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in Random Event Sequences:  
A FieldREG Application at the Christmas Revels**

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**INTERNATIONAL  
CONSCIOUSNESS RESEARCH  
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**ICRL REPORT #97.1**

# **Departures from Expectation in Random Event Sequences: A FieldREG Application at The Christmas Revels**

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September, 1997

## **Abstract**

A prediction that audience engagement would correlate with unusual deviations from expectation in the output of a microelectronic random event generator was confirmed in a series of ten replications of field recordings in two cities at a popular theatrical celebration of the Winter Solstice in 1995. A larger database gathered in 1996 in eight cities again generally confirmed the hypothesis, and together the two repetitions of the experiment provide statistically significant evidence that the behavior of a nominally random physical system may be influenced by human consciousness.

## **Introduction**

In December, 1995, San Francisco Bay Revels celebrated its tenth annual series of performances honoring the changing of seasons and the coming of a new year. The Revels are an exuberant form of music theater, widely recognized for their innovative incor-

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poration of participatory folk elements and traditional ritual into a modern theatrical context. Every December, Revels companies across the United States mount the Christmas Revels, a secular celebration of the Winter Solstice, for approximately 60,000 audience members. A distinctive feature of all Revels productions involves the way in which contrasting performance elements are deliberately juxtaposed against each other. Highly presentational moments, designed to emphasize the artistry of performers on stage, function to lift audience members out of daily life into an experience beyond themselves and their own capacities. Counterposing those moments are elements that serve to welcome and invite, moments of outright participation by the audience. The effect of that juxtaposition is a purposeful blending of high art with low, extraordinary with ordinary, the experience of awe with the experience of participation. It results in a marked quality of audience engagement: a strong sense of connection within the audience itself as well as between cast and audience members. As captured by one woman who wrote to the Director following her attendance at one of the 1995 performances: "What is it about Revels? Sitting there in the audience reminded me of falling in love. I lost a sense of myself as separate and alone. I became part of something bigger, part of some great surge of humanity celebrating itself, generation after generation."

Recent experimental work (Nelson, et al, 1996; Nelson, et al, 1997) using a portable random event generator (REG) indicates that when a group of people become cognitively or emotionally "resonant," a normally random event sequence generated in the environment may display non-random trends or deviations from expectation. By "resonant," we mean a collective state characterized by a high degree of group attention, intellectual cohesiveness, common emotional reaction or other coherent quality of subjectively

shared experience within a group. The Revels, with its affectively rich and tradition-nourished program, is the sort of environment that appears most often to correlate with such effects on the REG. We report first the results of a pre-planned experiment consisting of recordings made at seven San Francisco Bay Revels performances and three performances of the same show, mounted by the Revels company in Cambridge, Massachusetts. The same experiment was replicated in 1996 in these two cities and six others around the country, to expand the database and to provide a more substantial basis for interpretation.

## Procedure

The data are produced and recorded with a portable system called FieldREG, that generates computer files of random event sequences based on binary samples from a true random source.\* Samples are accumulated as "trials" consisting of the sum of 200 bits, and are taken at a rate of about one per second. The data files are accompanied by a time-stamped index that contains information identifying the beginning and end of specified segments: in this case, a series of distinct songs, dances, musical interludes and episodes of dramatic dialogue. The Revels database consists of FieldREG recordings made at individual performances, each two and one-half hours long, using software that allows designated F-Key index marking to identify segments, but which provides no

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\* We are indebted to Henry B. Miner for managing the FieldREG equipment, devising a form for precise documentation of the performance segments comprising each show, and for his careful and complete documentation of the Revels performances in San Francisco. We are also indebted to Darrell Griffin in 1995, and Barbara Miller, Ignacio Thayer and Eleanor Ling in 1996 for recording the Cambridge performances, and to Jeff Strong in Puget Sound, Matthew and Cynthia Cupack in Houston, Dale Neiburg in Washington, Will Hough in Portland, Kirsten Jester in Philadelphia, and Jeremy Osgood in Hanover for their contributions to the experimental project in their respective cities.

feedback information while recording. One of us (ELM, artistic director of San Francisco Bay Revels) provided a set of predictions for particular performance numbers that were anticipated to produce especially strong audience engagement and experiences of what we have termed resonance. The same pieces were specified again in 1996 for all eight cities, but in a few cases a substitute was required or a piece was unavailable due to small regional differences in the Revels productions. The corresponding data segments constitute the primary corpus for analysis. They include five short episodes from the show, ranging from a little over three minutes to about five minutes in length. The five episodes were readily identifiable in the program listings and included one dramatic interlude, two ritual dances performed by a team of highly trained male dancers, one carol accompanied by a spiral dance involving the whole audience, and another carol introduced by a poem which is recited in every Christmas Revels (the latter two carols were sung in participation with the audience). All five segments were extracted from each performance for analysis (with minor exceptions as noted). All performances were recorded with F-Key indexing and precise notations of times, permitting unambiguous identification of each segment for which an effect was predicted.

Our null hypothesis for this assessment is that the reactions of an audience and the ongoing activity of the performances will have no effect on the data stream produced by the random event generator. The alternative hypothesis we define as follows: the mean of the sample of trials in a pre-specified segment will differ from expectation, where the latter is defined by the theoretical distribution with mean 100, variance 50. To test whether such deviations exist, or are larger than we should expect from chance fluctuations, we can sum the squared normal deviates, or  $Z$ -scores, representing the mean shift

for each segment. The result is a  $\chi^2$  distributed quantity with degrees of freedom equal to the number of Z-scores (Snedecor and Cochran, 1980).\*

## Results

The  $\chi^2$  value for the 35 pieces from the seven shows in San Francisco in the original, 1995 experiment is 55.792, with 35 degrees of freedom, leading to a probability of  $p = .014$  that the accumulated deviations are just chance fluctuations. For the three 1995 Cambridge performances, the  $\chi^2$  is 21.221, with 15 degrees of freedom and a  $p$ -value of 0.130. For the combined database of five pieces in ten performances,  $\chi^2 = 77.014$ , with 50 degrees of freedom, leading to  $p = 0.008$ . Thus, the overall analysis in 1995 indicated that across performances, the predicted pieces correspond to FieldREG data segments that tend to deviate from the expectations for a random walk, with a chance probability of a few parts in 1000.

In 1996, the project comprised a total of 266 pieces or data segments drawn from 54 shows across the eight cities. The composite  $\chi^2$  is 298.755, with 266 degrees of freedom, which corresponds to a probability of  $p = 0.081$ . As we will describe in more detail, the database is quite complex, with results that vary greatly from one city to another and include two cases with trends strongly opposite to prediction. An alternative analysis based on a statistically adjusted probability for the most extreme deviation indicates a  $p$ -value of less than 0.005. In any case, the 1996 results generally confirm that of the 1995 application. If the two years are combined, the bottom line is

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\* We are grateful to Charles MacMillan of Lawrence Livermore Laboratories, whose independent analysis of the 1995 data confirmed the validity of our analytic approach and exactly replicated our findings.

$$\chi^2 = 375.768, df = 316, p = 0.011.$$

We will examine the 1995 database in some detail to provide a broad perspective on the nature of the experiment, followed by a summary and discussion of some distinctive aspects of the data from the 1996 Revels.

### Revels 95 Results

Table 1 shows the statistics for the separate performances in San Francisco and Boston in 1995, as well as the composite values, while Table 2 shows the results for the five individual pieces, combined across the ten performances.

Table 1: Combined Deviation Across Five Pre-Specified Segments:  
Seven Performances in San Francisco, Three in Cambridge

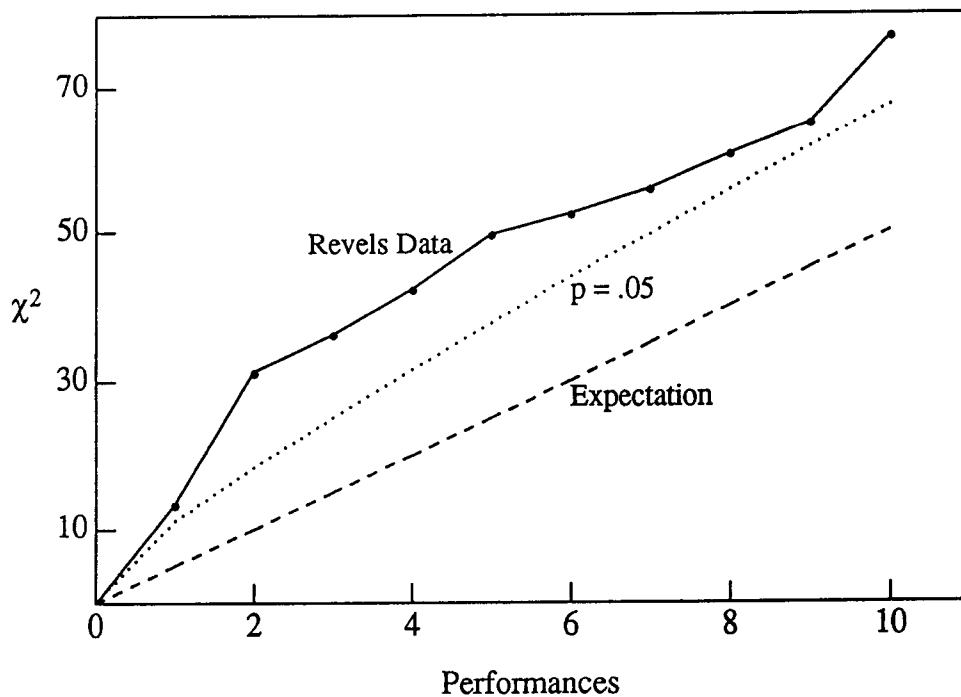
Performance	Chisq	df	p
San Francisco			
Dress Open, Dec 6	13.434	5	0.020
Opening, Dec 7	17.845	5	0.0031
Matinee, Dec 8	4.968	5	0.420
Evening, Dec 8	5.986	5	0.308
Matinee, Dec 9	7.390	5	0.193
Matinee, Dec 10	2.797	5	0.731
Evening, Dec 10	3.372	5	0.643
Cambridge			
Matinee, Dec 29	4.720	5	0.451
Evening, Dec 29	4.306	5	0.506
Matinee, Dec 30	12.196	5	0.032
Combinations			
San Francisco Alone	55.792	35	0.014
Cambridge Alone	21.221	15	0.130
Ten Performances	77.014	50	0.0084

Table 2: Combined Deviations across Ten Performances of Revels:  
Five Pre-Specified Segments

Segment	Chisq	df	p
Te Deum & Contest (dramatic dialogue)	15.799	10	0.106
Lord of the Dance (participatory carol and dance)	13.168	10	0.214
Abbot's Bromley (ritual dance)	22.481	10	0.013
Sword Dance (ritual dance)	13.767	10	0.184
Shortest Day & Mummers' Carol (poem and participatory carol)	11.798	10	0.299
Five Segments	77.014	50	0.0084

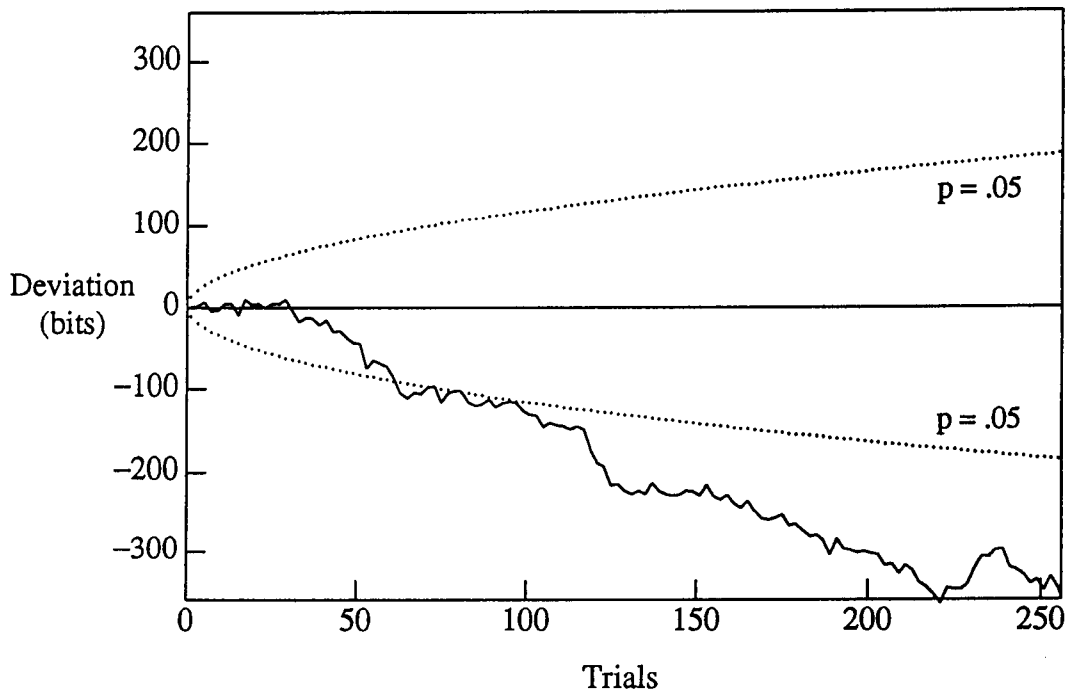
Figure 1 shows the accumulating squared deviations for the ten shows, compared with their expectation values and with the locus of the 5% probability for the cumulative  $\chi^2$  as new data sets are added.

Figure 1: Cumulative Chi-Square for Predictions:  
Ten Performances of the Christmas Revels



In addition to the preplanned, formal analysis, some exploratory assessment was undertaken. A Bonferroni-corrected extreme segment analysis was performed, in which the segment with the largest deviation was selected from those identified as particularly likely to engage the audience. Of the 50 segments, the most extreme deviation from random expectation occurred during the Abbot's Bromley Horn Dance, a ritual dance performed by men carrying deer antlers, in the opening night performance by San Francisco Bay Revels. Figure 2 shows the data for this segment of the random walk, in the form of a cumulative deviation from the expected value (indicated by the horizontal line). A parabolic envelope shows the locus of the one-tailed 5% probability for deviations of the mean from its expectation as the data accumulate.

Figure 2: Cumulative Deviations:  
Abbot's Bromley Horn Dance



The Z-score for this four-minute piece is  $-3.164$ , which individually corresponds to

a two-tailed p-value of 0.0016. The necessary Bonferroni correction for selecting one out of the 50 segments that might have been chosen leads to a  $p_B$  of 0.077, or a likelihood somewhat less than one in ten that this excursion was a chance occurrence. The Abbot's Bromley Horn Dance was also the most consistent of the five predicted segments in correlating with large deviations or strong trends in the data sequence; the average absolute Z-score is 1.325 (expectation is about 0.8, and the difference has a chance probability of about 0.006). The sum of squared Z-scores calculated for this piece across the series of performances yields  $\chi^2 = 22.481$ , with 10 df, and  $p = 0.013$ . (For the seven San Francisco performances, the corresponding statistics are  $\chi^2 = 19.025$ , 7 df,  $p = 0.0081$ .) It is worth noting that the Abbot's Bromley Horn Dance is described as an "ancient mid-winter ritual dance," linking it to relatively strong deviations found in other databases where ritual was the topic of discussion or constituted the actual activity of a group (Nelson, et al, 1996; Nelson, et al, 1997).

It is further worth noting that four of the five selected segments bear some relation to ritual. Two (the Horn and Sword Dances) are direct descendants of folk rituals performed yearly by local communities in the United Kingdom (and have, incidentally, strikingly similar parallels in antler and sword ritual dances found in a number of other cultures). Two more (Lord of the Dance and the Sussex Mummers' Carol) are participatory pieces that have come to constitute traditional components of every Revels performed in celebration of the Winter Solstice -- to such an extent that some performers loosely refer to them as "Revels rituals." Revels audiences have come to expect them as the pieces that close Acts I and II respectively, regardless of the provenance or culture or time period from which the rest of a particular show hails. (Indeed, when the Sussex

Mummers' Carol was omitted at the end of a Cambridge Revels some years ago, the audience stood up in spirited protest and began singing the carol themselves, creating a marvelous if unexpected cacophony of sound, as trumpets, trombones, horns and timpani doggedly continued with a seventeenth-century French carol in an unrelated meter and key.)

### Revels 96 Results

The results in San Francisco and Cambridge not only provided evidence for the proposed hypothesis, but stimulated considerable interest in possible interpretations related to the felt impressions of both audiences and participants in the Revels programs. A larger and more inclusive project to take FieldREG data at eight locations was undertaken, to replicate the original work and to extend the generality of our findings. While there are minor differences in the program, the intention and design is largely consonant across all Revels performances. Table 3 summarizes the FieldREG data by city, and includes the number of performances in each, the number of FieldREG trials, and the  $\chi^2$  with its degrees of freedom and associated probability.

Table 3: Combined Deviation for Revels 96  
Eight Cities, 54 Performances

City	Performances	N-Trials	Chisq	df	p
Boston	16	14692	90.155	80	0.205
Hanover	4	4543	12.257	20	0.907
Houston	5	5774	44.055	24	0.008
Philadelphia	5	5267	20.640	25	0.713
Portland	6	4624	34.151	28	0.196
Puget Sound	5	6181	47.081	24	0.003
San Francisco	7	8420	33.391	35	0.546
Washington	6	8508	17.025	30	0.972
Total 1996	54	58019	298.755	266	0.081
Total 95 & 96	64	69193	375.768	316	0.011

Certain details are interesting and potentially instructive, though they should be interpreted carefully, and may reflect either chance fluctuations or real effects. The table shows that the hypothesized effect is highly variable, with two of the eight cities, Houston and Puget Sound, independently producing a highly significant overall deviation ( $p$ -values of 0.008 and 0.003), and two others, Hanover and Washington, showing a strong tendency to the opposite trend ( $p$ -values of 0.093 and 0.028). The latter cases are difficult to interpret, but there is some precedent in particular types of applications reported elsewhere (Nelson, et al, 1997).

In addition to the  $\chi^2$  analysis, and to check its result from another perspective, we also determine the probability of the most extreme deviation among the pre-defined data segments and calculate an adjusted value that corrects for the selection of one from multiple opportunities. The extreme-value assessment is a (usually) more conservative approach, since it uses the results from only one segment as opposed to accumulating small effects from all segments. In this case the extreme value probability estimate for Revels 96 is somewhat more persuasive than that based on the chi-square analysis, at a few parts in 1000. The largest individual segment deviation was recorded within the Puget Sound database; the piece was the Sword Dance (which shares a strong ritual quality with the Abbot's Bromley Horn Dance) during the December 14 Matinee. It had a  $Z$  of -4.21, and a Bonferroni-adjusted probability within its local context of 0.000613. If we take this as representing one of eight shows, the required further adjustment yields a  $p$ -value of 0.0049. If we adjust for the 266 separate pieces of the full 1996 database, the adjusted  $p$ -value is 0.0034, and the Bonferroni-adjusted probability for the combined

database across both 1995 and 1996 is  $p = 0.0042$ . Thus, we have results that would occur by chance only about four times in 1000 repetitions of this complex, two-year experiment involving first two, then eight cities each doing several shows.

## Conclusions

The database provides evidence from multiple perspectives for a significant correlation of the FieldREG data stream with those particular portions of the Revels program that were predicted to have strong potential for producing audience engagement or resonance. These results correspond to those obtained in previous FieldREG studies and help strengthen the tentative interpretations made thus far in this research program. They support the more general suggestion that groups of people, especially when they are attuned and engaged by a common theme, may produce something like a "consciousness field" that induces a small but statistically identifiable bias in a nominally random sequence, thereby constituting a possible agency for creating order in random physical processes.

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