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Electrodermal Presentiments of Future Emotions

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Abstract—In previously reported double-blind experiments, electrodermal activity (EDA) monitored during display of randomly selected photographs showed that EDA was higher before emotional photos than before calm photos ($p = 0.002$). This differential effect, suggestive of precognition, was dubbed "presentiment." Three new double-blind experiments were conducted in an attempt to replicate the original studies using the same basic design, but with new physiological monitoring hardware, software, stimulus photos, subject populations, and testing environments.

The three replications involved 109 participants who together contributed 3,709 trials. The new studies again showed higher EDA before emotional photos than before calm photos ($p = 0.001$). All four experiments combined involved 133 participants and 4,569 trials; the associated weighted mean effect size (per trial) was $e = 0.064 \pm 0.015$, over 4 standard errors from a null effect. As a more general test, presentiment predicts a positive correlation between pre-stimulus EDA and independently assessed emotionality ratings of the photo targets. The observed correlation across all four experiments was significantly positive ($p = 0.008$).

Consideration of alternative explanations, including expectation, sensory cues, hardware or software artifacts, inappropriate analyses, and anticipatory strategies, revealed no suitable candidates that could systematically generate the observed results. This series of four experiments, supported by successful replications conducted by other investigators, appears to demonstrate a small magnitude but statistically robust form of precognition in the human autonomic nervous system.

Keywords: electrodermal activity—precognition—autonomic nervous system anticipation

Introduction

Many people have experienced intuitive hunches or forebodings about future events that later turned out to be correct. Most such hunches can be attributed to unconscious inferences, others are undoubtedly coincidences, instances of selective memory, or due to forgotten expertise. However, sometimes a hunch seems so intrinsically unlikely and yet turns out to be valid, that one wonders whether such experiences, often on the edge of conscious awareness, might involve perception of future information. In a series of experiments designed to test this idea under double-blind conditions, I explored whether the human

autonomic nervous system would be able to correctly anticipate exposure to randomly selected calm or emotional photographs (Radin, 1997).

Those initial studies provided evidence for what I called *presentiment*. I used this term, in contrast to precognition, as the latter implies conscious awareness (i.e., pre-*cognition*) of future events. Publication of the initial results in this journal prompted a number of other researchers to attempt to replicate the effect. Some of the replications focused primarily on electrodermal activity (EDA), as in the original studies (Bierman, 2000; Bierman & Radin, 1997, 1998; Norfolk, 1999; Parkhomtchouk et al. 2002; Spottiswoode & May, 2003; Wildey, 2001). Others explored different physiological measurements, including functional magnetic resonance imaging (MRI; Bierman & Scholte, 2002) and heart rate variability (McCraty, 2002). All of the replications reported results consistent with the original findings.

This paper reviews the results of presentiment experiments that I conducted from 1996 through 2000, only the first of which was previously published (Radin, 1997). All these experiments were primarily proof-oriented rep-lications using different hardware and software implementations, subject populations, environmental conditions, and photo stimuli. Experiment 1 was the initial series of tests, Experiment 2 was a straightforward replication, Experiment 3 was conducted as a proof-of-principle demonstration in an industrial research laboratory, and Experiment 4 explored the use of a custom-designed psychophysiological monitoring device. To avoid repeating descriptions of common design elements, a brief overview of the general procedure will be described first and then appropriate details added as each experiment is discussed.

Method

Basic Experimental Procedure

A participant (P) is seated in front of a computer monitor displaying a black screen. The experimenter attaches EDA electrodes (Ag-AgCl, 8 mm diameter) to the volar surfaces of the distal phalanges of the index and middle fingers of P's non-dominant hand. The electrodes are secured with Velcro straps, and electrode gel is used to enhance contact with the skin. After the experimenter ensures that the physiological hardware is recording the EDA data properly, P is instructed to press a button at will. When this occurs (see Figure 1), the computer waits 5 seconds, then it selects a photo at random from a large pool of possibilities, displays it for 3 seconds, and then the screen goes blank again for 10 seconds. After the 10-second ''cool-down'' period, the computer instructs P to press the button again when ready to begin the next trial. A typical session may last 30 minutes, during which time 40 trials are run. The design is double-blind in the sense that neither P nor the experimenter know in advance which photos will be displayed in a given session, or in what sequential order.

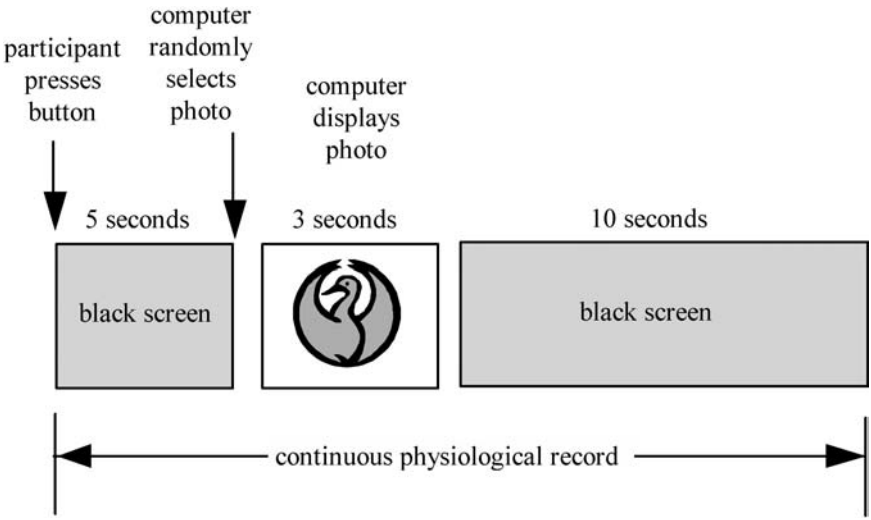

Fig. 1. Illustration of basic experimental protocol.

Hypotheses

The concept of presentiment postulates that present physiological states are correlated with near-term future experiences. When those futures involve emotional experiences, as evoked through the use of photographs of varying emotionality, the correlation is postulated to be detectable as a present-time arousal of the autonomic nervous system. This idea leads to three progressively more general hypotheses.

Hypothesis 1. This hypothesis states that EDA before display of emotional photos will be larger than EDA before display of calm photos. This differential prediction is tested by partitioning all trials in an experiment into emotional and calm subsets of equal size. These subsets are formed based upon prior assessments of the emotionality of the target photos. The probability of the resulting differences in EDA is formally tested using a nonparametric statistical method known as randomized permutation analysis (Blair & Karniski, 1993).

Hypothesis 2. This hypothesis states that as the contrast between emotional and calm trials increases, the magnitude of the presentiment effect will also increase, and vice versa. This is tested by sorting all trials according to their pre-assessed emotionality ratings, then comparing the top 1% most emotional vs. the 1% most calm trials, then the top 2%, and so on up to 50% (which is then the same as Hypothesis 1). No specific prediction is made for the emotional contrast level that would show the largest effect, but it is expected that the peak might fall somewhere between 5% and 25%. This is because a few photos with very high or very low emotionality assessments would provide strong emotional contrasts, but at the cost of low statistical power. And an assessment made with

many photos of varying emotionality would provide greater statistical power, but at the cost of weaker emotional contrast.

Hypothesis 3. This hypothesis generalizes the first two hypotheses and predicts a positive correlation between the pre-assessed emotionality ratings and changes in EDA prior to the stimuli.

Method of Analysis

Electrodermal activity (EDA) refers to variations in electrical resistance of the skin. These fluctuations are due to activity of the eccrine sweat glands, which are activated by the sympathetic nervous system (Bouscein, 1992). The specific form of EDA used in these studies was skin conductance level (SCL). SCL has been used as the principal physiological measurement in these and in many of the replication attempts primarily because SCL is a conveniently measured and widely used indicator of overall autonomic activity. All SCL data in these experiments were uniformly analyzed using a simplification of the technique employed in the initial studies (Radin, 1997).

An SCL "sample" refers to an instantaneous measurement of absolute skin conductance. For the sake of exposition, let us assume in this discussion that one trial is 18 seconds in length (as shown in Figure 1) and that the sampling rate is 5 Hz; thus each trial consists of 90 samples. Let us further assume that an experiment consists of 20 participants, each of whom runs 30 trials, for a total of 600 trials.

To analyze the results of an experiment, each SCL sample in each trial is normalized as $z_{ij} = (x_{ij} - m_j)/s_j$, where in our example i refers to samples 1–90, $j =$ 1 to 600 trials, x_{ij} refers to the raw SCL value for sample i in trial j, m_j is the average of the 25 samples in the 5-second pre-stimulus period in trial j (i.e., from the starting button press to just before the photo appears), and s_j is the standard deviation of those same 25 samples. Then, all normalized trials z_{ij} are clamped to zero after the button press as $p_{ij} = (z_{ij} - z_{1j})$, where z_{1j} refers to the first normalized SCL sample after the button press in trial j, and i ranges across all samples 1–90.

The p_{ij} values are thus *changes in normalized SCL* (i.e., ΔSCL). Normalized SCL is of interest, rather than absolute SCL, because otherwise a few Ps with highly labile SCL signals would overwhelm the data from other, less labile Ps. And change in SCL is of interest because we are interested in event-related responses, i.e., how autonomic arousal fluctuates from the moment P decides to begin each trial, rather than in P's general level of sympathetic arousal or in spontaneous fluctuations in SCL.

To determine the statistical likelihood of the differences in ΔSCL observed before emotional and calm trials, randomized permutation analysis was employed as follows (Blair & Karniski, 1993):

1. The value $S_j = \sum_i p_{ij}$ was determined for each trial j, where the sum was taken over pre-stimulus samples $i = 1$ to 25 per trial, starting just after the initiating button press and ending just before stimulus onset.

2. All trials j were then sorted by each trial photo's pre-assessed emotionality ratings, in ascending order.
3. The sorted list in step 2 was divided into two equal subsets such that trials 1 to $j/2$ were defined as calm and trials $(j/2) + 1$ to j were defined as emotional.
4. The difference $D = \sum_e S_e - \sum_c S_c$ was determined, where $c = 1$ to $j/2$ and $e = (j/2) + 1$ to j.
5. The order of the emotionality ratings were randomly scrambled and steps 2 through 4 repeated 1,000 times, each time keeping track of the difference, say D'. Then the mean μ_D and standard deviation σ_D of all the D' values were determined.
6. Now $z = (D - \mu_D)/\sigma_D$ and its associated one-tailed probability was calculated. This p value represents the probability of observing a difference as large or larger than the observed D.

This process was then repeated for the 1% most emotional vs. 1% most calm trials, then the 2% most emotional and calm trials, etc., up to the 50% split as described in the above six steps. In this way, a total of 50 z scores were generated, one for each "emotionality contrast" percentage from 1% to 50%. Then effect size per experiment was calculated as $e = z/\sqrt{N}$, where N was the number of trials in each experiment.

Experiments

Experiment 1

Experiment 1a used a 66 Mhz desktop personal computer (PC) to control the test. Experiment 1b was similar to 1a except that it presented the stimulus photo for 1 second rather than 3 seconds. Experiment 1c was identical to 1a except that the experiment was run on a 75 Mhz notebook PC. Experiment 1d investigated combinations of three simultaneous physiological measures, including SCL. Because tests 1a and 1c used identical designs, data from those two tests were pooled for the present analysis ($N = 900$), and because the other two tests were primarily designed to explore variations on a theme, those data ($N = 280$ trials) were excluded. It is worth mentioning that both of the excluded datasets individually provided positive evidence for the presentiment hypothesis (Radin, 1997).

Participants. Experiments 1a and 1c involved 24 Ps recruited from friends, staff, faculty, and students visiting the Consciousness Research Laboratory, University of Nevada, Las Vegas (UNLV). Ps were restricted to adult volunteers, and all were required to sign an informed consent explaining that photos portraying a wide range of emotions would be displayed. Immediately before starting the experiment, Ps were asked to provide a verbal affirmation to proceed.

Procedure. P was asked to sit in an office chair approximately 2 feet in front of a color computer monitor. The experimenter attached electrodes to record SCL (as previously described), heart rate, and peripheral blood flow, the latter two using a photoplethysmograph on the fingertip of the fourth digit of the non-dominant hand. These signals were monitored by a J&J Engineering (Poulsbo, WA) Model I-330 physiological data acquisition system (SCL digitized with 12-bit resolution using the constant voltage method at 0.3 volts; conductance measures range from 1 to 100 μS with ±0.05% accuracy). The physiological monitor and experiment protocol were controlled by a DOS-based program written in Microsoft QuickBasic 4.5 by the author. SCL samples were recorded at 5 Hz.

P was instructed to rest the hand with the electrodes in her lap (the female gender will be used hereafter to avoid awkward phrasing). In her dominant hand, she held a computer mouse with her index finger resting on the left mouse button. When ready to begin each trial, she pressed the mouse button and waited to see a picture on the computer monitor. After the button press, the computer selected a target photo at random, there was a 5-second delay during which the screen remained black, the selected picture was displayed for 3 seconds (as illustrated in Figure 1), and then the screen went black again. After a 10-second cool-down period, a message appeared on the screen alerting P to begin the next trial by pressing the mouse button at will. SCL was continuously monitored during each trial but not between trials in this experiment. P viewed 41 pictures in a single session, one picture at a time. The experimenter talked P through the first trial to ensure that the procedure was understood, and then the remaining 40 trials were conducted by P alone. Only the last 40 trials were used for subsequent analysis.

If P needed to stretch or move between trials, she was asked to do so as needed and then settle down before continuing. After P indicated that she understood the procedure, the experimenter retired behind an opaque wall-screen and P conducted the remaining 40 trials unobserved and at will. To enhance the display contrast of the stimulus pictures during the experiment, and to reduce possible electrical interference with the monitoring equipment, the overhead fluorescent lights were turned off and a dim red incandescent lamp (10 watts) was turned on. The laboratory was air conditioned to approximately 72°F and humidity levels were generally dry.[1]

Targets. At the beginning of each trial, the QuickBasic 4.5 pseudorandom number generator (PRNG) was re-seeded with the computer's clock time at the moment of the button press, and the target was selected out of a pool of 120 digitized color photographs. Calm targets included photos of landscapes, nature scenes, and people; emotional targets included erotic, violent, and accident scenes. Most of the calm pictures were selected from a Corel Professional Photo CD-ROM. Most of the emotional pictures were selected from photo archives accessible over the Internet.

Pictures were displayed in color, at 600 × 800 screen resolution, in a screen area about 6 inches wide by 4 inches high. If during a session a given target was

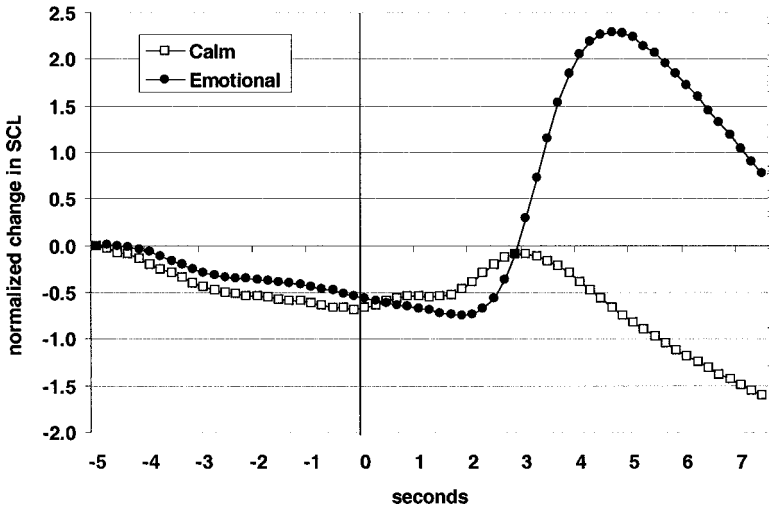

Fig. 2. Average normalized change in skin conductance level (ΔSCL) for calm and emotional trials in Experiment 1. A total of 860 trials were contributed by 24 participants. The pre-stimulus period is indicated by negative seconds; stimulus onset was at time 0; stimulus offset at 3 seconds. Randomized permutation analysis indicated that the observed difference in pre-stimulus SCL is associated with $z = 2.92$, $p = 0.002$ (one-tailed).

randomly selected again, another picture with the closest pre-assessed subjective emotionality rating—but not previously shown in that session—was selected in its place. Participants were unaware of the size of the target pool, or the ratio of calm to emotional photos, thus selecting targets without replacement would not have biased their expectations about the upcoming targets. This target-selection strategy was used to help ensure that each successive trial was as novel as possible. Novelty was important because the experiment was designed to evoke an orienting response (Kimmel et al., 1979), and novelty is one factor known to stimulate such responses.

To provide the independent subjective assessments of the target pictures, three men and three women were independently asked to examine each of the 120 pictures presented in randomized orders, and to rate each picture from 1 (calm) to 5 (emotional). Their average ratings were used to assign an emotionality value to each photo.

Results. Figure 2 graphically summarizes the results of Experiment 1, split into two equally sized datasets, one calm and the other emotional according to the target emotionality ratings. The vertical line in the graph shows the moment of stimulus onset. Skin conductance is expected to react 2 to 3 seconds after an emotional stimulus, and this response is evident in Figure 2. The difference in SCL before emotional and calm stimuli ($p = 0.002$) is the hypothesized presentiment effect.

Experiment 2

Participants. Participants in this study included 50 volunteers who ran the test at the Consciousness Research Laboratory, UNLV, and six who ran the same test at Interval Research Corporation, Palo Alto, CA, using the same physiological equipment and (nearly) the same stimulus pool. Most participants at UNLV ran 40 trials per session; those at Interval ran 30 trials per session. The testing environment at UNLV was the same as described in Experiment 1; trials at Interval were conducted on a 300 MHz desktop PC. The testing environment at Interval was a small office where participants sat in front of a computer monitor at a desk, in an ordinary office chair. During the experiment, office lights were turned off and windows were blocked. The office was air conditioned to about 72°F and humidity levels were comfortably moderate.

Procedure. The same electrodes, physiological hardware, and software from Experiment 1 were used in this study. However, unlike in Experiment 1, where the target photo was determined by the time of each button press used to initiate a trial, in this study the PRNG selected the target immediately prior to its display, thus ensuring that when P started each trial, the future emotional experience really was in the future, and not determined at the beginning of the trial.

To accomplish this, the computer program created a new seed-number immediately prior to stimulus onset by adding the value of the PC's internal clock time to the instantaneous values of three continuously monitored physiological signals: SCL, heart rate, and peripheral blood flow. This sum formed a seed-number used to initialize the PRNG, which was used in turn to select the target photo. The physiological signals were used to help form the PRNG seed-number because the clock time component of the seed-number was more or less determined even 5 seconds after the button press, whereas the instantaneous values of the physiological variables were not. It should be noted that the correlation between seed-numbers and the target photos selected by this PRNG was effectively zero ($r = 0.0007$); thus P could not infer the identity of the target even if the PC's clock time and the instantaneous physiological measurements were explicitly known (these values were not available to P).[2]

After the target photo was selected, it was retrieved from the PC's hard disk and displayed for 3 seconds. Through this process, from the moment a button press initiated a trial to just before the stimulus was displayed, the target was not yet determined. Nor were there sounds due to movements of the computer's hard disk, or electromagnetic changes in the computer monitor display, or any other sensory hints that might have provided clues about the identity of the upcoming target.

In addition, even though participants did not know the size or composition of the target pool, target photos were randomly selected in such a way as to prevent statistical hints about the future targets from accumulating over the course of a session. As in Experiment 1, to avoid repeating a stimulus photo that had

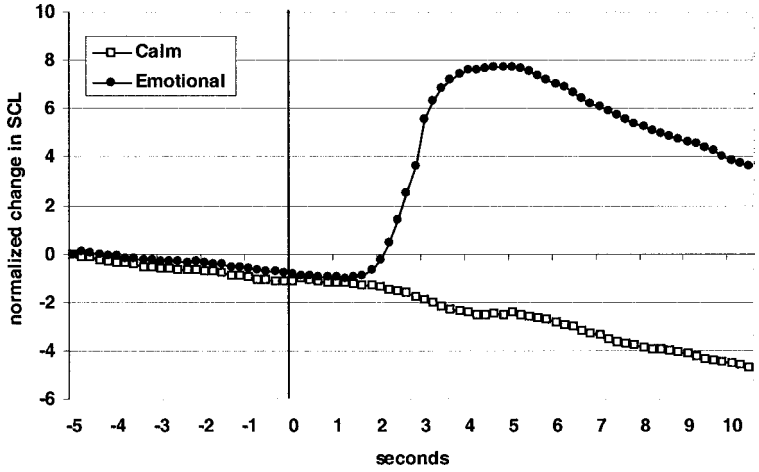

Fig. 3. Average normalized change in skin conductance level (ΔSCL) for calm and emotional trials in Experiment 2. This experiment consisted of a total of 2,059 trials, contributed by 56 participants. Randomized permutation analysis indicates that the difference in pre-stimulus ΔSCL curves is associated with $z = 1.23$, $p = 0.110$ (one-tailed).

already been selected, the computer noted the selected target's emotionality rating and randomly selected another picture with the nearest rating, and used that instead. In this way, the probability of observing a calm or emotional target on any given trial was held constant throughout the experiment, and no targets were repeated.

Targets. Thirty new pictures were added to the photo pool from Experiment 1, bringing the total to 150. Five men and five women were asked to independently examine the pictures, one at a time, in random order. The rating dimension consisted of a 100 point scale, and the rating method asked each person to view a picture on a computer screen and move a pointer across a sliding scale to indicate his or her assessment. Each person's assessments were individually normalized into standard normal deviates (z scores), and z scores per target were combined across all 10 people to provide a distribution of target emotionality assessments.

Results. Figure 3 shows the results of Experiment 2. As in Experiment 1, ΔSCL was slightly higher for emotional vs. calm photos ($p = 0.11$); this rise started immediately after P pressed the button used to initiate each trial.

Experiment 3

This experiment used new hardware and software, a new photo pool, and three new participant populations and testing environments. Also, rather than running 40 trials per participant, 30 trials were used to alleviate the physiological accommodation observed in some participants in the first two experiments.

Participants. Forty-seven volunteers were recruited from staff and visitors to Interval Research Corporation, Palo Alto, CA, and from participants at seminars held in Port Antonio, Jamaica, and Esalen Institute in Big Sur, CA.

The test environment at Interval Research was described in Experiment 2. The test environment for trials collected in Jamaica was in a closet in a small cottage next to the ocean. The lights were turned off and there were no windows nearby, so the room was dimly lit. Participants sat in a straight-back chair in front of a laptop PC screen. The test environment at Esalen Institute was a bedroom in a house overlooking the ocean. Window shades in the room were drawn, dimming ambient illumination. Participants sat in a straight-back chair in front of a laptop screen. At Esalen, the atmosphere was moderately humid and the temperature was about 75°F. In Jamaica, the atmosphere was very humid and the temperature was about 85°F.

Procedure. Trials contributed at Interval were conducted on a 300 MHz desktop PC; the other trials were run on a 233 MHz laptop PC. In both cases the Windows NT4.0 operating system was used. The physiology equipment used was a J&J Engineering Model I-330C2 (six channel, battery-powered, psychophysiological monitor with 12-bit resolution, measuring SCL in the range 1 to 100 μS with an accuracy of ±0.5%, using the constant current method with 2.5 μA for excitation). Electrodermal measurements were continuously collected at 10 Hz for the duration of the session, including between trials. The program used a 6-second pre-stimulus period, in contrast to the 5-second period used in Experiments 1 and 2.

A new controlling program was written for this experiment in Microsoft Visual C++ 5.0. The program allowed use of either the C++ PRNG or a noise-based truly random number generator (RNG) to select the targets. All trials run at the Interval office used an Orion RNG (ICATT interactive media, Amsterdam, The Netherlands). The Orion is an electronic noise-based, truly random generator that passes Marsaglia's Diehard test, a gold-standard randomness testing suite (Marsaglia, no date). All trials run in Jamaica and Esalen used the C++ PRNG. Targets were selected by re-seeding the PRNG with the computer system's clock (with 1 millisecond resolution) or by sampling from the true RNG, immediately before the stimulus picture was displayed.

Targets. The target pool consisted of the 80 most calm and the 40 most emotional pictures from the International Affective Picture System (IAPS, Bradley et al., 1993; Ito et al., 1998), where ''calm'' and ''emotional'' were defined by the emotionality ratings (averaged across gender) that accompany the IAPS picture set. In an attempt to further enhance the contrast between the emotional and calm targets, participants wore headphones that played one of 20 randomly selected noxious sounds for 3 seconds during presentation of emotional pictures (i.e., screams, sirens, explosions, etc.). Calm pictures were presented in silence.

The use of a 2:1 ratio of calm to emotional photos would seem to add noise to the analysis of Hypothesis 1 (which is therefore a conservative test), since that analysis sorts targets by their pre-assessed emotionality ratings and splits the

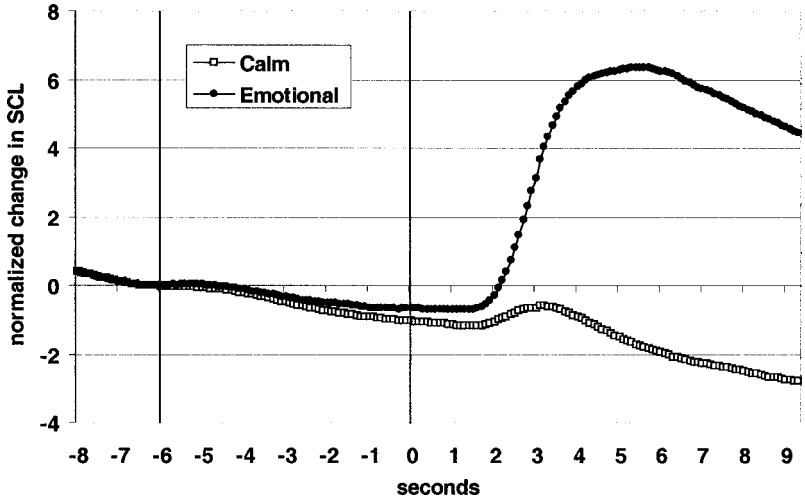

Fig. 4. Average normalized change in skin conductance level (ΔSCL) for calm and emotional trials in Experiment 3. Each trial was initiated at –6 seconds; stimulus onset was at 0 seconds. A total of 1,410 trials were contributed by 47 participants. Randomized permutation analysis indicates that the difference in pre-stimulus curves is associated with $z = 3.34$, $p = 0.0004$ (one-tailed).

data into *two* equal subsets. But in practice, people show strong idiosyncratic responses to photos, and this significantly blurs a nominal dichotomy into a continuous scale of emotionality. Thus, splitting the trials into two equal subsets does not introduce as much noise as one might expect.

Results. Figure 4 shows the results of Experiment 3. In this study because data were recorded continuously, it was possible to evaluate and graph ΔSCL values before the trial-initiating button press. This graph shows that mean ΔSCL levels were indistinguishable before the button press, but as in the two previous studies the signals began to differentiate according to the future stimulus starting immediately after the trial began ($p = 0.0004$).

Experiment 4

Participants. Participants in this study were recruited from visitors to the Boundary Institute, Los Altos, CA. The test environment was similar to that at Interval Research except that the controlling computer was a 300 MHz laptop PC. All tests were conducted in an office where participants sat in an office chair in front of the laptop at a desk. The office lights were turned off and a window was shaded by miniblinds. The office was air conditioned to about 72°F and humidity levels were comfortably moderate.

Procedure. The physiological equipment was an experimental eight-channel SCL monitor custom-designed by a team at Interval Research Corporation (the device used the constant current excitation method at 2.5 μA and had 16-bit

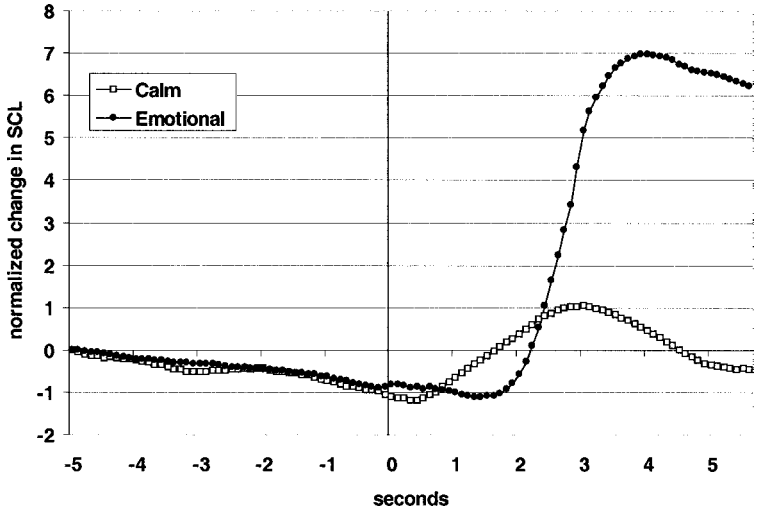

Fig. 5. Average normalized change in skin conductance level (ΔSCL) for calm and emotional trials in Experiment 4. A total of 240 trials were contributed by six participants. Randomized permutation analysis indicates that the difference in pre-stimulus curves is associated with $z = 0.59$, $p = 0.28$ (one-tailed).

resolution). Software drivers for the device were written at Interval Research Corporation in Microsoft Visual Basic 5.0; the experiment itself was written in Visual Basic 5.0 by the author. SCL measurements were continuously collected at 10 Hz for the duration of the session. The experimental design employed a 5-second pre-stimulus period.

The SCL electrodes were also custom-made. Each electrode consisted of a gold dot, 10 mm in diameter, deposited on a flexible printed circuit board material. Two such electrodes were attached to the first two fingers without electrode paste, using a Velcro fastener. The experimental electrodes and the physiological monitor were designed with the goal of eventually creating an inexpensive research package that would allow independent investigators to easily and quickly conduct replications of the presentiment experiment. This goal was eventually abandoned because it was felt that if positive evidence for presentiment were obtained using these devices, it would be criticized on the basis that the data were collected using non-standard equipment and electrodes.

Targets. As in Experiment 3, the IAPS photos were used, but in this case the targets were selected uniformly at random, with replacement, from the entire set of some 700 IAPS photos (the size of the IAPS pool changes with each new update). Targets were selected by the Visual Basic 5.0 PRNG based on the system clock time immediately after the last SCL sample of the pre-stimulus period had been collected.

Results. Figure 5 shows the results of Experiment 4. Note that unlike the previous three experiments, this study showed a positive post-stimulus response

TABLE 1
Informational Summary of the Four Experiments

Experiment	Location	Trials	Participants	Trials/ Session	Targets	EDA Measure	Equipment
1a,c	UNLV	860	24	20 or 40	120 custom	Conductance	J&J 1330
2	UNLV & IRC	2,059	56	30 or 40	150 custom	Conductance	J&J 1330
3a	IRC	570	19	30	IAPS	Resistance	J&J 1330C2
3b	Esalen	180	6	30	IAPS	Resistance	J&J 1330C2
3c	Jamaica	660	22	30	IAPS	Resistance	J&J 1330C2
4	Boundary	240	6	40	IAPS	Resistance	Custom
Total		4,569	133				

not only for emotional trials, but also for calm trials. As postulated by Hypothesis 2, the weak contrast between post-stimulus calm and emotional trials may have accounted for the weak differential results observed in the pre-stimulus period ($p = 0.28$).

General Results

Table 1 summarizes key elements of the four experiments. In Experiments 1a and 1c a total of 900 trials were run, but the file containing data from one session of 40 trials was corrupted, so a total of 860 trials were available for analysis. In Experiment 2, fifty people contributed 40-trial sessions at UNLV and six people contributed 30-trial sessions at Interval Research Corporation. A small number of trials did not record properly, leading to a total of 2,059 usable trials. Most of the failures were due to one of the SCL electrodes spontaneously breaking contact with the participant's skin; others were due to equipment failures possibly caused by power spikes or by the PC's operating system freezing for unknown reasons. With use of new physiological equipment, uninterruptible power supplies, and newly designed software, all sessions run in Experiments 3 and 4 were recorded properly and all data were analyzable.

Table 2 shows the results of testing Hypothesis 1 for each experiment, for the three replication experiments combined, and for all four experiments combined. The original experiment produced a significant effect size of $e = 0.100$, $p = 0.002$. The three replication experiments resulted in a combined effect size of about half that magnitude, but with four times as many trials it was statistically more significant, $e = 0.049$, $p = 0.001$. Over all four experiments, the combined effect size was $e = 0.060$, $p = 3 \times 10^{-5}$. The overall mean weighted effect size (weighted by number of trials per experiment) was $e = 0.064 \pm 0.015$, $p = 1.3 \times 10^{-5}$.

Post-Stimulus Responses

Figure 6 shows the weighted mean effect size (weighted per number of trials) for both pre-stimulus and post-stimulus ΔSCL data combined across the four

TABLE 2
Results of Experiments

	E1	E2	E3	E4	E2–4	E1–4
z	2.92	1.23	3.34	0.59	2.98	4.04
N	860	2059	1410	240	3709	4569
p	0.002	0.11	0.0004	0.28	0.001	0.00003
e	0.100	0.027	0.089	0.038	0.049	0.060

Note: Results of each experiment (E), experiments 2–4 combined, and all four experiments combined, in terms of z score, number of trials, p value, and effect size, e.

experiments and for emotionality contrasts ranging from 1% to 50%. As a measure of post-stimulus activity, the sum of ΔSCL values from 2.5 to 3.5 seconds after stimulus onset was used.

At the 50% emotional vs. calm contrast level (i.e., Hypothesis 1) the post-stimulus effect size was more than 20 standard deviations from chance. For Hypothesis 2, the post-stimulus effect size was observed to peak at the 5% emotionality contrast and then decline with increasing percentage. And for Hypothesis 3, the expectation that more emotional targets would result in larger post-stimulus EDA was confirmed with the correlation $r = 0.28$, $t = 19.7$, $N = 4{,}569$, $p \approx 0$. The strong positive effect size for post-stimulus ΔSCL indicates that an orienting response was observed as expected for emotional stimuli.

Pre-Stimulus Responses

What is unexpected is that the weighted mean effect size for *pre*-stimulus ΔSCL was significantly above zero for all levels of emotional contrast beyond 5%. To explore whether these results were possibly driven by a few outliers, an analysis was performed based upon the *median* values of pre-stimulus ΔSCL, rather than the sum. This resulted in an overall mean weighted effect size $e = 0.049$, about 2.9 standard errors above chance, and an unweighted Stouffer Z score $= 3.31$ ($p = 0.0005$). This indicates that the observed results are not due to outliers, but reflect a generalized phenomenon.

The peak weighted effect size of $e = 0.23$ at a 1% contrast was 2.2 standard errors above chance, but given the 50 overlapping and therefore dependent statistical tests, this is not a particularly persuasive result. The next highest peak of $e = 0.15$ at an 8% emotional contrast level was 4.05 standard errors above chance, which is more interesting. The weighted mean effect size then declines to $e = 0.06$ at the 50% contrast. Thus, in accordance with Hypothesis 2, higher emotional contrasts did seem to result in higher differential effects.

As the most general test, Hypothesis 3 predicted a positive correlation between the pre-assessed emotionality ratings vs. pre-stimulus ΔSCL levels. The resulting correlation was small in magnitude, but as predicted it was

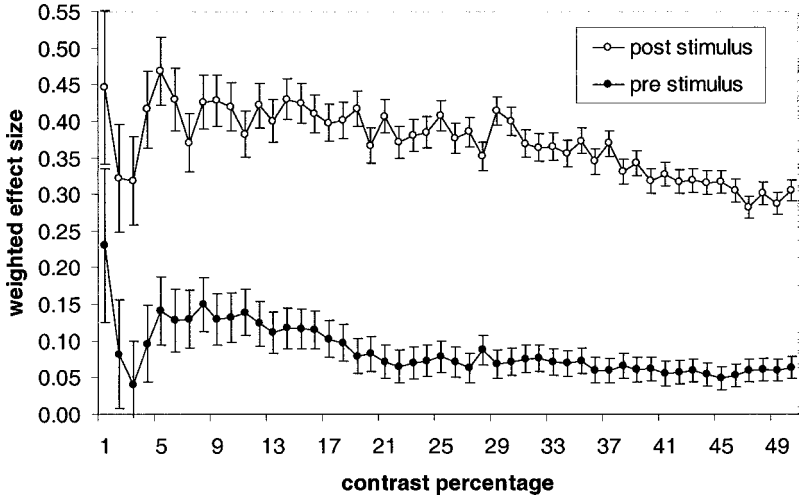

Fig. 6. Weighted mean effect size and one standard error bars for post-stimulus and pre-stimulus ΔSCL, in terms of emotional contrast percentage. An emotional contrast percentage of 1% represents those trials with the most emotional 1% and most calm 1% of the trials, or 2% of all available trials. The 50% contrast level includes all trials.

significantly positive: $r = 0.04$, $t = 2.42$, $N = 4{,}569$, $p = 0.008$. Support for Hypothesis 3 indicates that prior to viewing randomly selected emotional photos, participants' autonomic nervous systems not only responded more than before calm photos, but responded more *in proportion* to the independently assessed emotionality levels of the future stimuli.

In individual experiments, for Experiment 1 $r = 0.04$, $t = 1.28$, $N = 860$, $p = 0.10$. For Experiment 2, $r = 0.03$, $t = 1.29$, $N = 2059$, $p = 0.10$. For Experiment 3, $r = 0.05$, $t = 1.93$, $N = 1{,}410$, $p = 0.03$. And for Experiment 4, $r = -0.02$, $t = -0.34$, $N = 240$, $p = 0.64$.

Discussion

Alternative Explanations

Commonly proposed alternative explanations for the observed results include (1) sensory and statistical cues about the upcoming targets; (2) data collection, measurement, and/or analytical artifacts; (3) selective reporting biases; (4) participant or experimenter fraud; and (5) conscious or unconscious anticipatory strategies. All of these factors were considered in the process of designing and running these experiments. Each explanatory category is addressed in turn.

Sensory or statistical cues. If the computer's hard disk retrieved the target photo immediately after the button was pressed to begin a trial, and if the calm targets differed from the emotional targets either in terms of where they were

located on the disk or their size, then the participant might have learned to associate the computer's hard disk sounds with different upcoming targets. To avoid such possibilities, in all experiments the targets were not retrieved off the hard disk until immediately before they were displayed. Also, recall that in Experiments 2 through 4 the targets were not even selected until immediately before they were displayed. In short, the software in all of these experiments was designed to ensure that there were no differences in sounds, displays, or other physical cues until just before the target was displayed. Given that evidence for presentiment effects in these studies began 5 to 6 seconds prior to the stimulus, sensory cues are not a viable explanation.

Statistical cueing might occur if the sequence of targets was non-random. To circumvent this possibility, first the PRNGs and true RNG used in these experiments were checked for sequential randomness before they were used, and all proved to be adequately random under long-term calibration conditions. Second, the majority of participants in these tests ran a single session of 20 to 40 trials, an insufficient number of trials for most people to learn sequential biases, unless the biases are extreme. And third, examination of the actual sequence of targets used in these experiments showed that the autocorrelations to lag 15 were all in alignment with chance expectation.

Hardware, software, and analytical artifacts. To avoid the possibility that any given implementation of the experiment might have introduced hardware or software-specific artifacts, three different physiological monitoring systems, three software programs and PC operating systems, many different computers, and four types of random number generators (three PRNGs and a true RNG) were employed to provide replications using different experimental setups.

In all experiments, the software was designed to ensure that the physiological data representing the pre-stimulus period were already recorded in the computer's memory before the target was selected (Experiments 2–4) or displayed (all experiments). The software in all experiments marked the SCL data in real-time with the current condition of the test (i.e., pre-stimulus, stimulus, or post-stimulus) to ensure correct synchronization with external events. As a result, the hardware, software, and data collection mechanisms used in these experiments are unlikely to be sources of systematic bias that could explain the observed results.

To avoid possible violations of distributional assumptions associated with parametric statistical tests, nonparametric randomized permutation analysis was used to evaluate the results.

Selective reporting. Because results similar to those presented here can undoubtedly be mimicked by carefully selecting data, special care was taken to analyze all available trials in all of the author's presentiment experiments conducted so far. The only data excluded were 280 trials from Experiments 1b and 1d, since they were collected with different experimental designs or intentions, and in any case both of those experiments had produced positive effects (Radin, 1997).

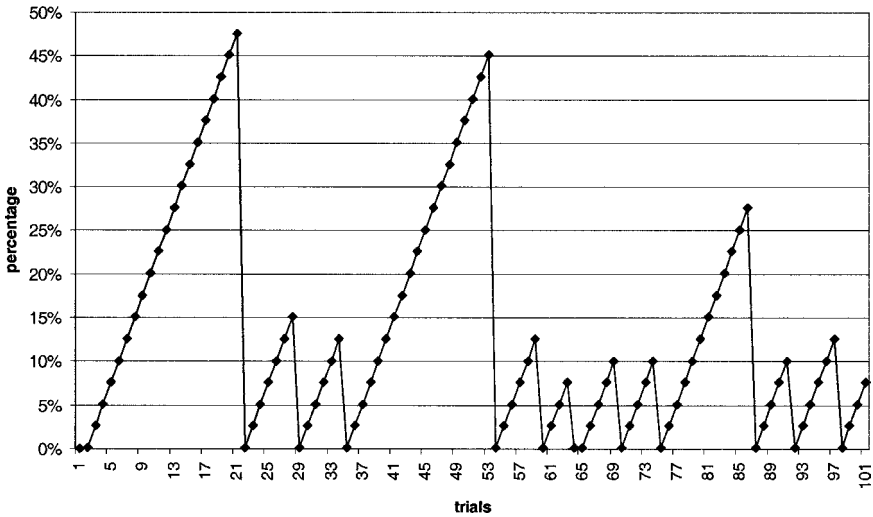

Fig. 7. Simulation of an idealized anticipatory strategy. The *y*-axis is the degree of autonomic arousal, the *x*-axis is successive trials. The top of each "arousal" ramp represents an emotional trial; all other trials are calm.

Participant or experimenter fraud. Participant fraud would have been difficult to perpetrate in this experiment. If P had tried to tamper with the equipment after the experiment began, the physical movements would have been detected by the physiological monitor as large, sustained artifacts. No such artifacts were evident in the data. Further, P had no access to the equipment in advance of or after experimental sessions, and P typically ran a single session. So it would have been difficult to arrange for more sophisticated forms of tampering. If P had described her experience to another P who was going to run the test later, it is conceivable that the second P might exhibit higher overall sympathetic arousal due to advance knowledge about the photo stimuli, but that could not explain the differential effect observed in these experiments. The question of experimenter fraud can only be resolved through successful independent replications, which are now available.

Anticipatory strategies. This is the most common and *prima facie* the most plausible conventional explanation for the observed effects. The idea assumes the use of an experimental design with dichotomous stimuli: emotional vs. calm, or stimulus vs. no stimulus. With such a design, it is conceivable that on sequential trials the participant's EDA would increase with each successive calm trial, since anticipation would keep increasing until the emotional trial appeared. Thus, EDA would peak on the emotional trial and then reset back to zero on the next trial, as illustrated in Figure 7.

If this strategy were followed either consciously or unconsciously, then EDA averaged across all emotional trials would be higher than EDA averaged across

calm trials. Simulation and analytical studies have confirmed the existence of this bias (e.g., Dalkvist et al., 2002; Wackermann, 2002). The same simulations also show that with longer sessions, or after pooling trials across many participants, that these biases can become vanishingly small.

Anticipatory simulation studies are valuable in highlighting worst-case scenarios, but they also oversimplify what actually occurs in these experiments. For example, as previously mentioned, people's idiosyncratic responses to photos inevitably blur the dichotomous distinction between calm and emotional targets. A more realistic anticipatory simulation might use targets with a continuous range of emotionality, and it would adjust the arousal value for trial $N + 1$ up or down according to the emotionality rating of trial N.

But idealized simulations and strategies aside, we can investigate whether anticipatory strategies can explain the observed results by examining the actual data. To do this, data from Experiments 2 and 3 were pooled; this provided a set of 3,469 trials, contributed by a total of 103 participants. The pre-stimulus sums of ΔSCL (i.e., $\sum\Delta$SCL) prior to stimulus onset in each of the two experiments were normalized separately and then combined.[3] Then the targets were separated into two classes: *emotional*, defined as those trials with the top 26% emotionality ratings, and *calm*, defined as those 74% with lower emotionality ratings. These percentages were selected to create about a 1:3 ratio of emotional to calm targets to ensure that there would be an adequate number of calm targets in a row to test the expectations of an anticipatory strategy. Based on this definition of emotional and calm targets, 13 of the 103 participants were identified who independently obtained significant ($p < 0.05$) emotional vs. calm differences in their pre-stimulus responses. Together these people contributed a total of 450 trials, and as a group they represented (by selection) extremely strong evidence for presentiment.

An anticipatory strategy supposes a positive trend between the number of calm trials before an emotional trial vs. $\sum\Delta$SCL for each of those trials, as illustrated in Figure 7. Note that this trend, which can be evaluated with a simple linear correlation, cannot include the emotional trial itself, since that would confound testing an anticipatory strategy with a genuine presentiment effect.

Figure 8 shows the observed means of $\sum\Delta$SCL for calm trials 1 to 13 steps before an emotional trial, and for the emotional trial itself (the ''0'' point on the *x*-axis), with one standard error bars. The error bars become progressively smaller because the number of sequential calm trials before an emotional trial decreases with the number of total trials. For example, there are many more cases of say, the sequence C–E (one step away) than there are of the sequence, C–C–C–C–C–E (five steps away).

The weighted linear correlation between mean $\sum\Delta$SCL and trial number for steps $13 \rightarrow 1$ was positive, but not significantly so ($r = 0.29$, $p = 0.17$). Notice that with one exception, all of the mean $\sum\Delta$SCL values prior to the emotional trial were *negative*, and three were significantly negative, including the trial immediately preceding the emotional trial. Thus, contrary to the expectations of

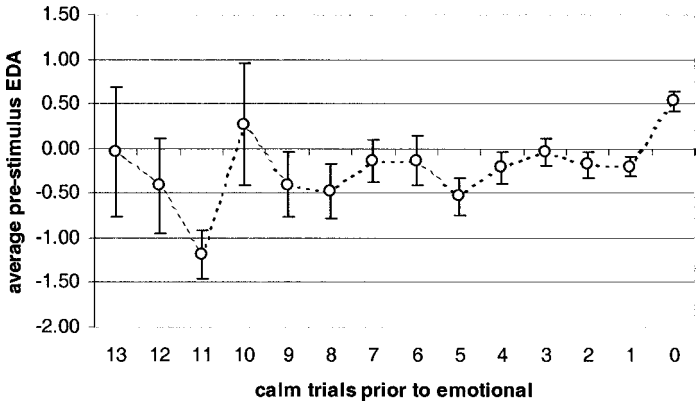

Fig. 8. Average $\sum\Delta$SCL, and one standard error bars, for up to 13 calm trials prior to an emotional trial (at 0), for 13 participants in Experiments 2 and 3, each of whom showed an independently significant presentiment effect.

an anticipatory strategy, a subset of participants specifically selected for exhibiting strong differential results suggestive of a genuine presentiment effect showed *relaxation* responses before the emotional target rather than progressive arousal. In sum, while idealized anticipatory strategies might provide an explanation of the observed results in principle, the actual data did not indicate that such strategies were employed.

Sociological Aside

While working at Interval Research Corporation, I was asked to arrange for an independent critical evaluation of the methodology and results of Experiment 3. Because assessments of controversial evidence tend to differ depending upon whether opinions are presented in public or in private, to encourage an unbiased review it was agreed in advance that the identities of the reviewers and the specifics of their written reports would remain confidential.

Six experienced scientists were identified to conduct the review. Three were sympathetic to the possibility of precognition, and three were skeptical. The group's expertise included statistics, experimental psychology, personality and cognitive psychology, psychophysiology, computer science, and physics. The reviewers unanimously agreed that they could not identify any methodological flaws that could explain the observed outcomes. However, their personal opinions about whether the data persuasively demonstrated precognition fell into close alignment with their *a priori* beliefs about the possibility of precognition. This outcome demonstrated one of the key difficulties encountered when trying to achieve scientific consensus about controversial ideas, especially ideas that are not yet supported by well-accepted theories. Members of the Society for Scientific Exploration are undoubtedly familiar with this syndrome.

Conclusions

Four double-blind experiments, using different hardware and software implementations, subject populations, environmental conditions, and photographic stimuli, explored the possibility that some intuitive hunches, as reflected by fluctuations in the autonomic nervous system, may involve unconscious perception of future experiences. Overall the experiments supported this idea. Consideration of alternative explanations suggests that the observed effects were not due to known artifacts. It is tempting to speculate about possible theoretical explanations for these effects, especially the possibility that presentiment may be one way that the time-symmetries pervading fundamental physics manifest in human experience. But further speculations will be reserved for future publications.

Notes

[1] Temperature and humidity levels are reported because those factors are known to affect electrodermal responses, and this information may prove to be useful in future replications.

[2] To demonstrate that the QuickBasic 4.5 PRNG used in this experiment did not introduce an artifactual relationship between the physiological state and the resulting target photos, the PRNG was seeded with a number ($N = 1$), and then used to generate one random number from 1 to 150, using the same programming code as employed in the experiment. This created a seed-number, target-number pair. This process was repeated for seed-numbers $N = 2$ to 5000, and then a correlation was determined between the resulting pairs. If the seed-number was associated with the resulting target selection, then a positive correlation would be predicted. But no such relationship was found, $r = 0.0007$, $p = 0.96$, two-tailed.

[3] The reason for the normalization was that the pre-stimulus ΔSCL values were formed by summing the change in normalized SCL over all samples in the presentiment period, and given that the sampling rates in Experiments 2 and 3 were different (5 Hz and 10 Hz, respectively), those sums were different.

Acknowledgements

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