

# Predicting the Unpredictable: 75 Years of Experimental Evidence

Dean I. Radin

*Consciousness Research Laboratory  
Institute of Noetic Sciences  
625 Second Street, Suite 200, Petaluma, CA 94952*

**Abstract.** From time immemorial, people have reported foreknowledge of future events. To determine whether such experiences are best understood via conventional explanations, or whether a retrocausal phenomenon might be involved in some instances, researchers have conducted hundreds of controlled laboratory experiments over the past 75 years. These studies fall into four general classes, and each class has generated repeatable evidence consistent with retrocausation. The statistical results for a class of forced-choice studies is associated with odds against chance of about  $10^{24}$ ; for a class of free-response studies, odds about  $10^{20}$ ; for psychophysiological-based studies, odds about  $10^{17}$ ; and for implicit decision studies, odds about  $10^{10}$ . Effect sizes observed in the latter three classes are nearly identical, indicating replication of similar underlying effects. These effects are also in close agreement with the average effect size across 25,000 conventional social psychology experiments conducted over the last century, suggesting that retrocausal phenomena may not be especially unique, at least not in terms of the magnitude of effect. Bayesian analyses of the most recent classes of experiments confirm that the evidence is strongly in favor of a genuine effect, with Bayes Factors ranging from 13,669 to 1 for implicit decision experiments, to  $2.9 \times 10^{13}$  to 1 for psychophysiological designs. For the two most recent classes of studies examining retrocausal effects via unconscious physiological or behavioral measures, 85 of 101 studies (84%) reported by 25 different laboratories from the United States, Italy, Spain, Holland, Austria, Sweden, England, Scotland, Iran, Japan, and Australia, have produced results in the direction predicted by a retrocausal effect (odds against chance =  $1.3 \times 10^{12}$ , via a sign test). Assessment of the methodologies used in these studies has not identified plausible conventional alternatives for the observed outcomes, suggesting the existence of a genuine retrocausal phenomenon.

**Keywords:** retrocausation, physiology, empirical evidence

**PACS:** 11.30.Er , 11.30.-j

## INTRODUCTION

Throughout history people have reported intuitive hunches, premonitions, and forebodings later verified to be accurate.<sup>1</sup> Many such impressions can be explained as misinterpretations of mundane effects such as coincidence, selective memory, forgotten expertise, implicit inference, confabulation, or fraud.<sup>2</sup> The question addressed here is whether all cases of apparent foreknowledge can be accounted for by such explanations. Over the past 75 years, four classes of experiments have been

developed to test if it is possible, in principle, to gain information from the future under conditions that strictly exclude the usual array of ordinary explanations. This paper briefly reviews two of the earlier experimental methods and then describes in more detail recently developed methods that rely on unconscious measures.

## **FORCED-CHOICE EXPERIMENTS**

The first class of experiments, known as “forced-choice,” was the prevailing methodology made popular by J. B. Rhine and colleagues from the 1930s to the 1980s.<sup>3</sup> These tests involved conscious selection of a target from a restricted set of targets, usually four or five, one of which would be randomly selected later. Targets in early studies were selected based on simple randomizing techniques such as card shuffling or dice tossing. In later studies more sophisticated methods were used, including mathematical algorithms based on temperature readings averaged across major cities on a future day, radioactive decay latencies, random bits derived from monitoring quantum tunneling effects in Zener diodes, etc.

Meta-analysis of 309 forced-choice experiments, conducted by 62 investigators and described in 113 articles published between 1935 and 1987, provides evidence for a small magnitude, repeatable effect (mean effect size  $e = 0.02$ , combined  $z = 11.4$ ,  $p < 6 \times 10^{-25}$ ).<sup>4</sup> Because selective publication practices are known to inflate the overall statistical assessment in a meta-analysis, the number of unpublished studies averaging a null effect that would be required to bring the overall result down to a non-significant level was determined. The resulting estimate was a ratio of 46 unpublished studies for each known study; this was judged to be implausible. In 246 studies with sufficiently detailed descriptions to allow for a methodological quality analysis, a small positive relationship was found between study quality and effect size ( $r = 0.081$ ,  $p = 0.202$ , two-tailed). This result was contrary to the hypothesis that the observed effect was due to poorly conducted experiments, because if that were true a negative quality vs. effect size correlation would be expected. In addition, the outcome per study, expressed in terms of a  $z$  score, correlated significantly with sample size ( $r = 0.156$ ,  $p = 0.003$ ), which is expected for a genuine effect given the increased statistical power of larger studies.

## **FREE-RESPONSE EXPERIMENTS**

While the effect size produced by the forced-choice experiments was statistically significant, the minuscule magnitude meant that most of the experimental trials were essentially noise. This was not persuasive to some because it suggested the possibility of undiscovered analytical mistakes or design flaws. In addition, the experimental task was abstract and divorced from real-world contexts, it was highly repetitive and ultimately boring, and the force-choice design encouraged development of conscious or unconscious statistical strategies to try to outguess the next target.

As a result, researchers began to explore free-response designs that allowed participants to report any impressions they may have gained about the future target. The targets were also changed from colors or abstract shapes to photos of natural

scenes or actual locations that an individual would travel to, and the studies were usually conducted as one trial per test session to eliminate repetitive guessing strategies and improve subjects' motivation and attention.

There were a number of free-response precognition replications reported by independent groups, but the large majority of relevant experiments were produced by two sources. The first was part of a US government-supported, classified project housed first at Stanford Research Institute (SRI) from 1973 to 1988, and then later at Science Applications International Corporation (SAIC) from 1988 to 1995.<sup>5</sup> The second source of studies was produced by the Princeton Engineering Anomalies Research Laboratory (PEAR) at Princeton University from 1978 through the late 1990s.<sup>6</sup>

Analysis of 770 free-response tests conducted at SRI provided an average effect size of  $e = 0.209$  (associated with  $z = 5.8$ ,  $p < 3.3 \times 10^{-9}$ ). Another 445 tests conducted later at SAIC resulted in an average effect size of  $e = 0.230$  ( $z = 4.85$ ,  $p < 6.1 \times 10^{-7}$ ).<sup>5</sup> At Princeton, a total of 653 sessions were conducted, resulted in an average effect size of  $e = 0.212$  ( $z = 5.42$ ,  $p < 3.0 \times 10^{-8}$ ).<sup>6</sup> The similar effect sizes replicated by two independent groups is noteworthy, as both were investigating the same underlying phenomenon. In addition, the effect size was an order of magnitude larger than that obtained by forced-choice methods. This confirmed the expectation that by using a method that was more closely aligned with how foreknowledge spontaneously occurs in the everyday world, and without the artificial constraints inherent to forced-choice designs, that more robust results would be observed.

## UNCONSCIOUS RESPONSE EXPERIMENTS

Encouraged by the success of free-response methods, investigators reasoned that because foreknowledge is commonly associated with visions, dreams, and other non-ordinary states of awareness,<sup>7</sup> perhaps conscious precognitive impressions are distortions of more veridical information that has been filtered through unconscious biases. This led to experiments designed to monitor unconscious responses prior to random selection of future events. These studies have been dubbed *presentiment* (pre-feeling) experiments to distinguish the idea from precognition (pre-knowing).

The largest class of unconscious response experiments involves measurement of psychophysiological fluctuations before unpredictable stimuli. In its simplest form, a future emotional response is predicted to cause greater nervous system activity in the present than would a future calm response.

These experiments may continually record variables such as skin conductance,<sup>8,9</sup> heart rate,<sup>10</sup> pupil dilation,<sup>11</sup> brain electrical activity,<sup>12</sup> or blood oxygenation in the brain,<sup>13</sup> while the subject views a series of randomly selected targets. Targets used have included emotional vs. calm images, happy vs. sad faces, audio tones vs. silence, light flashes vs. no flash, and audio tones vs. light flashes. The physiological state is examined a few seconds before the stimulus is randomly generated to test whether subjects are unconsciously anticipating the upcoming stimulus.

Given the unconventional nature of the hypothesis, these experiments are designed to prevent artifacts from mimicking the hypothesized results. Well designed studies include at least the following nine features: (1) random target selections are made

immediately before they are shown to eliminate the possibility of pre-stimulus cues; (2) nondeterministic truly random generators are employed to reduce the efficacy of conventional inferences and statistical guessing strategies; (3) targets are selected with replacement for the same reason; (4) different physiological monitoring systems, software control programs, computer operating systems, and random number generators may be employed to provide replications using different equipment; (5) data are recorded in the computer's memory or on hard disk before the stimulus is selected; (6) software marks the data in real-time with the condition of the test (i.e., pre-stimulus, stimulus, or post-stimulus) to ensure correct synchronization with external events; (7) nonparametric statistics are used to avoid violating assumptions of parametric tests; (8) if the data requires filtering, then causal filters are employed to ensure that the resulting signal depends only on past and present inputs; (8) all trials are analyzed according to pre-specified criteria to avoid selective reporting biases; (9) the plausibility of anticipatory strategies that might develop as a result of poorly randomized sequences of targets is assessed by examining the target frequency distribution and autocorrelations.

Meta-analysis of a clearly defined subset of 38 of these studies,<sup>14</sup> all of which involved human physiological measurements recorded prior to randomly selected stimuli, found that the mean fixed effect size was  $e = 0.26$  (i.e., assumes the effect is constant across all studies; combined  $z = 8.7$ ,  $p < 1 \times 10^{-17}$ ), and the random effect size was  $e = 0.28$  (i.e., assumes the effect varies randomly across studies;  $z = 6.07$ ,  $p < 1 \times 10^{-9}$ ). The analysis showed that higher quality experiments produced a larger effect size than lower quality studies, and that the number of unpublished reports averaging a null result required to reduce the overall level of significance to chance would be an unrealistic 680 experiments. A Bayesian analysis of these studies using existing knowledge to establish priors indicated that the Bayes Factor (ratio of the alternative hypothesis to the null hypothesis) for this set of studies was  $2.9 \times 10^{13}$  in favor of a genuine effect.<sup>15</sup> Analysis of variations in methodological quality, selective reporting practices, and anticipatory strategies indicated that none of those factors were plausible explanations of the results. A few examples of these studies are now provided to help illustrate the methods used in actual experiments.

## **Skin Conductance**

In this experiment, electrodes are attached to a subject's non-dominant hand to record skin conductance level (SCL). SCL is correlated with activity in the sympathetic nervous system and has been used in thousands of experiments investigating human emotional responses to various stimuli.<sup>16</sup>

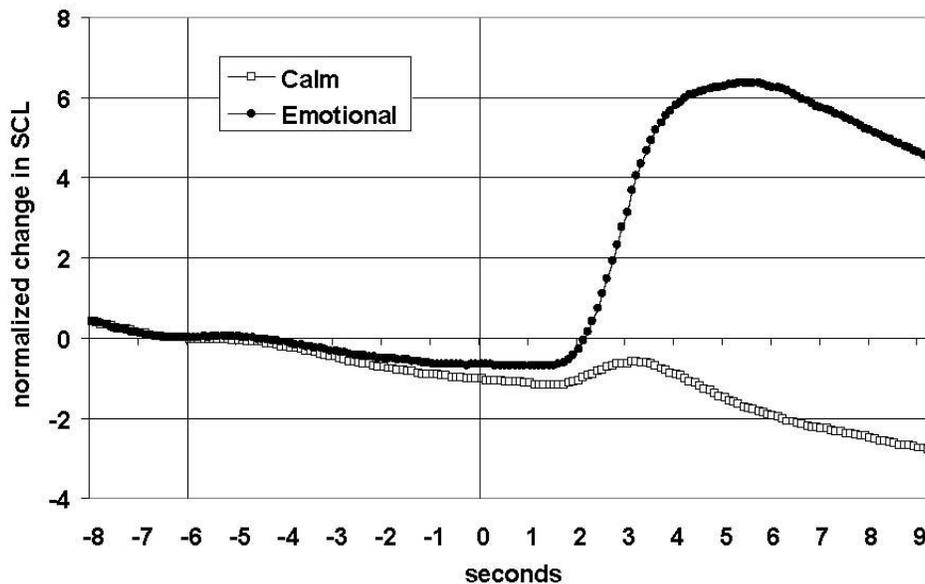
In a typical study, a physiological data acquisition system may record and digitize SCL at 10 samples per second. The experiment is run by a computer under a double-blind protocol whereby neither subject nor experimenter knows the sequence of future stimuli. In most cases the subject also does not know the contents of the target pool.

When ready to begin a trial, the subject presses a mouse button. The screen remains blank for 5 seconds, the computer then accesses a truly random number generator and uses the returned number to select (with replacement) a color photograph from a large pool of photos, and then it shows the photo for 3 seconds. This is followed by a blank

screen for 10 seconds as a cool-down period. Then a message appears on the screen instructing the participant to begin the next trial at will. A test session might consist of 30 such trials.

A target might be a photo of a calming scene, such as a landscape or a lamp, or it might be an emotional scene with erotic or violent content. Photos used in various implementations of this experiment have come from professional stock photographs, web-based photo archives, and the International Affective Picture System (IAPS), the latter developed for the National Institutes for Mental Health as a standardized picture set for studying emotional responses.<sup>17</sup>

The resulting SCL data are then averaged separately for all emotional and calm trials. The average curves are clamped to a common baseline at the start of the trial, and pre-stimulus differences between the curves for the two target categories are calculated using nonparametric methods. Result of an experiment by Radin<sup>9</sup>, involving 47 participants who contributed a total of 1,410 trials, is shown in Figure 1.



**FIGURE 1.** Average skin conductance in calm and emotional trials in a presentiment experiment. A button press to begin each trial occurred at -6 seconds, a randomly selected stimulus appeared at 0 seconds and was then displayed on a computer monitor for three seconds. Randomized permutation analysis indicates that the difference in pre-stimulus curves is associated with  $z = 3.34$ ,  $p = 0.0004$ , one-tailed.

## Pupil Dilation

The human eye is a convenient measure for studying presentiment effects because subjective states are reflected by three aspects of eye behavior: pupil dilation, spontaneous blink rate, and eye movement. Pupil dilation is commonly used to study attention, cognitive processing load, emotional response, anticipation, and the degree of balance between sympathetic and parasympathetic activation.<sup>18</sup> Eye gaze direction reflects real-time allocation of attention, mental imagery while imagining a scene, and preferential processing in the left vs. right brain hemisphere.<sup>19</sup> And spontaneous

blinking increases with a rise in dopamine, a brain neurotransmitter associated with emotional response.<sup>20</sup>

Based on previous studies it appears that the presentiment effect primarily correlates with sympathetic nervous system activity. This allows us to predict that the pupil would dilate more before emotional events than before calm events. We may also predict, based on speculations about brain lateralization effects, that presentiment information would be processed preferentially in the right brain hemisphere in right-handed people. We may further assume that because eye movements reflect mental imagery, then people who showed significant presentiment effects in pupil dilation might also exhibit correlations between their eye movements recorded before vs. while viewing a stimulus image.

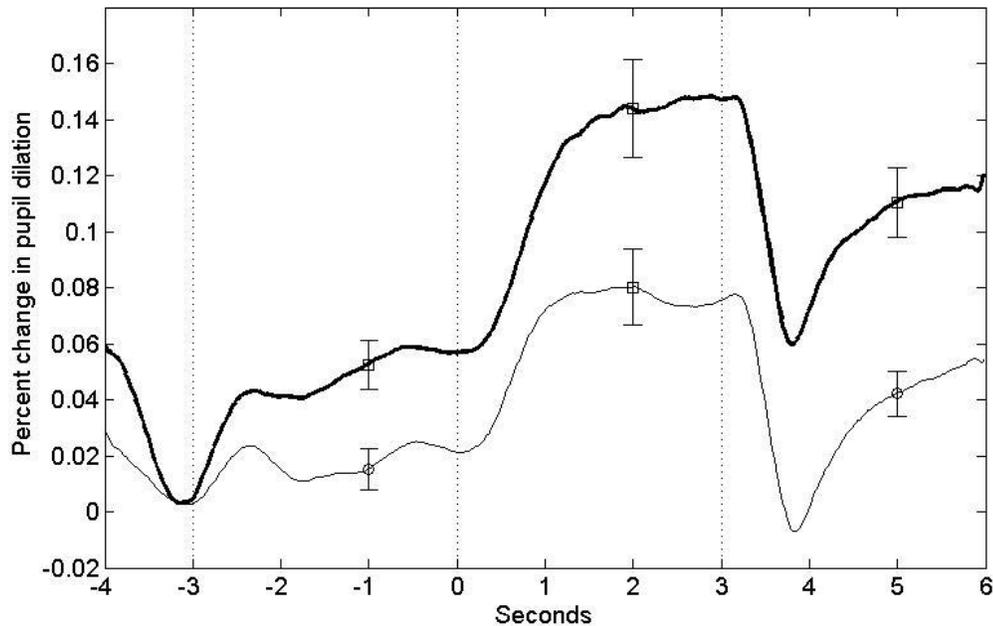
In an experiment reported by Radin and Borges,<sup>11</sup> a video eyetracking system provided eye movement direction and pupil diameter measures at 60 samples per second. A computer ran the experiment by coordinating activity in the eyetracking system with a second computer that was used to randomly select and display color photo images from the IAPS target set.

After the investigator calibrated the eyetracking apparatus to the subject's eye, the computer displayed a screen showing a uniform gray rectangle on a black background. When a "ready" message appeared on the screen, the subject clicked a mouse button at will, and the trial began. After the button press the screen remained gray for 3 seconds, then an image was randomly selected from the stimulus set (with replacement) and displayed it for 3 seconds, and then the screen returned to a uniform gray for 3 seconds. At this point a message appeared on the screen informing the subject to continue to the next trial at will.

Because images in this study were selected at random from the entire IAPS pool, most of the images used would have had emotionality ratings that were not especially emotional nor calm. The presentiment effect predicts that pre-stimulus responses anticipate post-stimulus reactions, thus to most easily detect this relationship it is necessary to ensure that the post-stimulus responses shows a strong calm vs. emotional contrast. To accomplish this, from the entire set of trials only those with the 5% most emotional and 5% most calm targets were used, where the emotionality rating used to create this contrast was based on the pre-established IAPS ratings.

In this study 33 volunteers contributed a total of 1,438 usable trials. Thirty-one subjects were right handed and two were ambidextrous. At the planned 5% level of emotional contrast, the differential effect in pupil dilation during the pre-stimulus period was significantly positive as predicted,  $z = 3.17$ ,  $p = 0.0008$  (see Figure 2).

In addition to the pupil dilation effect, at the same 5% emotional contrast there was more spontaneous blinking before emotional vs. calm pictures ( $z = 2.13$ ,  $p = 0.02$ ). Of the 33 subjects, 5 individually showed significant presentiment results. Their eye movements during the pre-stimulus period, when they were gazing at a gray screen, were weakly but significantly correlated with their eye movements recorded while viewing the stimuli ( $r = 0.049$ ,  $z = 2.91$ ,  $p = 0.002$ ,  $N = 190$  trials). By comparison, 5 other subjects selected based on their obtaining results closest to chance showed no significant correlation ( $r = 0.006$ ,  $z = -0.79$ ,  $p = 0.78$ ,  $N = 190$  trials). This suggests that presentiment effects are not just responses to future emotions, but also to information specific to those future targets.



**FIGURE 2.** The bold (top) line shows average proportional change in pupil dilation for the 5% most emotional targets over all 1,438 usable trials; the thin (bottom) line shows the same for the 5% calmest targets. Both lines are baseline adjusted to the average pupil dilation value per trial recorded during the 167 msec prior to the trial-initiating button press (at second -3). Stimulus onset is at second 0 and stimulus offset at second +3. Confidence intervals are plus and minus one standard error of the mean, and curves are smoothed 500 msec to clarify the figure.

## Electrocortical Activity

As independent replications of the original presentiment studies began to show reliable effects, it appeared that the experimental method might be robust enough to test an aspect of yogic lore suggestive of retrocausation. Advanced practitioners across many meditative traditions occasionally report states of exceptionally deep absorption.<sup>21</sup> During such experiences, everyday distinctions such as subject/object, me/you, and past/future, seem to dissolve. With practice, the meditator may achieve a state of mental spaciousness in which his or her awareness seems to extend through time.<sup>22</sup> From a neuroscience perspective, subjective experiences of “timelessness” are merely distortions caused by brain-generated illusions.<sup>23</sup> As a result, it is rarely considered that reports may be ontologically accurate.

However, given the results of presentiment experiments, these experiences deserve a closer look. Perhaps when one has achieved an appropriate state of awareness, the distinction between now and then actually does dissolve, and time is perceived as an illusion. Such a state was called *sam̐yama* in Patanjali’s Yoga Sutras, a prominent yoga document written in the second century BC.<sup>24</sup> Patanjali described in matter-of-fact terms that those who achieved stability in *sam̐yama* would experience

extraordinary mental abilities or *siddhis*, one of which was described as the ability to simultaneously perceive past, present and future.<sup>25</sup>

From a scientific perspective, it is a social obligation to publicly regard the idea of *siddhis* or mental powers as pure fantasy. But it turns out that there is an embarrassing class of temporal anomalies already described in the conventional scientific literature that is reminiscent of the “timelessness” under consideration here. Terms like *precognition* and *presentiment* can sometimes be found, albeit in apologetic tones. But more often one finds euphemisms such as “exceptional situational awareness,”<sup>26</sup> referring to the performance of jet fighter pilots who respond faster in combat situations than they should be able to; “anticipatory systems,”<sup>27</sup> a phrase used to describe how organisms plan and carry out future behavior; and terms like “postdiction,”<sup>28</sup> “subjective antedating,”<sup>29</sup> “tape delay,”<sup>30</sup> and “referral backwards in time.”<sup>31</sup> All of these concepts are brain processes proposed to explain apparent retrocausal effects. The underlying idea assumes that the brain has some sort of delay mechanism that fools us into seeing now what actually occurs later.

The machinations required to shoehorn observations suggestive of retrocausation into standard neuroscience assumptions seems similar to the attempts of medieval Scholastics to fit their epicycle models of the solar system into improved observations of the movement of the planets. It is possible, but awkward. And there is a simpler approach – rather than resorting to increasingly complex scenarios like “tape delays,” what if the yogic perspective is correct? What if ordinary time perception is an approximation of a deeper reality residing beyond the everyday constraints of space-time? When that reality is perceived from “inside” space-time, perhaps both past and future would be observed to influence the present.

Future influences on the present is what presentiment experiments are designed to test, so Radin et al designed a study for 16 subjects: Eight advanced meditators matched by age, gender, handedness, income and ethnicity to eight non-mediator controls.<sup>32</sup> Meditators with experience in practicing a *nondual* form of meditation were recruited because this style of meditation is associated with the experiential dissolution of dualities, including the dualism of interest: now vs. then. Elements of nonduality can be found in many of the world’s contemplative and philosophical traditions. These practices are best known in the West through the Dzogchen and Advaita forms of Zen meditation.<sup>33</sup>

Two simple stimuli were used in the experiment: a light flash and an audio tone. The light stimulus was a 250 msec flash provided by a pair of visual stimulator glasses; these produced a bright white flash about 1 cm from the pupil. The audio tone was a moderately loud (70 dB) noise burst provided over earphones. The stimuli were selected using a truly random number generator, and an electronic circuit marked the EEG record with a signal precisely at stimulus onset. Thirty-two EEG channels were acquired at 250 samples per second.

Subjects were fitted with the electrodes, visual stimulator glasses and earphones. They were told that the experiment would be conducted with eyes closed, in two sessions of about 15 minutes each, with a five minute break between the sessions. Each test session consisted of two tasks, and each task was repeated 50 times.

The first task asked subjects to press a button to start a trial at will. Three seconds later a truly random number generator selected one of four possible stimuli, and then

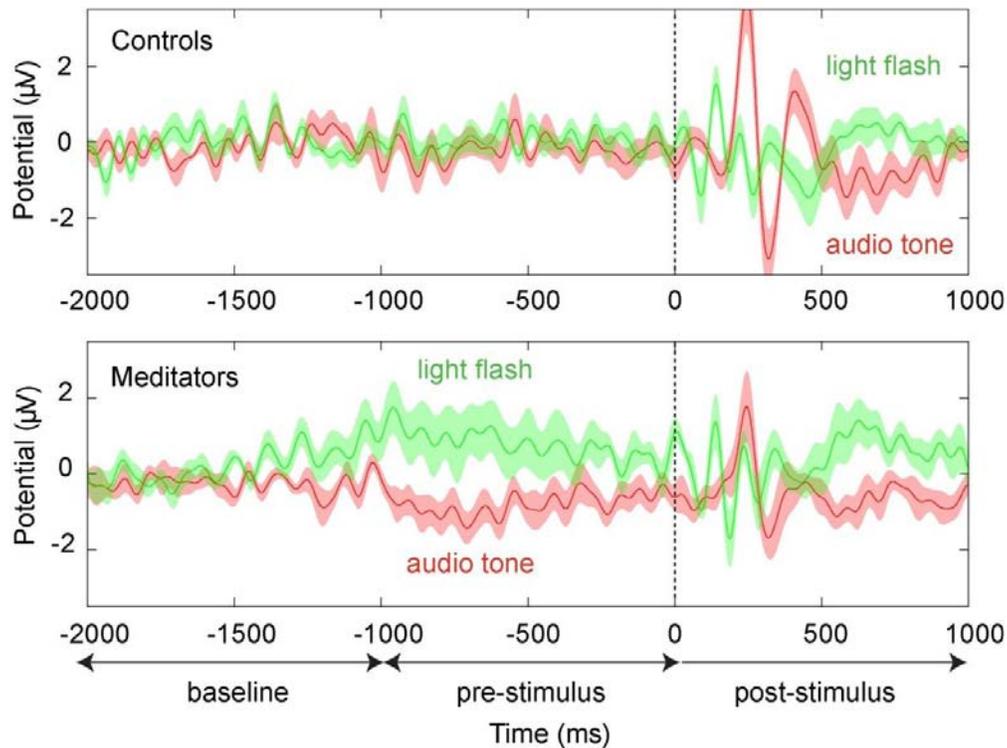
immediately presented it. The stimuli were a light flash, an audio tone, a light flash and audio tone together, or no stimulus. These were selected with *a priori* probabilities of 0.167, 0.167, 0.167, and 0.50, respectively. The second task began with a single button press, then a random inter-stimulus interval between 2 to 6 seconds was generated, followed automatically by a 2-second pre-stimulus period, then by a randomly selected light flash, audio tone, or blank stimulus (each with a priori  $p = 0.33$ ). Two seconds later the next trial automatically began. In both tasks the stimuli of interest were the light flashes and audio tones. The other stimuli were used as distracters to reduce unconscious counting strategies and to mask which stimuli were of interest.

Meditators in this study had an average of 21 years of a daily active practice; non-meditators had no active meditation practice. The presentiment hypothesis predicted that the brain's electrocortical activity would differ before unpredictable audio vs. light stimuli. The control group showed no significant differences between the two classes of stimuli. But within the meditation group 5 of 32 electrodes showed significant differences prior to light vs. audio stimuli, mostly over the right occipital region. This confirmed the prediction that the meditators' brains would behave differently depending on future, unpredictable stimuli. In comparing brain responses between the meditation and non-meditator groups, it was found that before audio tones 15 of 32 electrodes showed significant differences, distributed broadly over the occipital, inferior parietal, and inferior right frontal regions. This indicates that the meditators' were processing pre-stimulus information differently than non-meditators, at least for the audio stimuli. All of these analyses were adjusted for multiple comparisons, so the significant effects obtained in this study were genuine effects consistent with presentiment effects.

To help visualize the meditators' EEG activity before light flash vs. audio tone stimuli, we may examine the time-course of the EEG data for one electrode (right superior centroparietal). Figure 3 shows the means and one standard error of the mean envelopes for audio and light stimuli separately in the control and meditation groups, ranging from two seconds pre-stimulus to one second post-stimulus. It shows strong differences developing in the meditators' EEG signal about 1.5 seconds before the light vs. audio stimuli.

## **Implicit Behavior**

In a new type of presentiment experiment, the idea is to time-reverse the cause-and-effect sequence used to establish well-known phenomena in the cognitive and social sciences. For example, in a conventional social psychology experiment a subject might be asked to look at a pair of images presented on a computer screen. The images could be anything: two faces, two objects, or even two abstract shapes. The task is to select one image that is more likeable. The pairs of images used in this experiment have been pre-assessed by independent judges to ensure that each pair consists of equally likeable images. Thus, not surprisingly, subjects who have not seen these images before would also be expected to like each image about the same.



**FIGURE 3.** Mean potentials and one standard error of the mean envelopes for light and audio stimuli across all trials, shown by group, at a right superior centroparietal electrode. The signals are baseline adjusted from 2 to 1 second pre-stimulus. Time 0 is the moment of stimulus onset. For ease of visualization these data were smoothed with a 10 Hz high pass filter. Graph from Radin et al.<sup>32</sup>

Now, to investigate a phenomenon known as the “mere exposure” effect,<sup>34</sup> before a subject is asked to select one of the images, the computer first randomly selects one of the images and repeatedly presents it subliminally. The subject will have no conscious awareness of seeing that image, but when asked to select which one they prefer, they will select the image that they saw subliminally. This experiment demonstrates that we tend to like what we are familiar with, even when the familiarity is due to unconscious priming prior to making a decision. In a retrocausal version of this experiment, the subject first selects one of a pair of images, and only then does the computer randomly select one of the images and repeatedly presents it. This time-reversed mere exposure effect predicts that the *future* priming would bias the subject’s *present* decision.

In a series of 9 such experiments, involving more than a thousand subjects, Bem reported statistically significant evidence in 8 of 9 experiments.<sup>35</sup> Across all 9 experiments, the mean effect size was  $e = 0.22$ , and the combined  $z = 6.66$ ,  $p = 2.68 \times 10^{-11}$ .<sup>36</sup> This effect size is remarkably similar to effect sizes obtained in the free-response precognition studies, the psychophysiological presentiment studies, and also with effect sizes commonly observed in conventional psychological tests. Richard et al surveyed a hundred years of social psychology experiments (in 2003), involving some 25,000 experiments and 8 million people, and found that the average effect size was  $e = 0.21$ .<sup>37</sup> This means that what the retrocausal experiments are finding is not

especially surprising in terms of what is commonly observed in human psychological performance.

In a critique of Bem's studies, Wagenmakers et al. argued that a more appropriate statistical technique for analyzing this type of controversial data, which is invariably biased by the analyst's prior beliefs, is to use Bayesian techniques.<sup>38</sup> This approach requires that the analyst specify two types of *a priori* beliefs about the null (H0) and the alternative hypotheses (H1). The first is the belief that H0 is true. Wagenmakers et al. set these odds at 100 thousand trillion to 1 in favor of H0, reflecting their belief that retrocausation is essentially impossible. The second belief is associated with one's expectations of how effect sizes are distributed if H1 were in fact true. The outcome of such an analysis is expressed in terms of a Bayes Factor, which is the odds of H1 vs. H0 after the actual data are considered in light of the two prior beliefs.

Wagenmakers et al evaluated each of Bem's nine experiments separately, rather than as a group. Their assigned odds in favor of H0, combined with their choice of the distribution for H1, eliminated the possibility that any new data could influence the posterior odds in favor of H1. Thus, their conclusion that Bem's study did not provide evidence for a retrocausal effect was not surprising.

Using more realistic, knowledge-based priors relying on previous experimental data, and considering Bem's set of 9 studies rather than each one separately, Utts et al determined that the Bayes Factor in favor of genuine precognition in Bem's experiments was 13,669 to 1, or  $p < 7.3 \times 10^{-5}$ . To provide another perspective of the strength of this outcome, one's prior belief in precognition could be as low as 100 million to 1 in favor of H0, and Bem's data would still support H1. In other words, if one begins with the position that retrocausal effects are impossible, then no amount of positive evidence can shake one's faith in H0. But if one begins with the possibility that retrocausal effects *might* be real, even when that possibility is extremely small, then the strength of the existing evidence will substantially shift one's belief towards H1.

The implicit decision class of experiments is a recent development, and while some independent replications have begun to be reported as of this writing (2011), the replication rate with existing designs and new conceptual variations remains to be seen.

## **Animal Behavior**

Similar to anecdotes about human experiences of foreknowledge, there is a long history of animals reacting prior to major natural disasters, such as tsunamis and earthquakes.<sup>39</sup> Explanations offered for these observations include animal sensitivities to geomagnetic, electromagnetic and atmospheric disruptions prior to such events. Another possibility is that like humans, animals experience presentiment effects.

Intrigued by the compounding evidence for human presentiment, researchers have begun to expand this line of research into animal behavior. This category of experimentation is relatively new, but three experiments have been reported as of early 2011 are promising and provide reason to expect that future studies may continue to show significant outcomes. The studies involved earthworms, Bengalese finches, and Zebra finches.

In the first study, Wildey tested earthworms using a mechanical vibration to create the worm equivalent of an emotional stimulus, and no vibration as a “calm” control.<sup>40</sup> His experimental observations were consistent with outcomes reported in presentiment experiments, i.e. more activity prior to the vibration than before no-vibration. He also found that the more trials he collected, the more his data agreed with the presentiment hypothesis, which is what one would expect if the “signal” was a genuine one.

In the second study, Alvarez placed 47 Bengalese finches (*Lonchura striata*) into a cage, one at a time.<sup>41</sup> After a 15 minute period to become acclimated to the cage, at a time determined by true random generator a 15-second video clip was displayed on a video screen. The video consisted of a snake crawling towards the bird. When the finches see this type of snake (a horseshoe whip snake, *Coluber hippocrepis*), they display distinct alarm movements. For one type of control trial, the same procedure was followed but no video clip was displayed, and for a second type of control the alarm behavior was counted just before the 10 minute point during the initial acclimation period.

The birds were continuously filmed during the experiment, and the frequency of alarm behavior was counted from 0–3, 3–6, and 6–9 seconds before the snake image appeared. The same procedure was followed for the control trials. These counts were performed under blinded conditions, i.e., without knowledge of whether a given video record was prior to a snake video or no video. The results showed that the birds reacted to the snake video clip at least 9 seconds before it was shown, with the frequency of the alarm display during that period being greater than observed in the first type of control ( $t(46 \text{ df}) = 3.56, p < 0.0009$ , two-tailed) or the second control ( $t = 4.49, p < 0.00005$ , two-tailed). By contrast, there was no difference in counts between the two types of controls. In a third study with similar aims, Alvarez successfully replicated the Bengalese finch study with adult female Zebra finches (*Taeniopygia guttata*), using a startle stimulus (sound of a gunshot) instead of a snake video.<sup>42</sup>

## CONCLUSION

From time immemorial, people have reported hunches, premonitions, and foreknowledge about future events later verified to be accurate. Conventional explanations can undoubtedly account for many of these anecdotes, but for 75 years laboratory studies have investigated whether some of these experiences may be based on retrocausal effects. As of 2011, the accumulated empirical database consists of hundreds of experiments. For the two most recent classes of studies examining retrocausal effects via unconscious physiological or behavioral measures, 85 of 101 studies (84%) reported by 25 different laboratories from the United States, Italy, Spain, Holland, Austria, Sweden, England, Scotland, Iran, Japan, and Australia, have produced results in the direction predicted by a retrocausal effect (odds against chance =  $1.3 \times 10^{12}$ , via a sign test). Both frequentist and Bayesian statistical analyses agree that this literature provides independently repeatable evidence for effects suggestive of a genuine retrocausal phenomenon in humans and possibly in animals.

## ACKNOWLEDGMENTS

I am grateful to the Bigelow Foundation, the Bial Foundation, the Institut für Grenzgebiete der Psychologie und Psychohygiene, Interval Research Corporation, Boundary Institute, and the Institute of Noetic Sciences for supporting my research on presentiment. I would also like to acknowledge the Koestler Unit of Parapsychology, Department of Psychology, University of Edinburgh, where as a research fellow in 1993 I developed the idea for a psychophysiological-based presentiment experiment.

## REFERENCES

- 1 L. Dossey, *The power of premonitions*. (Dutton Adult, New York, 2009).
- 2 R. Wiseman and C. Watt, "Belief in psychic ability and the misattribution hypothesis: a qualitative review," *Br J Psychol* **97** (Pt 3), 323-338 (2006).
- 3 J. Gaither Pratt and J. B. Rhine, *Extra-sensory perception after sixty years; a critical appraisal of the research in extra-sensory perception*. (Bruce Humphries, Boston., 1967).
- 4 C. Honorton and D. C. Ferrari, "'Future telling': A meta-analysis of forced-choice precognition experiments, 1935-1987," *Journal of Parapsychology* **53**, 281-308 (1989).
- 5 J. Utts, "An Assessment of the Evidence for Psychic Functioning," *Journal of Scientific Exploration*, **10** (1), 3-30 (1996).
- 6 Brenda J. Dunne and Robert G. Jahn, "Information and Uncertainty in Remote Perception Research," *Journal of Scientific Exploration* **17** (2), 207-241 (2003).
- 7 S. Krippner, C. Honorton, and M. Ullman, "An experiment in dream telepathy with 'The Grateful Dead'," *J Am Soc Psychosom Dent Med* **20** (1), 9-17 (1973).
- 8 D. I. Radin, "Unconscious perception of future emotions: An experiment in presentiment," *Journal of Scientific Exploration* **11**, 163-180 (1997).
- 9 D. I. Radin, "Electrodermal presentiments of future emotions," *Journal of Scientific Exploration* **18**, 253-274 (2004).
- 10 P. Tressoldi, M. Martinelli, S. Massaccesi, and L. Sartori, "Heart rate differences between targets and non-targets in intuitive tasks," *Human Physiology* **31** (6), 646-650 (2005); R. McCraty, M. Atkinson, and R.T. Bradley, "Electrophysiological evidence of intuition: Part 1. The surprising role of the heart," *Journal of Alternative and Complementary Medicine* **10**, 133-143 (2004).
- 11 D. Radin and A. Borges, "Intuition through time: what does the seer see?," *Explore* **5**, 200-211 (2009).
- 12 D. Radin and E. Lobach, "Toward understanding the placebo effect: investigating a possible retrocausal factor," *Journal of Alternative and Complementary Medicine* **13** (7), 733-739 (2007).
- 13 D.J. Bierman and H.S. Scholte, "A fMRI brain imaging study of presentiment," *Journal of International Society of Life Information Science* **20** (2), 380-388 (2002).
- 14 J. Mossbridge, P. Tressoldi, and J. Utts, "Predictive Anticipatory Activity Preceding Unpredictable Stimuli: A Meta-Analysis," (under review).
- 15 P. Tressoldi, "Extraordinary Claims Require Extraordinary Evidence: The Case of Non Local Perception, a Classical and Bayesian Review of Evidences," *Frontiers in Psychology* **2** (117) (2011).
- 16 H. Sequeira, P. Hot, L. Silvert, and S. Delplanque, "Electrical autonomic correlates of emotion," *Int J Psychophysiol* **71** (1), 50-56 (2009).
- 17 M. M. Bradley and P. J. Lang (eds), *The International Affective Picture System (IAPS) in the study of emotion and attention*. (Cambridge University Press, New York, 2007).
- 18 K. Prehn, H. R. Heekeren, and E. van der Meer, "Influence of affective significance on different levels of processing using pupil dilation in an analogical reasoning task," *Int J Psychophysiol* **79** (2), 236-243 (2011).
- 19 P. Hollinger, R. Beisteiner, W. Lang, G. Lindinger, and A. Berthoz, "Mental representations of movements. Brain potentials associated with imagination of eye movements," *Clin Neurophysiol* **110** (5), 799-805 (1999).
- 20 S. A. Chermahini and B. Hommel, "The (b)link between creativity and dopamine: spontaneous eye blink rates predict and dissociate divergent and convergent thinking," *Cognition* **115** (3), 458-465 (2010).
- 21 R. Cahn and J. Polich, "Meditation states and traits: EEG, ERP, and neuroimaging studies," *Psychological Bulletin* **132**, 180-211 (2006); A. Newberg, A. Alavi, M. Baime, M. Pourdehnad, J. Santanna, and E. d'Aquili, "The measurement of regional cerebral blood flow during the complex

- cognitive task of meditation: A preliminary psychiatry research study," *Neuroimaging* **106** (2), 113-122 (2001).
- 22 Z. Josipovic, "Duality and nonduality in meditation research," *Consciousness and Cognition* **19**, 1119-1121 (2010).
- 23 M. Wittmann, V. van Wassenhove, A. D. Craig, and M. P. Paulus, "The neural substrates of subjective time dilation," *Frontiers in Human Neuroscience* **4**, 1-9 (2010).
- 24 J.H. Woods, *The yoga system of Patanjali*. (Harvard University Press, Cambridge, MA, 1927); J.H. Woods, *The yoga system of Patanjali*. (Motilal Banarsidass, Delhi 2007).
- 25 D. Simon, "The Yoga Sutras of Patanjali As-It-Is: Introduction, Commentaries, and Translation", (2011).
- 26 B. O. Hartman and G. E. Secrist, "Situational awareness is more than exceptional vision," *Aviation, Space, and Environmental Medicine* **62**, 1084 -1089 (1991).
- 27 R. Rosen, *Anticipatory systems*. (Pergamon Press, New York, 1985).
- 28 D. M. Eagleman and T. Sejnowski, "Motion integration and postdiction in visual awareness," *Science* **287**, 2036-2038 (2000).
- 29 F. A. Wolf, "The timing of conscious experience: A causality-violating, two-valued, transactional interpretation of subjective antedating and spatial-temporal projection.," *Journal of Scientific Exploration* **12**, 511-542 (1998).
- 30 D. C. Dennett (ed), *Temporal anomalies of consciousness*. (Springer-Verlag, Berlin, 1992).
- 31 B. Libet, "Unconscious cerebral initiative and the role of conscious will in voluntary action," *Behavioral and Brain Sciences* **8**, 529-566 (1985).
- 32 Dean I. Radin, Cassandra Vieten, Leena Michel, and Arnaud Delorme, "Electrocortical activity prior to unpredictable stimuli in meditators and non-meditators," *Explore* (in press).
- 33 D. Radin, C. Vieten, L. Michel, and A. Delorme, "Electrocortical activity prior to unpredictable stimuli in meditators and non-meditators," *Explore* (in press).
- 34 Y. Yagi, S. Ikoma, and T. Kikuchi, "Attentional modulation of the mere exposure effect," *J Exp Psychol Learn Mem Cogn* **35** (6), 1403-1410 (2009).
- 35 D. J. Bem, "Feeling the future: Experimental evidence for anomalous retroactive influences on cognition and affect," *Journal of Personality and Social Psychology* **100** (3), 407-425 (2011).
- 36 D. J. Bem, J. Utts, and W. O. Johnson, "Must Psychologists Change the Way They Analyze Their Data? A Response to Wagenmakers, Wetzels, Borsboom, & Van der Maas (2011)," *Journal of Personality and Social Psychology* (in press).
- 37 F. D. Richard, C. F. Bond, Jr. , and J. J. Stokes-Zoota, "One hundred years of social psychology quantitatively described," *Review of General Psychology* **7**, 331-363 (2003).
- 38 E. J. Wagenmakers, R. Wetzels, D. Borsboom, and H. van der Maas, "Why psychologists must change the way they analyze their data: The case of psi," *Journal of Personality and Social Psychology* **100**, 426-432 (2011).
- 39 H. Tributsch, "The Bionic Anticipation of Natural Disasters," *Journal of Bionic Engineering* **2** (3), 123-144 (2005).
- 40 C. Wildey, University of Texas, 2001.
- 41 F. Alvarez, "Anticipatory Alarm Behavior in Bengalese Finches," *Journal of Scientific Exploration* **24** (4), 599-610 (2010).
- 42 F. Alvarez, "Higher Anticipatory Response at  $13.5 \pm 1$  h Local Sidereal Time in Zebra Finches," *Journal of Parapsychology* **72** (2), 323-334 (2010).

Copyright of AIP Conference Proceedings is the property of American Institute of Physics and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.