024 bits for every experiment. "In practice, to avoid any residual bias resulting from non-random systematic errors in the apparatus or measuring process consistently favoring one state, the sense of the comparison between T1 and T2 is reversed for consecutive bits."[6] This circuit works like a flip-flop. For testing the distribution of multiple bit patterns, the hexadecimal

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5 Note that the plot of cumulative *z* scores in the RetroPsychoKinesis Experiment Summary on the Fourmilab Web site is erroneous and does not report the actual shape of the cumulative deviation from expectation. For more information see: http://bs.cyty.com/menschen/e-etzold/archiv/science/4milabRPKP/

6 http://www.fourmilab.ch/hotbits/how.html

values were converted into 4-bit binary equivalents and were rebuilt to a binary random data stream. All control experiment data were converted into binary bits (1,024 binary bits for each experiment). We counted how often a pattern of, for example, "000" or "111" bits (Nm = 3) appeared in the binary database, starting with 1-bit patterns and ending with the maximum length of a bit pattern with the same successive bits. Then all the successive 1-bit patterns were counted; next, the 2-bit patterns; third, the 3-bit patterns; and so on. The same procedure was used for 0-bit patterns. The total number of control runs was 60,163, partitioned in 6,162 samples. Sample size was 9,999 bits per sample. The patterns of single and paired 1s and 0s in the HotBits binary random data stream seem to be more than expected. The expected *N* for 1-bit patterns was 15,403,459.5. The actual result was 15,433,882 for the control data, 30,422.5 more than the theoretical expectation. For 2-bit patterns, the expected *N* was 7,701,729.8, but the actual result for the control data was 7,710,029, with a surplus of 8,299.2 in comparison to the theoretical expectation. And vice versa, the actual results for the following multi-bit patterns in the range of 4 bits up to 15 bits were below the theoretical expectation. This means that approximately 0.2% of the random data seems not to be really random in nature but to consist of sequences of alternating bits (010101 . . . for example), just like the flip flop is running empty without a random trigger. We have obtained 15.948 as the value for the empirical trial-level standard deviation. This is 0.3% less than the theoretical expectation of 16 bits per 1,024-bit experiment at the same level.

A similar observation was made in the MMI PortREG replication experiments, when calibrating the REG sources. Jahn and colleagues reported

> a slight excess of the bit sequences 01 and 10 over 00 and 11. The source of the effect is the design of the REG, which includes an XOR alternating template to eliminate actual physical bias in the threshold setting of the comparator. . . . The size of this excess of alternations is on the order of a few parts in 10,000 and is detectable if data sets are accumulated over a few days. (Jahn et al., 2000, p. 548)

For our purposes this does not affect the total bit score of the outcome of the experiment in a problematic way because for the total bit score it makes no difference whether we summed 1-bits out of a stream of 010101. . . or out of a stream of 000111. . . the sum is always the same. The longer the flip-flop is running empty, the more it will bring down the total outcome of the experiment to chance expectation. For the computations here it means that the main tests of the real retroPK for-the-record data should be done by using the difference of retroPK for-the-record data and control run data to eliminate any bias or flaw in the data. For future experiments, the random source of the Fourmilab RetroPK Project should be calibrated or the empirical trial-level standard deviation value should be used for statistical purposes instead of the theoretical standard deviation.

*The Hypotheses*

Radin and Rebman mentioned an interval of 2 to 3 days centered around the time of the full moon, in which a peak effect was found for 3 of 5 pay-out rates of casino games. They analyzed data of 49 to 50 moon cycles. They wrote: "The odds against chance that up to three of five casino games would independently show peak pay-out rates within one day of the full moon (i.e., slots and roulette) is just over 2,000 to 1." (Radin & Rebman, 1998, p. 208) I do not know how Radin and Rebman calculated these odds against chance, and it is not clear which exact time range is meant by the phrase "within one day of the full moon." If I estimate "one day of the full moon" as *2 days* centered around the exact full moon time, the chance that 1 casino game would show its peak pay-out rate in this interval is 1 to 14.5. For 3 games out of 5 the chance is approximately 1 to 2,000. In another context, they wrote that

> of the six major jackpots recorded over the course of the four year database, 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' occurring where they did by chance is less than 1 in 16,000. (Radin & Rebman, 1998, p. 208)

In this case, "within one day of the full moon" means *3 days* centered around the full moon time. This time interval was confirmed by Radin in a personal e-mail communication on September 15, 2004.

We assume that if there is an unusual anomalous effect in the full moon days, it has the power to cause a significant positive deviation of the retroPK results in days of low GMF, as Radin and Rebman stated that "a possible GMF correlation with casino payout percentages would be negative." (Radin & Rebman, 1998, p. 195)

With reference to the partitioning of the moon cycle in 29 intervals with a constant interval width, an average "daily" interval covers the width of a 12.4° lunar synodic phase. The moon's synodic period is constant, but comparisons between the different durations of lunations showed that the lunar phase degrees in the full moon interval vary with a time interval of up to 1 hr 24 min in a 2-day interval related to the observer on earth. One of the first assumptions was that an anomalous lunar periodic effect might depend on the moon's position in space related to sun and earth. Therefore the date and time stamps of all data with respect to lunar periodic evaluations were converted into a lunar phase degree, which is more precise with respect to moon position than using date and time calculations.

Because there was no exact expectation in which part of the full moon interval we would find an effect, two hypotheses were introduced in the spring of 2000 that marked the narrower and the wider limits of what could be interpreted as the full moon interval. These two hypotheses were published in Etzold (2000, p. 159) for future explorations. They were used in Etzold (2002a) for tests with respect to the lunar phase:

> Hypothesis A (one-tailed prediction) is related to Radin & Rebman's probability calculation for 3 of 5 payout rates of casino games and peak effects. "Within 1 day of the full moon" means 1 day before and 1 day after the full moon time, which covers the interval of 166.5° through 192.4° of the lunar phase. The interval width is 25.9°. This is the interval in which we expect a positive significant effect.
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> Hypothesis B (one-tailed prediction): If we extend this interval by 1 day, then the interval covers the maximum range mentioned by Radin and Rebman in the jackpot calculation of 161.3° through 198.6° of lunar phase, in which they found peak effects and in which we expect a positive significant effect. The interval width is 37.3°.

Both intervals yielded significant results in the first examination (Etzold, 2000, p. 160). However, in the replication study (Etzold, 2002a, p. 78) only the result of the 166.5°-192.4° full moon interval was—now negatively—significant, and we want to examine the reasons for the reversal of the effect. Therefore, the interval width of Hypothesis A (166.5°-192.4°) was chosen for examination here. This interval is also equivalent to 1 day before and 1 day after the full moon as it was used in other studies. As we have no evidence for defining further different full moon time intervals, we have one interval in which we might expect a significant effect.

## Method

### *Time-Series Analysis With Respect to Moon Phases*

For the lunar-periodic analysis, the date and time of every Fourmilab retroPK experiment was converted into a lunar phase degree, as defined by Meeus:

> By definition, the times of New Moon, First Quarter, Full Moon and Last Quarter are the times at which the excess of the apparent longitude of the Moon . . . over the apparent longitude of the Sun is 0, 90, 180 and 270 degrees, respectively. (Meeus, 1995, p. 179)

The software for this conversion of date and time into a lunar phase degree was written by Andreas Hoerstemeier. This conversion was checked against the lunar phase dynamic time data from *Astronomical Tables of the Sun, Moon and Planets* (Meeus, 1995, pp. 190-192). The difference of dynamic time versus UTC is 63 sec for the year 1997 and increased up to 71 sec in 2005. No lunar phase degree errors were found with this software in minute-exact resolution, which confirmed that the software is working well. Because of the minimum phase degree resolution of 0.1° the maximum time error of 11.5 min UTC is possible. A retroPK experiment lasts an average of 2 min from the time the data is requested to the time the test results are presented. We can therefore estimate the maximum possible time error as being up to 14 min in the superposed retroPK data, sorted according to increasing lunar phase degrees.

The bit scores for every experiment were gathered separately by a sliding window function of every "before-selected" interval. This procedure was done synchronously for the retroPK data and the corresponding environmental parameters. Whereas the environmental data and the control run data contain nearly the same number of data points per interval, the retroPK data vary within a large range of numbers. In order to make the data comparable, Rosenthal's effect size *pi* for every interval was computed for the retroPK data, and the average values of the specified intervals were computed for the environmental parameters.[7]

## Results

A first attempt of the author to replicate the findings of Radin and Rebman with the Fourmilab retroPK data seems to confirm them with a positive significant effect of $z = 3.24$ for the 166.5°-192.4° full moon interval (Etzold, 2000, p. 160). The data of this study constitute Sample 1 in the analyses here. In the summer of the year 2000 the situation changed rapidly. A significant strong negative effect with $z = -2.49$ in the full moon interval eliminated the entire accumulated positive deviation (Etzold, 2002a, p. 78). The data of this study constitute Sample 2 in the analyses here.

This reversal seems similar to that reported by Radin in his casino study (Radin, 1997, p. 187). But in view of the one-tailed full moon hypothesis, the replication of the positive effect found before failed with the new data. In the discussion of this failed replication, one author recommended testing the data for bidirectional psi (Ertel, 2002) and another author stated that

[7] Tables showing the effect sizes, standard errors for effect size values and *z* scores for each lunar phase interval are available from the author.

this replication had to fail due to the predictions of the model of pragmatic information (Lucadou, 2002). Another researcher (Houtkooper, 2002) and the author himself (Etzold, 2002b, 2006) assumed an anomalous experimenter effect as the true reason for his findings. Since the effect of the first study was hypothesized, there was a real effect in the second study, which is evident in the difference of both studies with $z = 4.03$ ($p = .00006$, two-tailed). But before discussing such far-reaching assumptions, it should be demonstrated that the observed effects cannot be explained by simpler assumptions such as the action of changing physical parameters. If such physical or environmental parameters can be ruled out, it is time to discuss the MPI or the anomalous experimenter effect in the context of the data here. The total results of the entire retroPK for-the-record database in October 2005 showed no significant full moon effect: In the interval of 166.5°-92.4° lunar phase, we found 14,720 test results (bit score = 853) with a total $z$ score of 0.44 ($p = .33$, one-tailed). All other remaining retroPK 178,704 for-the-record data (i.e., those not within the 166.5°-192.4° full moon interval) yielded a nonsignificant bit score of -8,439 with $z = -1.23$, nonsignificant. The difference of full moon versus non-full moon data was $z = 1.18$. The control run results were nonsignificant in the mentioned intervals.

The very promising initial results of the first few years were not as reliable as they first seemed to be. It would be a great step forward if we knew why. At first we examined known modulator variables such as gravitational forces and geomagnetic and solar activity that could modulate the retroPK effect in the full moon interval. In further steps we created additional hypotheses based on the earlier findings and tested them with the data of Sample 1 and Sample 2 to find out the reasons for the overturning of the effect. These hypotheses could be tested with the additional data that had accumulated in the years 2001-2005, Sample 3.

### *Modulating Variables*

Although hundreds of studies seem to provide evidence of PK effects, the existence of such effects remains controversial (Bösch, Steinkamp, & Boller, 2006). The understanding of the parameters that modulate the performance of anomalous effects is necessary for future research. If the parameters were known, we could perhaps generate conditions in laboratory research to improve the results and reduce the number of experiments and the amount of time required to perform them. Based on Radin's and Rebman's findings, hypotheses were formulated that are being tested with the Fourmilab retroPK data.

### *The Tidal Effect*

The first physical modulator variable for lunar periodic effects was suggested by the graphs of Puharich's telepathy results in relation to lunar phase (Radin & Rebman, 1998, p. 198): the tidal effect—the gravitational influence of the moon on the earth. With respect to this suggestion, we propose the following hypothesis:

> Hypothesis C (one-tailed prediction): the gravitational influence of the moon with the tides is associated with high retroPK scores.

If the tides were a modulator variable of the lunar effects found in the retroPK data, we would expect a similar lunar effect in the new moon interval because the gravitational influence at new moon is as high as at full moon. What we did find was more significant activity in the full moon quarter but no corresponding effect in the new moon position, so we might exclude gravity as a possible influence of retroPK performance.

*Geomagnetic Field*

Radin and Rebman also claimed an influence of the moon's position on the geomagnetic field, and they predicted that "a possible GMF correlation with casino payout percentages would be negative" (Radin & Rebman, 1998, p. 195). Based on Radin and Rebman's predictions, we propose the following hypotheses:

> Hypothesis D: GMF activity is associated with the lunar phase, especially in times of a quieter geomagnetic field (Radin & Rebman, 1998, p. 209).
> Hypothesis E (one-tailed prediction): high retroPK scores in the Fourmilab retroPK database are correlated with low GMF activity (Radin & Rebman, 1998, p. 195).

GMF activity is not a predictable value as, for example, are lunar tidal effects, which can be calculated with great accuracy. We wanted to test Hypothesis D with the evaluation of the 3-hr geomagnetic ap index values, obtained by the World Data Center for Geomagnetism, Kyoto, for the period under analysis. Date and time of the GMF ap index values were first converted into a lunar phase degree value (new moon = 0°, first quarter = 90°, full moon = 180°, last quarter = 270°). Afterward, the data were sorted in ascending order according to the lunar phase. We assumed that GMF might be high in the full moon intervals and made the comparison with the remaining data. The cumulative scores of the cumulative mean shift deviation (Cum ap) for the geomagnetic field according to the lunar phase were computed as a function of $n$ with

> $\text{Cum ap}(n) = \text{ap}(1) + \text{ap}(2) + \ldots + \text{ap}(n)$, with $\text{Cum ap}(0) = 0$.
> Note that by definition $\text{Cum ap}(0) = \text{Cum ap}(N)$.

For the ap index values of the entire period, the mean is 13.783 with a standard deviation of 22.083. In the interval of 166.5°-192.4° lunar phase we found 1,805 ap index values with a mean shift deviation sum of -2,546. The remaining 23,733 ap index values yielded a mean shift deviation sum of 2,532.4. For the specified interval, we found that GMF is not high in the full moon period. It is lower than in the average of the remaining lunar cycle data.

With respect to Hypothesis E (positive retroPK scores in the Fourmilab retroPK database correlating with low GMF activity), we found low GMF activity in the full moon interval for the entire database, but not a corresponding high positive result in the total retroPK for-the-record data. So far, the data do not show anything that reliably modulates retroPK performance. This might indicate that GMF alone is not the only parameter that modulates retroPK performance.

*Solar Activity and GMF*

Radin already noted that the lunar-GMF data for 1991 to 1994 used in the analysis of casino payouts resulted in a negative relationship. This suggests, not surprisingly, that the lunar-GMF link is more complicated than a simple linear relationship can model. Other geophysical and extraterrestrial factors are probably involved, including the solar rotation cycle (Radin, 1997, p. 315). Based on Radin's assumption, the next hypothesis was introduced:

> Hypothesis F (one-tailed prediction): retroPK scores are negatively correlated with solar activity such as increasing sunspot numbers, coronal holes, and solar flares because GMF activity is driven by solar activity.

The parameters according to Radin and Rebman (1998, pp. 212 and 216) for testing this hypothesis are sunspot numbers, 10.7 cm solar radio flux, and solar wind speed. All of these environmental parameters are related to solar activity. The GMF ap index reacts to solar activity with a longer delay because it is affected by the solar wind, which needs some days to make its way from the sun to the earth. The correlation of these environmental factors with retroPK effects might reveal whether retroPK performance is more likely affected by global factors than by solar activity.

For the sun, moon, and earth interaction it is important to note that the magnetosphere of the earth is blown out by the solar wind into a teardrop shape far into deep space. The magnetotail of the drop stretches in the direction opposite from the sun, actually reaching beyond the lunar orbit. This long magnetotail extends more than 600,000 km from the earth. Models of the magnetotail were described by Tsyganenko (2002a, 2002b). Buffeted by fluctuations in the velocity and density of the solar wind, the magnetosphere's size and shape are constantly changing, especially in times of high solar activity.

The shape of the full moon peak in the retroPK for-the-record data (Etzold, 2000, p. 157) showed that the effect already appears prior to the day of the full moon and decreases after the full moon. This is the time when we can expect the moon to cross low-density plasma in the tail lobes and high-temperature plasma in the plasma sheet of the magnetotail (Lichtenstein & Schubert, 1976). Because the earth revolves around the sun at a high speed, the magnetotail is not oriented straightforwardly like the shadow of the earth on the earth's nightside but is asymmetrically curved in the direction of the arriving moon (Tsyganenko, 2002b), so the time interval between the moon's entering the magnetotail and the full moon is longer than the time between the full moon and the moon's leaving the magnetotail. The lunar cycle interval of the moon's passage through the plasma sheet of the far magnetotail might be between 156° and 195° lunar phase, which means that the moon spends approximately 3 days each month in the magnetotail. In comparison with the interval of Hypothesis A (166.5°-192.4°), the moon enters the plasma sheet 10.5° earlier and leaves it 2.4° later than in the hypothesized interval. Because the size and diameter of the magnetotail change with the changing GMF and solar activity, it is not possible to predict exact lunar phase degrees for the moon's entering and leaving the magnetotail. Also, especially in lunar eclipse times, the moon might move deeper through the plasma sheet of the magnetotail. If this passage of the moon through the magnetotail is responsible for the full moon effect in the retroPK data, we have to look for physical effects of the lunar passage to find the actual modulator variable of retroPK performance.

*Sunspot Number*

We know that GMF is modulated by solar activity too. Solar activity varies within the 11-year sunspot cycle. Observation of the sun has shown that sunspots do not appear at random over the surface of the sun but are concentrated in two latitude bands on either side of the equator. These bands first form at mid-latitudes, widen, and then move toward the equator as each cycle progresses. Sunspot activity that is located at the equator might affect the earth more strongly than sunspot activity at mid-latitudes. The sunspot number represents solar activity on the sun itself, but the number does not report whether the earth is affected by solar activity.

We collected the sunspot numbers for the evaluation period and expected that low sunspot numbers would correlate with a high retroPK effect size. The sunspot data were retrieved from the RWC Belgium World Data Center for the Sunspot Index.

*10.7-cm Solar Radio Flux*

Another parameter of solar activity is the 10.7-cm solar flux (F10.7 index). It is the amount of solar noise that is emitted by the sun at the 10.7-cm wavelength. It reflects the actual and precise level of solar activity. Observed F10.7 index data were obtained from the Dominion Radio Astrophysical Observatory in Penticton, Canada. They are available as daily values, measured within three successive hours at local noon. Already in Etzold (2000, pp. 163-165), a significant negative relationship of the F10.7 index with retroPK data was noted. If we find a significant sunspot/retroPK correlation, we have to expect a significant F10.7 index/retroPK correlation also.

*Solar Wind*

The dependence of anomalous cognition effect size on solar wind speed was reported by Spottiswoode and May (1997). In this analysis, most of the solar wind data were taken from the database of the ACE spacecraft. ACE data became available in February 1998. Due to the lack of a solar wind database, we had to combine two plasma speed sources for the computation of the correlation. Solar wind data prior to that time were taken from the database of the WIND spacecraft. Both spacecraft are positioned at the L1 libration point, which is a point of earth-sun gravitational equilibrium, in order to continuously observe the solar wind an hour or so before it intercepts the magnetosphere.

Hourly averaged plasma speed data of the WIND spacecraft from January 11, 1997–February 4, 1998, were obtained from the OMNIWeb database of the NASA/Goddard Space Flight Center, and plasma speed data of the ACE spacecraft from February 5, 1998–October 8, 2005, were obtained from the ACE Science Center.

*The Lunar Eclipse Hypothesis*

The angle of the moon's position related to the ecliptic plane changes with its revolution around the earth. Eclipses occur only if the moon crosses the ecliptic within a maximum deviation of 0.5° from the ecliptic plane. The moon travels along an orbit inclined by 5.1° to the ecliptic plane, so it passes through the ecliptic plane only twice a month, called the ascending and descending nodes.

> Hypothesis G: If the retroPK performance is modulated by the lunar magnetotail passage, we can expect retroPK performance to be improved on days of lunar eclipses when the moon is moving deep through the magnetotail of the earth rather than on other full moon days when the moon is moving through the outer rings of the magnetotail.

This hypothesis was already suggested in Etzold (2000, p. 171). For this test the absolute value of the deviation from ecliptic is taken, because it does not seem to make any difference whether the moon passes in the lobes above or below the magnetotail when its position is far from an expected eclipse in full moon days. On these full moon days the deviation from the ecliptic plane reaches its highest degree value of the lunar cycle (approximately 4-5° deviation from the ecliptic plane) and the moon is moving through the outer rings of the magnetotail (Tsyganenko, 2002b; Wilson, et. al., 2004). This hypothesis would be confirmed by a significant negative correlation with the retroPK data. The designation of the parameter for the lunar deviation from ecliptic is "Deviation from ecliptic" or "Deviation" in the tables.

## Regression Analysis and Correlations

The environmental parameters are the F10.7 index, the average sunspot number, the solar wind speed, the GMF ap index, and the moon's deviation from the ecliptic, in that order, as independent variables of the analysis. The sunspot number and the F10.7 index represent effects close to the solar surface, whereas the GMF ap index and the solar wind speed represent effects close to earth. The moon's deviation from the ecliptic is the position of the moon inclined toward the ecliptic plane.

We have seen that the HotBits REG is not well calibrated. For safety reasons, the original retroPK for-the-record data were not used for this analysis, but the difference of the effect size *pi* of the retroPK for-the-record data and the control run data was used as the dependent variable of the analysis. If a faulty nonrandom trend were present in the random data, it would be neutralized by computing the difference of the effect size values for every lunar cycle. Certainly, this would increase the random noise in the test and reduce the variance, but it is necessary to examine whether the retroPK for-the-record data are valid.

Because of large clusters of missing data in the control run database, retroPK for-the-record data were included in this test only when corresponding control data for these intervals were available. So we could use retroPK for-the-record data of only 86 lunar cycles out of 105. These are the data of the intervals from December 26, 1997, 23:06 UTC–April 28, 2002, 19:01 UTC and March 12, 2003, 22:47 UTC–Oct. 8, 2005, 12:45 UTC, with a minimum of 15 experiments in the full moon interval of April 11, 1998, and a maximum of 592 experiments on July 4, 2004. The average number of experiments is 153.5 per full moon interval with a standard deviation of 113. Depending on what correlation might be significant, this could be an indicator of the actual location where we can expect an influence on retroPK performance. The following tables list the retroPK for-the-record full moon data correlations and the retroPK for-the-record non-full moon data correlations with environmental parameters. Table 1 shows the descriptive statistics.

*The Full Moon Interval*

TABLE 1
DESCRIPTIVE STATISTICS OF THE 166.5°-192.4° FULL MOON INTERVAL DATA

| Variable | *M* | *SD* | *N* |
|---|---|---|---|
| RetroPK (- control data) | .00015 | .0027 | 86 |
| F10.7 | 141.96 | 51.08 | 86 |
| Sunspots | 74.92 | 44.32 | 86 |
| Solar wind | 463.73 | 100.87 | 86 |
| GMF ap | 13.087 | 12.43 | 86 |
| Deviation from ecliptic | 3.16 | 1.54 | 86 |

*Note.* Column 1: Parameters. Column 2: Means. Column 3: Standard deviations. Column 4: Number of samples.

TABLE 2
PEARSON CORRELATION MATRIX FOR RETROPK FOR-THE-RECORD MINUS CONTROL DATA CORRELATIONS OF THE 166.5°-192.4° FULL MOON INTERVAL DATA WITH ENVIRONMENTAL PARAMETERS AND SIGNIFICANCE FOR PEARSON CORRELATIONS

| | Pearson Correlation Matrix | | | | | |
|---|---|---|---|---|---|---|
| Parameter | RetroPK (- control) | F10.7 | Sunspots | Solar wind | GMF | Deviation |
| RetroPK (- control data) | 1.000 | | | | | |
| F10.7 | -.259** | 1.000 | | | | |
| Sunspots | -.198* | .824# | 1.000 | | | |
| Solar wind | -.061 | -.120 | -.071 | 1.000 | | |
| GMF ap | -.189* | .187* | .227* | .618# | 1.000 | |
| Deviation from ecliptic | -.228* | -.018 | -.071 | .044 | -.015 | 1.000 |

*Note.* Column 1: Parameters. Row 1: Designation. Row 2: Parameters. Row 3-8 with Column 2-7: Pearson's $r$ values with $df = 84$. * $p \leq .05$; ** $p \leq .01$; # $p \leq .001$ (one-tailed).

Table 2 reports the Pearson correlation results. The retroPK for-the-record minus control data correlation with F10.7 index data reached statistical significance ($p$ = .008, one-tailed). The correlation with average sunspot numbers yielded $p$ = .034; with GMF ap index, $p$ = .04; and with moon's deviation from ecliptic, $p = .017$. The correlation with solar wind speed was nonsignificant. The high significant correlation of solar wind speed with GMF ap index data and F10.7 index data with sunspot numbers revealed their close relationship.

TABLE 3
REGRESSION COEFFICIENTS OF THE 166.5°-192.4° FULL MOON INTERVAL DATA

| Parameter | Std. beta | *t* | *p* |
|---|---|---|---|
| Intercept | | 1.724 | .089 |
| F10.7 | -.265 | -1.429 | .157 |
| Sunspots | .044 | 0.235 | .815 |
| Solar wind | .025 | 0.181 | .857 |
| GMF ap | -.169 | -1.196 | .235 |
| Deviation from ecliptic | -.233 | -2.240 | .028 |

*Note.* Column 1: Parameters. Column 2: Standardized beta. Column 3: Student's $t$ with $df = 85$. Column 4: Probability (two-tailed).

Table 3 reports the regression coefficients. Of the variance for full moon interval results, 14.4% could be explained by the predictors, but only 6.7% by the F10.7 index and 5.2% by the moon's deviation from the ecliptic. The other parameters were nonsignificant: sunspot numbers, which explained 3.9% of the variance; GMF, 3.6% of the variance; and the solar wind speed, 0.4% of the variance.

F10.7 and the moon's deviation from the ecliptic explain more than 50% of the total variance in a stepwise regression. The standardized beta correlation coefficient for the F10.7 index in the stepwise regression was -.263 with $p = .012$, and for the deviation it was -.233 with $p = .026$.

TABLE 4
DESCRIPTIVE STATISTICS OF THE NON-FULL MOON INTERVAL DATA

| Variable | *M* | *SD* | *N* |
|---|---|---|---|
| RetroPK (- control data) | .00007 | .0007 | 86 |
| F10.7 | 143.4 | 38.55 | 86 |
| Sunspots | 78.58 | 35.77 | 86 |
| Solar wind | 451.73 | 54.44 | 86 |
| GMF ap | 14.59 | 6.33 | 86 |
| Deviation from ecliptic | 3.16 | 1.54 | 86 |

*Note.* Column 1: Parameters. Column 2: Means. Column 3: Standard deviations. Column 4: Number of samples.

*Non-Full Moon Intervals*

Table 4 shows the descriptive statistics for the non-full moon interval data, Table 5, the Pearson correlations, and Table 6, the regression coefficients.

TABLE 5
PEARSON CORRELATION MATRIX FOR RETROPK FOR-THE-RECORD MINUS CONTROL DATA CORRELATIONS OF THE NON-FULL MOON INTERVAL DATA WITH ENVIRONMENTAL PARAMETERS AND SIGNIFICANCE FOR PEARSON CORRELATIONS

| | Pearson Correlation Matrix | | | | | |
|---|---|---|---|---|---|---|
| Parameter | RetroPK (- control) | F10.7 | Sunspots | Solar wind | GMF | Deviation |
| RetroPK (- control data) | 1.000 | | | | | |
| F10.7 | .037 | 1.000 | | | | |
| Sunspots | .070 | .910# | 1.000 | | | |
| Solar wind | .192 | -.151 | -.184 | 1.000 | | |
| GMF ap | .111 | .047 | -.022 | .759# | 1.000 | |
| Deviation from ecliptic | .070 | -.004 | -.001 | .098 | .035 | 1.000 |

*Note.* Column 1: Parameters. Row 1: Designation. Row 2: Parameters. Row 3-8 with Column 2-7: Pearson's $r$ values with $df = 84$. * $p \leq .05$; ** $p \leq .01$; # $p \leq .001$ (one-tailed).

No correlations for the retroPK for-the-record minus control data with environmental parameters were significant.

TABLE 6
REGRESSION COEFFICIENTS

| Parameter | Std. beta | $t$ | $p$ |
|---|---|---|---|
| Intercept | | -1.703 | .092 |
| F10.7 | -.143 | -0.534 | .595 |
| Sunspots | .250 | 0.944 | .348 |
| Solar wind | .284 | 1.620 | .109 |
| GMF ap | -.094 | -0.541 | .590 |
| Deviation from ecliptic | .045 | 0.416 | .679 |

*Note.* Column 1: Parameters. Column 2: Standardized beta. Column 3: Student's $t$ with $df = 85$. Column 4: Probability (two-tailed).

Table 7
Summary and ANOVA for Data of Full Moon Interval versus the Remaining Data of Non-Full Moon Intervals

| Lunar phase interval | Full moon: 166.5°-192.4° | | Non-full moon: 0°-166.5° and 192.4°-360° | |
|---|---|---|---|---|
| Summary | $R^2 = .144$, $R = .379$ | adj. $R^2 = .09$ | $R^2 = .059$, $R = .244$ | adj. $R^2 = .001$ |
| ANOVA | $F(5, 80) = 2.683$ | $p = .027$ | $F(5, 80) = 1.012$ | $p = .42$ |

The ANOVA is significant for the full moon interval but not for the non-full moon interval data. It was hypothesized that a significant difference exists between full moon data versus non-full moon data. The correlations for the full moon interval were predicted to be negative, and the difference from the non-full moon data were predicted to be significant.

Table 8
Difference between Correlations

| Parameter | RPK minus control data for full moon | RPK minus control data for non-full moon | Probability for difference of full moon versus non-full moon |
|---|---|---|---|
| F10.7 | -.259 | .037 | .026 |
| Sunspots | -.198 | .070 | .041 |
| Solar wind | -.061 | .192 | .05 |
| GMF ap | -.189 | .111 | .026 |
| Deviation from ecliptic | -.228 | .070 | .026 |
| *R* | .379 | .244 | .17 |

*Note.* Column 1: Parameters. Column 2: RetroPK for-the-record minus control data for full moon interval with $N = 86$. Column 3: RetroPK for-the-record minus control data for non-full moon intervals with $N = 86$. Column 4: Probability (one-tailed).

In this test reported in Table 8, the differences of the retroPK for-the-record minus control run data for full moon versus non-full moon data are significant for the F10.7 index, the sunspot numbers, the solar wind speed, the GMF ap index, and the deviation from the ecliptic. The difference of the multiple *R*s was nonsignificant, but overall, these results suggest that retroPK performance in the full moon interval is modulated by solar activity in combination with geomagnetic effects and the moon's deviation from the ecliptic.

*The Full Moon Effect's Overturn*

Let us return to the question from the very beginning. After a longer period of an increasing full moon effect in the years 1997 through 1999, the situation changed rapidly in the year 2000, and the effect became strongly negative. As we have seen, one reason might be changing solar and GMF activity. We wanted to test this and extract all the retroPK for-the-record data that were analyzed in the first study, when we had obtained the highly significant positive result in the full moon interval. This is Sample 1. For Sample 2 we extracted all data that were analyzed in the replication study, when we had obtained the significantly negative result in the full moon interval. Due to the lack of 11 months of control data in the first period, the real retroPK for-the-record data were used instead. If, as the latest tests might indicate, a true effect is present in the data, we would expect an increase of significance in the following tests because we are using real data without any noise induced by the control data, as in the tests before, reported in Tables 1-8. Tests of significance have to be one-tailed because of Hypotheses E and F, which predict negative correlations for the full moon interval. The correlations with the environmental parameters are reported in Table 9.

TABLE 9
PEARSON CORRELATIONS FOR RETROPK FOR-THE-RECORD DATA OF THE FIRST STUDY (SAMPLE 1) AND THE REPLICATION STUDY (SAMPLE 2) OF THE 166.5°-192.4° INTERVAL WITH ENVIRONMENTAL PARAMETERS

| | Sample 1 ($N$ = 38) | | Sample 2 ($N$ = 18) | |
|---|---|---|---|---|
| Parameter | $r(36)$ | $p$ | $r(16)$ | $p$ |
| F10.7 index | -.268 | .052 | -.411 | .045 |
| Sunspot number | -.273 | .048 | -.477 | .023 |
| Solar wind | -.125 | .23 | .241 | .83 |
| GMF ap index | -.243 | .072 | -.108 | .34 |
| Deviation from ecliptic | -.244 | .07 | .032 | .55 |

*Note*. Column 1: Parameters. Column 2: Pearson's $r$ values for Sample 1. Column 3: Probability (one-tailed) for Pearson correlations. Column 4: Pearson's $r$ values for Sample 2. Column 5: Probability (one-tailed) for Pearson correlations. Probabilities were computed by converting the correlation values into Student's $t$, which was used for test of significance.

Although both studies had yielded completely different results in the studies before with a psi-hitting effect *z* score of 3.24 (Etzold, 2000, p. 160) and a psi-missing effect *z* score of -2.49 (Etzold, 2002a, p. 78), we obtained here in both cases negative correlations for the F10.7 index, sunspot numbers, and GMF ap index. The solar wind and moon's deviation from the ecliptic yielded negative correlation coefficients for Sample 1 and positive correlation coefficients for Sample 2. These are not reliable predictors of retroPK performance.

In the next analysis, the means and standard deviations for the total full moon data of every parameter were computed. Based on these values, the Stouffer *z* scores for every parameter of both samples were calculated and compared:

Table 10
Stouffer z Scores for All Parameters of Sample 1 and Sample 2

| Parameter | Sample 1 ($N$ = 38) | Sample 2 ($N$ = 18) | z *diff* | *p* |
|---|---|---|---|---|
| RetroPK | 2.40 | -2.56 | 3.51 | .0004 |
| F10.7 | -1.62 | 2.91 | 3.20 | .0014 |
| Sunspots | -0.92 | 3.81 | 3.34 | .0008 |
| Solar wind | -2.63 | 0.70 | 2.35 | .018 |
| GMF ap | -1.65 | 1.33 | 2.11 | .034 |
| Deviation from ecliptic | -0.55 | -0.06 | 0.35 | .72 |

*Note.* Column 1: Parameters. Column 2: *z* scores for Sample 1. Column 3: *z* scores for Sample 2. Column 4: Difference of *z* scores for Sample 1 and Sample 2. Column 5: Probability for difference of *z* scores (two-tailed). For computing the retroPK *z* scores, the empirical mean value and the empirical standard deviation of the effect size values for every lunar cycle interval were used separately as in the case of the environmental parameters.

The changing of the retroPK outcome in Table 10 was accompanied by a large change of the means for the environmental parameters. Remarkable changes were registered for the deviation from the expectation of the perihelion parameters and GMF activity. This might indicate not only that a reliable effect is present but also that the negative correlation of the retroPK versus perihelion parameters is constant in both cases and that the reversal of the mean deviation in the retroPK results is dependent on changing means of solar activity between Sample 1 and Sample 2. The comparison of the *z* scores confirms the observed negative correlation of the retroPK scores with the environmental parameters.

We have analyzed here the data up to August 7, 2001, but the total database includes much more data, up to October 8, 2005. On the basis of the findings here, we predicted that the correlation for retroPK versus sunspots and versus the F10.7 index would be significant for the remaining data. But first let us see in Table 11 how the means for these three samples have changed:

TABLE 11
DESCRIPTIVE STATISTICS: MEANS AND STANDARD DEVIATIONS

| Parameter | Total data | Sample 1 ($N = 38$) | Sample 2 ($N = 18$) | Sample 3 ($N = 49$) |
|---|---|---|---|---|
| | | Means | | |
| RetroPK | .5004 | 0.50126 | .49916 | .50026 |
| F10.7 | 138.09 | 124.410 | 173.763 | 135.605 |
| Sunspots | 71.06 | 64.294 | 111.667 | 61.388 |
| Solar wind | 452.28 | 409.120 | 468.930 | 479.637 |
| GMF ap | 12.35 | 9.250 | 15.968 | 13.423 |
| Deviation from ecliptic | 3.18 | 3.039 | 3.156 | 3.292 |
| | | Standard deviations | | |
| RetroPK | .002 | 0.028 | .001 | .0015 |
| F10.7 | 51.93 | 42.960 | 38.358 | 57.166 |
| Sunspots | 45.26 | 40.951 | 41.108 | 42.402 |
| Solar wind | 101.01 | 82.165 | 115.074 | 99.340 |
| GMF ap | 11.55 | 6.446 | 20.351 | 9.841 |
| Deviation from ecliptic | 1.55 | 1.582 | 1.597 | 1.524 |

*Note.* Column 1: Parameters. Column 2: Values for total full moon data. Column 3: Values for Sample 1. Column 4: Values for Sample 2. Column 5: Values for Sample 3.

Let us see in Table 12 what is the case in the full moon data of Sample 3, which were generated after the time interval of the replication study.

Table 12
Pearson Correlations for RetroPK for-the-record Data of the Remaining Data (August 7, 2001–October 8, 2005; Sample 3) of the 166.5°-192.4° Lunar Phase Interval With Environmental Parameters ($N = 49$)

| Parameter | $r(47)$ | $p$ | $z$ scores |
|---|---|---|---|
| RetroPK | - | - | -0.60 |
| F10.7 | -.349 | .007 | -0.34 |
| Sunspots | -.246 | .044 | -1.50 |
| Solar wind | -.032 | .41 | 1.90 |
| GMF ap | -.065 | .33 | 0.65 |
| Deviation from ecliptic | -.125 | .2 | 0.52 |

*Note*. Column 1: Parameters. Column 2: Pearson's $r$ values for Sample 3. Column 3: Probability (one-tailed) for Pearson correlations. Column 4: $z$ scores for all parameters of Sample 3. For Sample 3, $N$ is 49. For computing the retroPK $z$ score the empirical mean value and the empirical standard deviation of the effect size value for every lunar cycle interval were used separately as in the case of the environmental parameters. The $z$ score based on bit score computations is $z = 0.27$.

These data of Sample 3 also yielded strong negative correlations for the perihelion parameters. Sunspot numbers are significant at the $p = .05$ level and the F10.7 index is even significant at the $p = .01$ level. Again, GMF, solar wind speed, and deviation yielded nonsignificant results, but all parameters show negative correlations.

In contrast to Sample 2, the means of the environmental parameters came closer to the means of Sample 1. The $z$ scores for the perihelion parameters were negative. So in total we could expect a positive retroPK outcome for Sample 3. The means for the retroPK data and the correlation results of the perihelion parameters confirm this expectation.

This negative dependence of the retroPK for-the-record data effect size in the full moon interval on the environmental parameters might be responsible for the observed effect's overturn in the year 2000. In times of low solar activity, the retroPK outcome yields significant positive mean deviations. When solar activity increases, the positive deviation shrinks to a nonsignificant level in the range of mean expectation. When solar activity is high, the retroPK outcome appears as significant negative mean deviations. The correlations do not distinguish between psi-hitting and psi-missing; both effects are part of the same scale.

## Discussion

Lunar periodic effects in parapsychological research have been a bone of contention up until now. We collected the material suggesting a full moon effect and tested the large database of the Fourmilab RetroPsychoKinesis Project. We found significant effects, particularly in the full moon phase in the first 3 years of the Fourmilab RetroPsychokinesis Project. But, however encouraging the first result may have been, the effect changed in a later evaluation and finally disappeared. In earlier papers (Etzold, 2002a; Lucadou, 2002; Schestag, 2002; Walach, 2002, Etzold, 2006) the model of pragmatic information by Walter von Lucadou was discussed, which seems to predict such changing and disappearing. Another suggestion was an anomalous experimenter effect (Etzold, 2002b, 2005). This examination revealed that the observed effects appearing, changing, and disappearing could be understood as the result of changing physical parameters. In view of these findings, it is no longer necessary to claim an anomalous experimenter effect or to interpret the effect's changing as a result of the MPI.

No evidence could be found for Hypothesis C (tidal influences). For GMF ap index correlations and solar wind speed we found nonsignificant results in the regression analysis, but in each case the correlations were negative. Only the difference of full moon data versus non-full moon data was significant. This might indicate that the retroPK performance is driven by direct influences of solar activity that come to earth at light-speed rather than by an indirect influence of solar wind plasma. But this is only half of the truth. In full moon times there is a small window in which participants of the Fourmilab RetroPK Project might be sensitive to subtle solar influences, so when they participate in an experiment for the record, their results are negatively correlated with solar activity.

In summary, we see that the significant results of retroPK for-the-record runs of the full moon interval can be explained mostly by solar predictors such as sunspot activity and the F10.7 index. Both parameters measure activity on the surface of the sun. Their high correlation of $r$ (84) = .824, $p$ = 2 x E-22 with each other confirms their close relationship.

The results for Hypothesis G indicating that retroPK performance might be higher when the moon is moving deeply through the plasma sheet of the magnetotail than when moving through the outer rings of the plasma sheet were significant in the regression analysis of the full moon interval and in the difference of full moon data versus non-full moon data. In the tests with the database divided into three samples, no significant effects were found. So the question whether the depth of the moon's passing through the magnetotail might cause an effect remains undecided.

Hypothesis F indicated that retroPK effects are negatively correlated with solar activity because GMF activity is driven by solar activity. The basic assumption was that GMF is the primary parameter as given in Hypothesis

E (high retroPK scores in the Fourmilab retroPK database are correlated with low GMF activity), so Hypothesis F is dependent on Hypothesis E. The analysis at hand shows that the stronger parameter might be the direct influence of solar activity and not GMF. This might indicate a complex interaction of a direct solar influence accompanied by interactions of the moon with the earth's magnetosphere during full moon. This might also indicate that the parameters we examined are not the primary parameters responsible for the full moon effect found in the retroPK for-the-record data. There might still be an unknown parameter that modulates retroPK performance more strongly.

Some oscillations in the random movement of the retroPK experiment curve for the first evaluation (Etzold, 2000, pp. 157, 161, 171) suggest that the moon's interaction with solar wind and earth's magnetosphere stimulates some kind of electromagnetic waves with ultra-low frequencies. It is known that ultra-low frequencies (ULF) and their additional interference frequencies can affect human behavior (Wilson et al., 1990), for example by modulating human brain wave activity. We know that a variety of waves are generated by interactions of the solar wind with the magnetosphere: magnetohydrodynamic waves of ultra-low frequencies, standing waves, and transversal waves, all in the range of 1 mHz 10 Hz (Stellmacher, 1998). These waves and frequencies change according to changing solar activity. In full moon times, the moon passes through the magnetotail: "The observations . . . show that the magnetotail plasma environment strongly influences lunar electromagnetic induction." (Schubert, Sonett, Smith, Colburn, & Schwartz, 1975, p. 279) These changes were registered as altered magnetohydrodynamic wave frequencies in the magnetosphere, especially in times of a quiet geomagnetic field and low solar activity. In such conditions the moon tunes (or detunes) these wave frequencies when crossing the magnetotail (Schubert et al., 1975; Hood & Schubert, 1978). The transfer function amplitude for the moon in the plasma sheet during the full moon interval is approximately 1.7 to 2 for frequencies between 2 and 6 mHz and decreases to 0.7 to 1.2 transfer function amplitude when the moon is in the lobes of the magnetotail. ULF effects in connection with the moon's passage through the magnetotail were explored in the 1970s during the Apollo Program but unfortunately those studies were not continued.

ULF waves, especially in the range of 1-10 mHz, could be responsible for the varying retroPK performance, as observed in the full moon data here. If this were confirmed, the use of artificial magnetic field waves in the 1-10 mHz range might be promising candidates for producing high-scoring psychokinesis results in laboratory experimental research.

Many studies with respect to human behavior in the past have failed to find any lunar effect. The present examination shows that the situation is much more complicated than previously believed. We have found two physical parameters that we think affect retroPK performance: solar activity and the lunar phase. The next period of low and increasing solar equatorial sunspot activity is expected in the years 2007 through 2011. This might be a good time for a new high full-moon-effect phase in the coming years of the Fourmilab RetroPsychoKinesis Project.

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