

Psychophysiological Evidence of Possible Retrocausal Effects in Humans

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Abstract. If the human nervous system operates exclusively according to conventional causal assumptions, then one's physiological status before exposure to a randomly selected stimulus should not depend on the nature of that stimulus. However, if meaningful dependencies are observed it would suggest that some aspect of the nervous system is sensitive to the future, implying a possible retrocausal effect. To test this idea, a series of double-blind experiments were conducted to investigate whether pre-stimulus physiological measures were meaningfully related to post-stimulus responses. Skin conductance levels of individuals were recorded before, during and after exposure to randomly selected calm or emotional pictures. Results showed that pre-stimulus skin conductance levels prior to the stimuli showed a differential response (131 participants, 4,569 trials, $p = 0.00006$, two-tailed), consistent with a retrocausal phenomenon. In another experiment, participants viewed a randomly determined light flash or no flash while their brain electrical potentials were being monitored. Slow cortical potentials in 13 females differentiated significantly before stimulus onset ($p = 0.007$, two-tailed). Numerous conventional explanations for these observations were examined and rejected as implausible, and these experiments have been successfully replicated by several independent investigators. Collectively these studies challenge the assumption that human psychophysiology can be adequately modeled solely by unidirectional causal processes.

Keywords: retrocausation, time reversal, autonomic nervous system

PACS: 11.30.Er , 11.30.-j

INTRODUCTION

Most physical models of macroscopic systems, regardless of how complex those systems may be, assume that observed behavior can be completely understood in ordinary causal terms. Human anticipatory behavior is likewise commonly assumed to be explainable as a sequence of cause-effect processes [1-2].

In spite of these assumptions, people throughout history have reported intuitive hunches about future events that later turned out to be correct. Many such hunches can be adequately explained by psychological factors such as unconscious inference, coincidence, selective memory, and forgotten expertise. But occasionally a hunch turns out to be valid, and yet seems so intrinsically unlikely, that one wonders whether such experiences might involve perception of genuine information from the future.

Two classes of laboratory experiments have been conducted to investigate what might be called *presentiments* of future events. The first class involves consciously guessing the outcomes of randomly generated future stimuli. Most tests involving conscious reports have been based upon a forced-choice design in which a person is

asked to pick which one of say, four lamps, will be selected by a truly random process after the person's choice. Meta-analysis of 309 forced-choice experiments published from 1935 to 1987 provides independently repeated evidence for conscious presentiments that is statistically far beyond chance expectation [3].

The second class of experiments involves unconscious measures. One variation examines event related potentials in the brain while a person views a series of visual targets, one of which will be selected randomly in the future. In a series of such experiments, evoked responses before correct selection of future targets were found to significantly differ from evoked responses before incorrect selections [4-6]. Similar experiments have reported significant differences in heart rate while viewing one of a set of images that was later randomly selected as the target [7].

In a simpler form of this experiment, physiological factors before dichotomous stimuli are monitored to see whether the nervous system unconsciously discriminates between randomly selected future events. Physiological measures in these experiments have included skin conductance level [8-15], non-specific skin conductance response (i.e., spontaneous fluctuations in skin conductance level) [16-17], heart rate [13-14], event related electrical potentials in the brain [13-14], slow cortical potentials in the brain [18-21], and blood oxygenation levels in the brain [22]. Dichotomous stimuli in these studies have included emotional vs. calm pictures, stylized happy vs. sad faces, light flashes vs. no flashes, and audio startle tones vs. silence. In some of these studies participants initiated trials of fixed time lengths, in others stimuli appeared spontaneously at random times. The majority of these experiments have reported statistically significant evidence for presentiment.

This paper summarizes the design and results of simple dichotomous experiments conducted by the author involving measurement of skin conductance levels and (with E. Lobach) slow cortical potentials in the brain.

SKIN CONDUCTANCE EXPERIMENTS

A participant is asked to sit in a chair in front of a color computer monitor showing a blank screen. After describing the nature of the study and obtaining informed consent, the experimenter attaches surface electrodes (Ag-AgCl, 8mm diameter) to the index and second fingers of the non-dominant hand to record skin conductance level (SCL). A Velcro band secures the electrodes, and an isotonic skin conductance electrode gel is used to improve electrical contact with the skin. Skin conductance is monitored by a computer-controlled physiological data acquisition system providing digitized SCL from 5 to 10 samples per second (systems used included J&J Instruments Model I-330, Model I330-C2, and a custom-designed device). The experiment is automatically controlled by a PC to provide a double-blind protocol in which both the participant and the experimenter are blind to the future stimuli.

When ready to begin each trial, the participant simply presses a mouse button. The screen remains blank for 5 seconds, the PC then randomly selects 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 (Fig. 1). After the 10 second cool-down period, a message appears on the screen instructing the participant to begin the next trial at will.

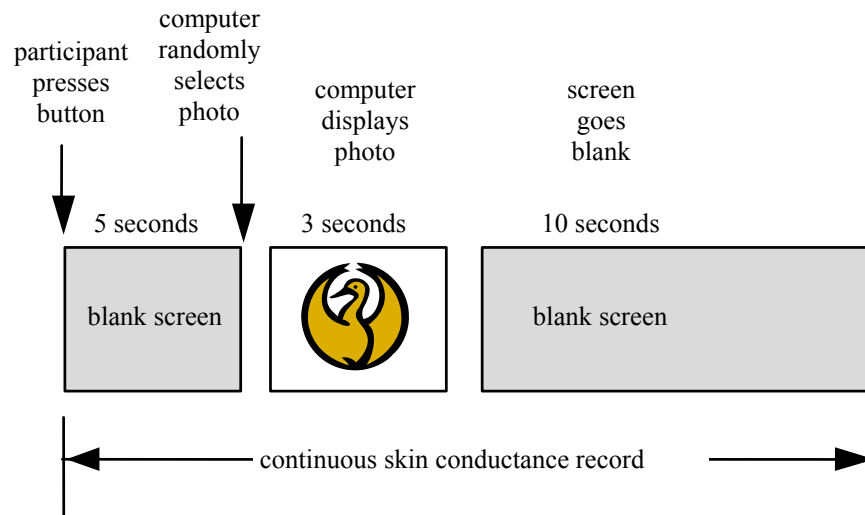


FIGURE 1. Illustration of basic experimental procedure.

The experimenter coaches the participant through one trial to ensure that he or she understands the procedure, and then the participant runs the remaining trials alone. The first demo trial is not used in the final data analysis.

Target Stimuli

Calm targets include photos of neutral or calming scenes, including landscapes, nature scenes, and people. Emotional targets include scenes with erotic, violent, or accident content. The photos in various versions of this experiment came from stock professional photographs, web-based photo archives, and the International Affective Picture System, the latter developed for the National Institutes for Mental Health as a tool for studying emotional responses [23]. All of the photos used in these studies were viewed by teams of independent judges to provide average subjective emotionality ratings for each photo.

Hypotheses

The presentiment hypothesis postulates that future, non-inferable experiences unconsciously influence our present physiological state. This predicts that changes in SCL before emotional photos will be greater than similar measures before calm photos. To test this idea, trials are partitioned into sets of emotional and calm trials based on the pre-assessed average emotionality ratings of each photo. After collecting many trials, the resulting difference in mean pre-stimulus SCL values is assessed using a nonparametric statistic (randomized permutation analysis [24]).

In a more general sense, presentiment predicts that pre-stimulus changes in the autonomic nervous system would fluctuate *in proportion* to the emotionality of the future stimulus. To test this, a Pearson correlation may be examined between the pre-assessed emotionality ratings and the pre-stimulus changes in SCL.

Method of Analysis

Each SCL sample in each trial is first normalized as $z_{in} = (x_i - \mathbf{m})/s$, where \mathbf{i} is the sample number within trial \mathbf{n} , x_i is the SCL value for sample \mathbf{i} , \mathbf{m} is the average of all samples in the pre-stimulus period in trial \mathbf{n} (i.e. from the starting button press to just before stimulus onset), and s is the standard deviation of all samples in the pre-stimulus period. All normalized trials contributed by all participants across all sessions are then clamped to the baseline SCL value at stimulus onset, as $s_{in} = (z_{in} - z_{0n})$, where z_{0n} is the first data sample after the button press in trial \mathbf{n} , and \mathbf{i} ranges across all samples in the epoch.

This analysis is thus based on *changes in normalized SCL* (Δ SCL). Normalized SCL is used rather than absolute SCL because in an analysis that combines data across subjects a few participants with high magnitude or high variance SCL could otherwise strongly overwhelm the majority of data from other, less labile participants. To determine the statistical likelihood of differences observed between pre-stimulus emotional and calm trials, a randomized permutation analysis was used, as followed:

1. The value $S_n = \sum s_{in}$ is determined for each trial \mathbf{n} , where the sum is taken over all pre-stimulus Δ SCL samples \mathbf{i} in the epoch, starting at the initiating button press and ending just before stimulus onset.
2. All trials across all sessions are then sorted by each trial's pre-assessed emotionality ratings, in ascending order.
3. The top half of the sorted list in step 2 is defined as calm trials and the bottom half as emotional trials.
4. The difference $\mathbf{D} = \sum S_E - \sum S_C$ is determined, where E indicates the emotional trials and C the calm trials.
5. The order of the emotionality ratings is randomly scrambled and steps 2 through 4 repeated 1,000 times, each time keeping track of the new value for \mathbf{D} . These randomized permutations are used to generate a distribution of \mathbf{D} values from which a mean and standard deviation are formed.
6. A standard normal deviate $z = (\mathbf{D} - \mu_D) / \sigma_D$ is calculated to assess the statistical likelihood of the observed difference \mathbf{D} , where μ_D is the mean and σ_D the standard deviation of the randomized \mathbf{D} values formed in step 5.

Results

In the first experiment a total of 24 volunteers contributed 860 trials. SCL after an emotional stimulus is expected to rise sharply about 2 to 3 seconds after the stimulus; this response is evident in Fig. 2. This also confirms that the physiological monitoring equipment was operating correctly. SCL after calm stimuli also rose slightly due to release of anticipation. Of principal interest is that the pre-stimulus levels for calm and emotional trials significantly differed, as predicted by presentiment ($z = 2.92$, $p = 0.002$, one-tailed).

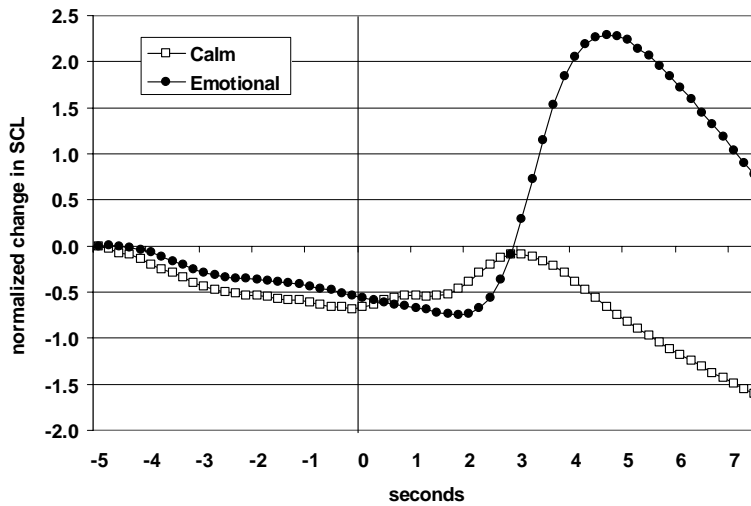


FIGURE 2. Results of the first presentiment experiment involving 24 participants who contributed 860 trials. The ordinate is in terms of mean normalized change in skin conductance level (Δ SCL) for equal numbers of calm and emotional trials. The stimulus photos appeared at 0 seconds on this graph. Randomized permutation analysis indicates that the pre-stimulus Δ SCL for emotional trials was significantly higher than the same measure for calm trials $z = 2.92$, $p = 0.002$, one-tailed.

Following the first study three similar experiments were conducted. They were based on the same design but used different sets of photographs, physiological equipment, computers, operating systems, controlling software, participant populations, and testing environments. Fig 3 shows the results of the third and largest study, which employed a truly random number generator (randomness based on noise from a Zener diode) to select the target photos immediately before stimulus onset, and involved 47 participants who together contributed 1,410 trials.

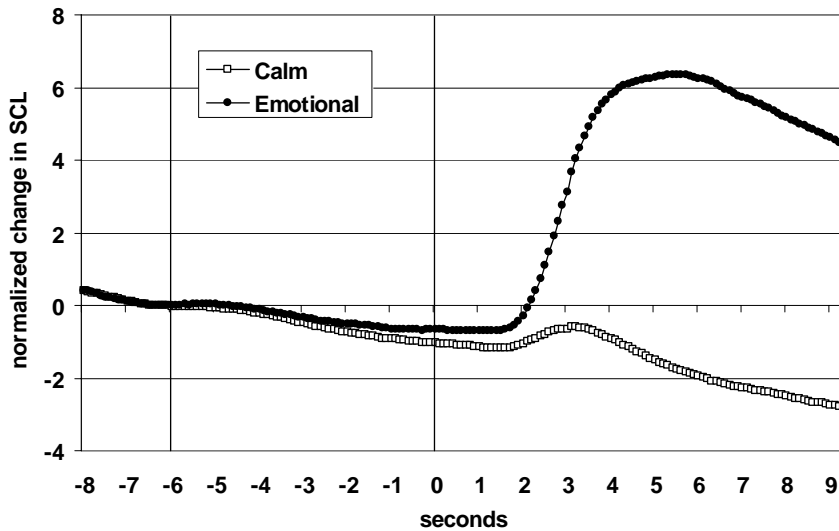


FIGURE 3. Results of the third experiment with 47 participants. The button press to start each trial is noted at -6 seconds, the stimulus appeared at 0 seconds. Randomized permutation analysis indicates that the difference in pre-stimulus curves is associated with $z = 3.34$, $p = 0.0004$, one-tailed.

A Stouffer Z score was used to combine the results across all four experiments, involving 131 participants and 4,569 contributed trials. This resulted in $z = 4.0$ ($p = 0.00003$), confirming the basic presentiment hypothesis. (A Stouffer Z weighted by the number of trials in each experiment resulted in $z = 4.3$.) A test of the relationship between the pre-assessed emotionality ratings vs. the pre-stimulus Δ SCL levels resulted in a significantly positive correlation ($r = 0.04$, $t = 2.42$, $N = 4,569$, $p = 0.008$, one-tailed), confirming the general presentiment hypothesis.

Alternative Explanations

Given the surprising nature of this outcome, numerous alternative explanations were examined in an attempt to find artifacts or design flaws that might have accounted for these results. These included:

Sensory Cues. To eliminate the possibility that sensory cues alerted the participant about the upcoming stimulus, the randomly selected target photos were not retrieved off the computer's hard disk until immediately before they were displayed. In addition, in the last three experiments the photos were not even *selected* until immediately before display. Given that SCL began to differentiate in these studies 5 to 6 seconds prior to stimulus onset, sensory cuing is not a plausible explanation.

Statistical Cues. Statistical cueing might occur if the sequence of targets was non-random and could eventually be inferred. To circumvent this possibility, the random number generators used in these studies were checked for sequential randomness before they were used, and all proved to be adequately random under long-term calibration conditions. In addition, the vast 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 those biases are extreme. Statistical evaluation of the actual sequence of targets used in these experiments showed that the autocorrelations through lag ± 10 were in alignment with chance expectation.

Hardware, Software, and Statistical Artifacts. To avoid the possibility that any given instantiation 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 pseudorandom algorithms seeded with truly random numbers and a truly random hardware circuit) were employed to provide conceptual replications using different experimental setups [11]. The software was designed to ensure that the physiological data from the pre-stimulus period was already recorded in the computer's memory or on the hard disk *before* the stimulus was selected (Experiments 2-4) or displayed (all four experiments). The software 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. Finally, to avoid possible violations of 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 presentiment experiments (based on skin

conductance measures) conducted by the author. (In the spirit of full disclosure, 280 trials were excluded from consideration in this paper because they were used in experiments with different designs; in any case both of those experiments produced positive effects [10].)

Anticipatory Strategies. This is the most plausible remaining conventional explanation. This strategy requires a dichotomous design, i.e. one with two distinct stimulus conditions such as emotional vs. calm. With such a design, it is conceivable that the participant's SCL might monotonically increase on each successive calm trial, reflecting the participant's rising anxiety about seeing an emotional photo. SCL would be at a peak when an emotional trial finally appeared, and then it would reset back to baseline on the next trial, reflecting the participant's relaxation based the (gambler's fallacy) assumption that it would be unlikely that two emotional trials would follow each other.

With such a strategy, followed either consciously or unconsciously, then because the emotional trials would always be at the peak of each ramp, SCL averaged across emotional trials would be higher than the SCL averaged across calm trials. Simulation studies have shown that a small bias consistent with this strategy does indeed exist [25]. However, those same simulations also show that upon pooling trials across many participants (the approach taken here) that these biases become vanishingly small.

Besides the simulation results, we can also directly address the plausibility of anticipatory strategies by examining the actual data. To do this, data from two of the SCL experiments using the same physiological hardware and design, consisting of 3,469 trials contributed by 103 participants, were combined to provide a uniform dataset to investigate. Trials were separated into two classes: *emotional* trials were defined as those with the top 26% emotionality ratings, and *calm* as those with the bottom 74% 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 trials in a row to examine the anticipatory strategy. Based on this definition of emotional and calm targets, 13 of the 103 participants were identified, each of whom obtained significant ($p < 0.05$, one-tailed) emotional vs. calm differences in their pre-stimulus responses. Together this group contributed a total of 450 trials, and as a group they represented (by design) extremely strong evidence for presentiment effects.

An anticipatory strategy predicts a positive trend between the number of calm trials before an emotional trial, and the mean Δ SCL value for each of those trials. This trend, which can be evaluated using a simple linear correlation, should not include the emotional trial itself, as that would confound testing the anticipatory strategy model with a presentiment effect.

Fig. 4 shows the pre-stimulus mean Δ 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), along with one standard error bars. Notice that the error bars become progressively smaller because the number of sequential calm trials before an emotional trial decreases with an increasing number of calm trials. For example, there are many more cases of say, the sequence C – E (1 step away) than there are of say, C – C – C – C – C – E (5 steps away).

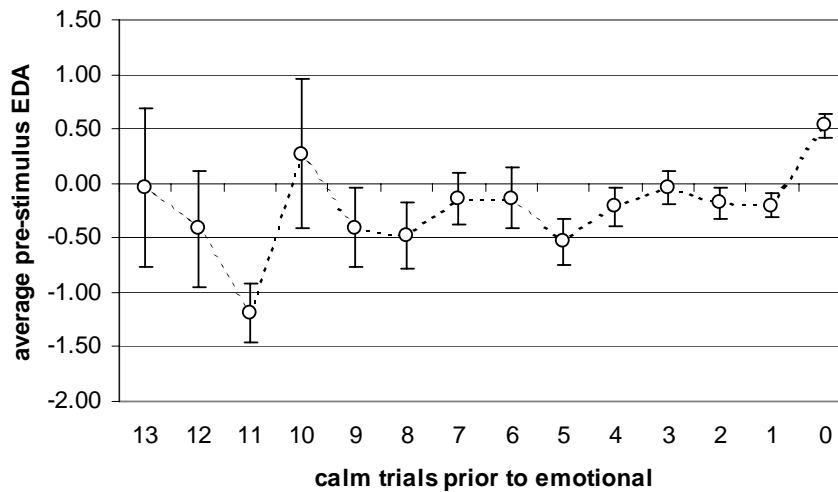


FIGURE 4. Mean Δ SCL (and one standard error bars) for up to 13 calm trials prior to an emotional trial (0), for 13 subjects in Experiments 2 and 3, each of whom showed an independently significant presentiment effect.

The weighted linear correlation for steps 13 \rightarrow 1 is positive, but not significantly so ($r = 0.29$, $p = 0.17$). In addition, with one exception (step 10), all of the mean Δ SCL values prior to the emotional trial were negative. Thus, contrary to an anticipatory strategy, participants selected for their apparently strong presentiment responses actually showed progressive *relaxation* before the emotional target, rather than progressive arousal. In addition, the mean Δ SCL just prior to the emotional trial was significantly negative. These results do not support an anticipatory model.

In sum, these experiments, combined with successful replications independently reported later, suggest that the presentiment effect is not due to known design flaws, hardware or software artifacts, anticipatory cues, or statistical errors.

Slow Cortical Potentials

In reviewing the experimental literature for tests similar to these presentiment studies, I ran across a suggestion made in the 1960s by the British statistician I. J. Good:

A man is placed in a dark room, in which a light is flashed at random moments of time.... The man's EEG (electroencephalogram) is recorded on one track of a magnetic tape, and the flashes of light on another. The tape is then analyzed statistically to see if the EEG shows any tendency to forecast the flashes of light [26].

Good's idea is interesting because slow cortical potentials (SCP) in the brain are commonly used to study the neurophysiology of anticipation [27]. From a neuroscience perspective, anticipation is considered "a state that is characterized by the activation of the brain areas required for the specific upcoming cognitive operations. For instance, anticipation of perceptual input may activate posterior brain areas, anticipation of affective input right frontal areas, and so on" [28]. This anatomical specificity, combined with Good's idea and the previous presentiment

studies, suggested a method to explore possible transtemporal processes underlying anticipatory attention.

In particular, presentiment predicts that SCPs in the visual cortex will behave differently before a light flash than before a no-flash control. Based on earlier results involving apparent presentiment in EEG using picture stimuli [14], this differential effect was predicted to become most evident about one second before the stimulus. To provide a design that avoided multivariate complications, a single EEG measurement was taken over the occipital lobe.

Procedure

Each participant was prepped with three EEG electrodes (Ag/AgCL 8 mm diameter). Electrodes were placed at O_z and both earlobes [29]; the left earlobe used as ground and the right as reference. Connections were tested to achieve minimal impedance (UFI Checktrode® Model 1089e), and then connected to a Biopac EEG-100C amplifier (16 bit resolution, 20,000 gain, 0.1-35 Hz bandpass, Biopac M-150 system). Digitized EEG data were recorded continuously throughout each experimental session at 250 Hz and saved to hard disk.

The participant relaxed in a comfortable chair and wore a pair of visual stimulator glasses (Model VSW-3, A/V Stim, San Rafael, CA). Three bright white LEDs were mounted in these glasses in front of each eye, with one LED positioned laterally towards the outside of the eye, and one above and one below. The stimulator was connected to an analog to digital circuit (Ontrak Control Systems, Sudbury, Ontario, Canada, Model ADR-100) which was in turn connected to a Windows-based computer through a serial port.

While wearing the stimulator glasses, the participant was asked to hold a computer mouse in his or her dominant hand and to press the left button at will. The button press started a timer that waited four seconds, then a truly random number generator (RNG; Orion, The Netherlands) was queried by the computer to decide whether to flash the six LEDs for 250 msec or to remain dark, with $p(\text{flash}) = p(\text{no-flash}) = 0.5$. After the flash or no-flash event, the timer waited another 4 seconds and then the computer sounded a short click tone to signal the end of the epoch, as shown in Fig. 5. The participant then began the next trial at will. Each recording session consisted of 100 trials. Note that during the 4 second period preceding stimulus onset, the stimulus was not yet determined.

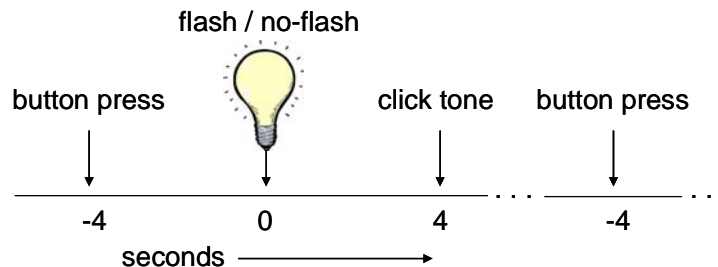


FIGURE 5. Experimental design. A hardware random number generator was sampled immediately before the stimulus to decide whether to flash or not flash the lamp.

After checking that EEG data were being properly collected, that the visual stimulator was operating as expected, and that the RNG passed a rudimentary randomness test for uniform distribution of flash/no-flash conditions, the experimenter placed a flexible, opaque shield around the participant's head to block distractions from ambient lights and movements. Each participant was asked to keep his or her eyes closed throughout the session to reduce eye blink and movement artifacts, and to remain as still as possible during each 8.25-second trial.

Analysis

EEG data were analyzed according to the following steps:

1. To reduce high frequency noise, each test session's EEG record was smoothed with a low-pass filter consisting of a sliding average window 3 samples in length, i.e. each smoothed sample s_i consisted of the average of original samples o_{i-2} , o_{i-1} and o_i . At 4 msec per original sample this provided a sliding average of 12 msec.
2. Epochs ± 1 second from stimulus onset (flash vs. no-flash) in each smoothed EEG record were extracted. If the absolute value of any sample during the pre-stimulus period exceeded $\pm 75 \mu\text{V}$, that epoch was considered to contain a potential movement artifact and was eliminated from further analysis. Selection of this threshold value was based on previous studies investigating SCPs [30].
3. Each epoch passing the artifact threshold in Step 2 was baseline adjusted by taking the difference between smoothed sample 1 (i.e., 1 second pre-stimulus onset) and the remaining 499 samples in each 2-second epoch.
4. An ensemble median curve was calculated for all flash epochs across all sessions, and a similar ensemble median curve calculated for all no-flash epochs. Median was used rather than the mean to provide a nonparametric curve less sensitive to potential outliers.
5. The summed difference between the flash and no-flash curves determined in Step 4 was calculated for the 1-second period pre-stimulus onset. Call this value sum_{pre} .
6. The original order of flash and no-flash conditions was randomly permuted [24].
7. Steps 4 – 6 were repeated 10,000 times, building up a distribution of randomly permuted sum_{pre} values. Call each of these permuted values $\text{sum}_{\text{pre-r}}$.
8. The mean (μ) and standard deviation (σ) of the distribution of $\text{sum}_{\text{pre-r}}$ were calculated, and then $z_{\text{pre}} = (\text{sum}_{\text{pre}} - \mu) / \sigma$ was determined. This z score is a normalized measure of pre-stimulus response. The presentiment concept predicts that z_{pre} would significantly differ from chance expectation; a two-tailed test was employed.

A secondary analysis examined the difference between the maximum deviation of the pre-stimulus median prior to a flash vs. the minimum deviation prior to a no-flash. A permutation method similar to that described in steps 7 and 8 was used to create a normalized max-min score, Z_{mm} .

Procedural control

To check whether hardware, software or analytical procedures might have introduced systematic artifacts in favor of the hypothesis, after the experimental data were collected a second set of 1,000 pre-planned epochs were collected using a “sham brain” (a grapefruit). The same EEG electrodes and visual stimulator glasses were affixed to the sham brain analogously to how they were attached to a human head, and 10 sessions of 100 trials each were run using the same procedures employed in the experiment, with one addition: Instead of a human pressing the button to initiate each epoch, a timer was used to generate a random inter-trial latency, and then the controlling program automatically started each trial.

Results

A total of 20 sessions of 100 trials each were collected. Participants included 13 females (ages 18 to 55) and 7 males (ages 48 to 65). Because of known gender differences in visual processing [31-32], data were evaluated separately for male and female participants. Of the 2,000 trials, 1,925 passed the $\pm 75 \mu\text{V}$ artifact rejection criterion, thus 96% of the data were used in the subsequent analysis. (After the second session the EEG amplifier gain was adjusted and in the last 18 sessions 98.9% of the data were usable.) Among all 2,000 trials, 1,015 were randomly assigned to the no-flash condition and 985 to the flash condition. These stimulus conditions were distributed in accordance with chance expectation ($z = -0.69$ for proportion of flash conditions), as were autocorrelations of the sequence of flash vs. no-flash conditions, calculated through lag ± 50 .

For females, the presentiment hypothesis was supported with $z_{pre} = 2.72$, $p = 0.007$ (all p-values are two-tailed), and $z_{mm} = 3.45$, $p = 0.0006$. For males, the same analysis was weakly negative, $z_{pre} = -1.64$, $p = 0.10$, and $z_{mm} = -1.36$, $p = 0.18$. The gender difference between z_{pre} outcomes was significant, $z = 3.08$, $p = 0.002$, as was the difference for z_{mm} , $z = 3.40$, $p = 0.0007$. Fig. 6 shows the median curves for all 13 females for ± 1 second around the stimulus onset; Fig. 7 shows the same curves ± 5 seconds to show the results in context (with 200 msec smoothing for the sake of clarity). The control test with a sham brain resulted in a nonsignificant difference, $z_{pre} = -1.34$ ($p = 0.18$, with 490 no-flash and 510 flash trials).

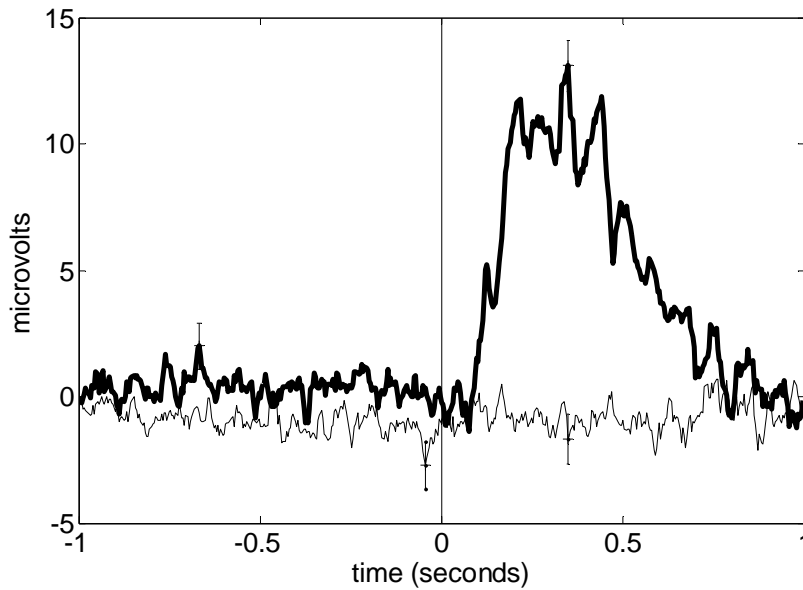


FIGURE 6. Median EEG signals at O_z for the 13 female participants combined, with baseline subtracted one second pre-stimulus (stimulus shown as time 0), and smoothed using a sliding average window of 12 msec. The bold line is the median during flash trials, the thin line is the no-flash control. Error bars are one standard error.

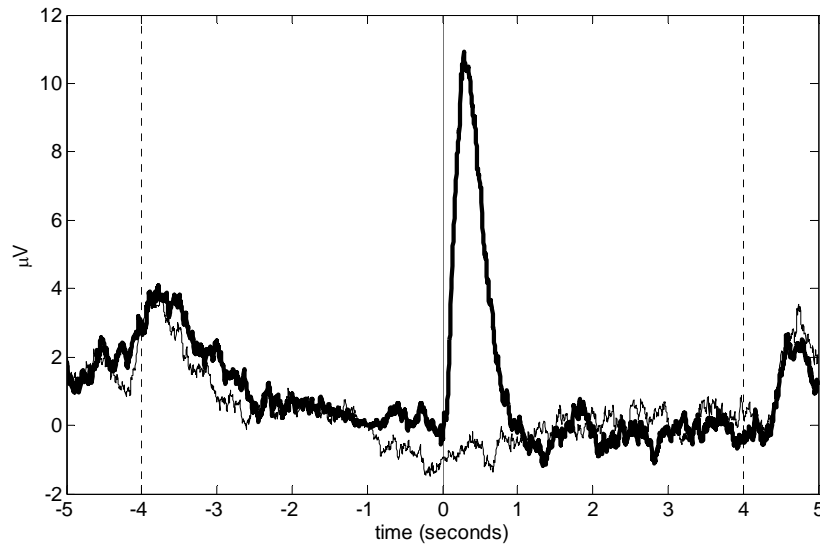


FIGURE 7. Median EEG signals for 13 female participants ± 5 seconds from stimulus onset, with baseline subtracted 1 second pre-stimulus, and smoothed with a sliding average window of 200 msec. The bold line is the median during flash trials, the thin line is the no-flash control. These curves differ slightly from those in Fig. 6 because of the longer smoothing window used to enhance the curve's clarity.

To study the difference in the flash vs. no-flash curves in a simpler fashion, for each trial we determined two directions (rise or fall) that the SCPs could change over the half-second period ranging from -1 to -0.5 seconds pre-stimulus by examining whether SCP at -0.5 seconds pre-stimulus was positive or negative (SCP at -1 second

pre-stimulus was set to 0 by design). Counts within the four possible categories (SCL fall vs. rise by flash vs. no-flash), evaluated for females in a 2×2 contingency table, resulted in a chi-square = 7.25, $p = 0.007$ (see Fig. 9). The same analysis for males resulted in a nonsignificant chi-square = 0.42, $p = 0.51$.

This indicates (for females) that in epochs when nothing happened (the no-flash condition) the majority of SCPs continued to follow a negative trend; this is consistent with a state of continued anticipation (negative SCP is associated with anticipation). By contrast, in epochs where the future contained a light flash, then the majority of SCPs showed a rising trend.

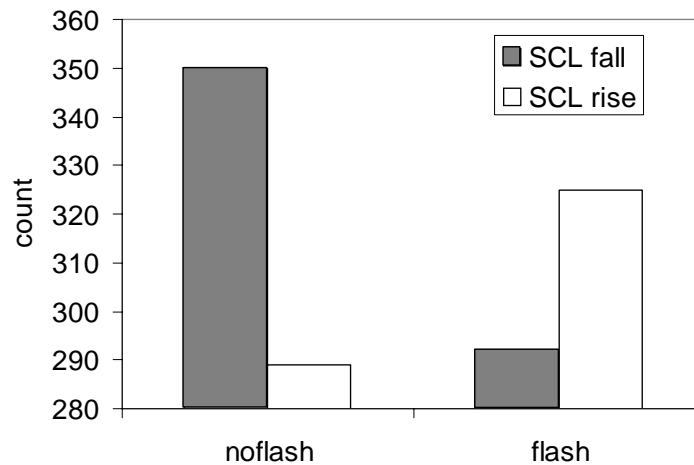


FIGURE 9. There were more trials with SCP falling when the epoch future condition was a no-flash, and more trials with SCP rising when the future condition was a flash ($p = 0.007$).

Alternative Explanations

Most alternative conventional explanations were rendered implausible by the experimental design and controls; others could be evaluated analytically. The former include sensory and expectation cues about the future stimuli, procedural errors, and movement artifacts; the latter includes sensitivity of the results to various analytical parameters.

Sensory cues were not available because the decision to generate a flash or no-flash condition was made by a truly random process immediately before stimulus onset. *Expectation cues* were controlled because the random process selected the two conditions with equal probability ($p = 0.5$), and later analyses showed no biases in the sequence of stimulus conditions. Thus no statistical strategy could have been used to outguess the successive stimuli. *Procedural artifacts* including hardware, software and analytical errors were tested using the sham brain control, and no evidence was observed of systematic bias that might have produced the observed results.

Movement artifacts were moderated by asking participants to keep their eyes closed during the entire recording session and to remain as still as possible during each 8.25-second test epoch. Actually, even if there were movement artifacts in the EEG, to produce the observed results (in the female data) the movements would have had to

occur differentially in accordance with the presentiment hypothesis. To explore whether the observed outcome might have been sensitive to the selected threshold of 75 μV , the analysis was repeated (on the female data) using artifact rejection thresholds ranging from 25 μV to 145 μV in steps of 10 μV . This analysis indicated that the statistical outcome was stable at $z_{pre} \sim 2.5$ for thresholds at or greater than 45 μV , or equivalently for 80% of the data or more.

Another free parameter in this analysis was the selection of the point within the prestimulus period in which to subtract the baseline. We selected one second because observations in previous presentiment experiments suggested that pre-stimulus responses might be time-symmetric with respect to stimulus onset. That is, if a post-stimulus response ends about N seconds after stimulus onset, then the presentiment effect might begin about N seconds *before* stimulus onset. To test the sensitivity of this timing parameter, the female data were re-analyzed by clamping the two curves from -4 seconds to -0.2 seconds before stimulus onset (in steps of 40 msec), and then recalculating z_{pre} for each of these pre-stimulus periods. As shown in Fig. 10, this revealed that the optimal time to detect a presentiment effect was between -1.3 and -0.8 seconds pre-stimulus, and that the effect became increasingly apparent starting about -2 seconds pre-stimulus. This suggests that the effect was not highly dependant on precise timing.

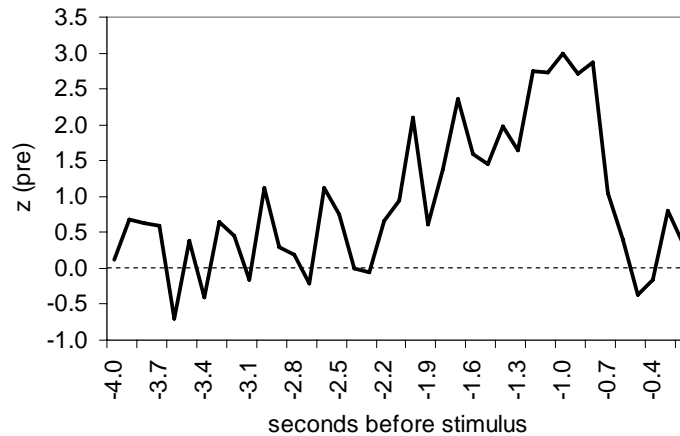


FIGURE 10. Results of z_{pre} score after clamping the median curves from 4 seconds to 200 msec pre-stimulus onset. This shows that the peak presentiment effect occurred about 1.4 to 0.8 seconds before the stimulus.

Could the results have been due to one or two participants who produced unusually deviant outcomes? Ten of the 13 individual female sessions resulted in positive z_{pre} scores, and 6 of the 7 male sessions resulted in negative z_{pre} scores, thus the results were not due to a few deviant sessions.

DISCUSSION

The studies presented here and the cited replications [4-22] suggest that the human nervous system anticipates future events that cannot be sensed or inferred in conventional ways. There are two principal unconventional contenders for interpreting

these outcomes, one “passive” and the other “active.” The passive interpretation proposes that some aspect of the mind/brain is sensitive to events that are about to unfold [17]. This presumably requires that future events must exist in some perceivable form, otherwise there would be nothing available to respond to in the present. The active interpretation suggests that anticipation alters the probabilities of potential future events [35]. Ways of distinguishing between these two possibilities have been proposed [36], but so far theoretical proposals that adequately account for macroscopic time-reversals have lagged behind the accumulating empirical evidence.

One might expect that if these effects are genuine then we would expect to observe them not only in special laboratory tests, or in people who occasionally report verifiable premonitions. They would presumably be ubiquitous, in which case besides presentiment experiments, where else might we find time-reversed effects?

Mainstream literature

Phenomena suggestive of time-reversed effects are occasionally reported in the mainstream psychological and neuroscience literature. The term “precognition” is infrequently mentioned, and then only in apologetic tones, but more often euphemisms are used. These include “exceptional situational awareness,” used to describe the performance of some jet fighter pilots who respond faster than they “should” be able to in combat [37]; “anticipatory systems,” used to describe how biological systems plan and carry out future behavior [38]; and terms like “postdiction” [39], “subjective antedating” [40], “tape delay” [41], and “referral backwards in time” [42], all referring to neurological mechanisms proposed to explain how sometimes we are conscious now of events that actually occurred in the past. An example of the latter is the “color phi” effect described by Dennett [41]:

If two or more small [colored] spots separated by as much as 4 degrees of visual angle are briefly lit in rapid succession, a single spot will seem to move.... What happened to the color of “the” spot as “it” moved? The answer ... was striking: The spot seems to begin moving and then change color abruptly *in the middle of its illusory passage* towards the second location.... (emphasis in the original).

How are we able to fill in the second color spot before the second flash occurs? In Dennett’s words: “Unless there is precognition in the brain, the illusory content cannot be created until *after* some identification of the second spot occurs in the brain” [40]. Dennett goes on to use metaphors such as “tape delays” and “editing rooms” to account for this back-reference. However, as we’ve seen, another possibility is that the common sense notion of unidirectional time-flow is a projected façade built upon a genuine and comparatively simpler time-reversed or time-symmetric reality.

Stroop experiments

If time-reversed effects are pervasive, then they should sometimes be recognized as such, even by scientists who aren’t expecting to encounter them. An example of this is the case of Holger Klintman from Lund University, Sweden. In the early 1980’s, Klintman was conducting a double-blind reaction time (RT) experiment based on a “Stroop task” [43-44].

The Stroop task goes as follows: Imagine a page of color-names printed in colored inks: green, blue, red and yellow. You are asked to read aloud the colors of the color-names as quickly as possible. It is well known that if the ink colors and names match, then the time it takes you to complete the task will be much shorter than if the colors and names mismatch. This differential effect, named after its discoverer, John Ridley Stroop, is a remarkably robust effect that has spawned hundreds of experimental variations [45]. The effect is attributed to cognitive–perceptual interference between the brain’s processing of colors versus color names.

Klintman was interested in improving the sensitivity of his measurements by calibrating each RT with a prior baseline RT. He asked people to first identify the color of a colored rectangle as quickly as possible, and then report (by speaking aloud) whether a subsequent color-name matched or mismatched the color of the rectangle. The initial color identification task was the baseline reaction time (RT1), and the second was a Stroop task (RT2).

To Klintman’s surprise, even though a random number generator determined the match/mismatch condition after RT1 was already recorded, Klintman found that RT1 depended to some extent on RT2. He dubbed this apparent backwards time effect “time reversed interference” (TRI). After conducting five TRI conceptual replications, he concluded that the TRI effect was not an artifact. The combined result for all five of his experiments was associated with $p \sim 10^{-6}$.

A few years later, Camfferman [46] attempted a replication of Klintman’s TRI experiment. His participants saw equal numbers of trials with a color patch followed by a name (“color-name” task), or a name followed by a color (“name-color”), and the order was counterbalanced within participants. He found a significant difference in average reaction times with the color-name task, but not with the name-color task. However, because he also discovered a positive correlation between RT1 and RT2, Camfferman concluded that Klintman’s assumption that RT1 was independent of RT2 was wrong, and that the apparent TRI effects were really due to variations in general alertness than to a time-reversed effect.

While Camfferman’s observation that RT1 and RT2 are related due to forward-time correlations is undoubtedly correct, his conclusion that Klintman’s observations could be *completely* attributed to variations in alertness may have been premature. After all, Klintman had hoped to exploit the known dependencies between RT1 and RT2 to form a more sensitive measure for RT2, but in the process he discovered an unexpected dependency that could not be explained simply as variations in alertness.

To explore Klintman’s findings and Camfferman’s objections in more detail, May and I re-examined the TRI effect in three conceptual replications based on a simpler design [47]. Using new hardware, software and analytical methods, we found significant evidence ($p < 0.001$) for a TRI effect and also that the effect could not be attributed solely to variations in alertness. A few years later, an attempted replication by another group was reportedly not successful in replicating Klintman’s findings [48], or our simplification of Klintman’s method (however, they also failed to use our simpler design and analytical methods).

Experiments conducted for other purposes

Studies published in *Science* examining brain activity and skin conductance during a gambling task reported “compelling new evidence that intuition plays a crucial role in helping people make sensible decisions and clues to how ‘gut feelings’ work in the brain” [49-50]. In examining the design and results of those studies, I was struck by how similar they were to the presentiment experiments.

I mentioned this resemblance to a colleague, Prof. Dick Bierman (University of Amsterdam), who explored whether presentiment anomalies could be found in data from previously published, mainstream psychophysiological experiments. He located three suitable datasets that could be re-analyzed, all using SCL measures [51]. The first was from an experiment on the speed with which fear arises in animal-phobic participants vs. non-phobic controls [52], the second was from gambling studies [50, 53-54], and the third was from an experiment studying the effect of emotional priming on the evaluation of Japanese characters [55].

In all three datasets, Bierman found physiological anomalies closely resembling the presentiment effect: SCL preceding randomized emotional stimuli were higher than before calm stimuli. The combined result across the three studies was statically significant ($p < 0.01$), suggesting that retrocausal effects may permeate human behavior, even appearing in experiments conducted for other purposes.

Interpretations

The outcomes of these experiments imply some form of macroscopic time-reversal. Besides scientists, this worries philosophers because they imagine that retrocausation would necessarily evoke logical paradoxes. Wouldn't information from the future change the present and thereby change the future from whence the information originated? And wouldn't that create an inescapable temporal recursion? The answer is yes, but only under two special conditions: First, if the future is absolute or fated to occur in only one way, and second, if precognition is perfectly accurate. However, if the future is probabilistic or if precognition is imperfect, or both, then the paradox dissolves. In any case, it is not suggested here that time-reversed effects change the past. As Braud [56] put it,

Once an event has occurred, it remains so; it does not “un-occur” or change from its initial form. It appears, instead, that the intentions, wishes, or ... “efforts” influence what happens (or happened) in the first place.

In other words, time-reversed effects may probabilistically influence past events that were disposed to being influenced at the time, but the same influence cannot change what actually did occur, nor can it change events that are not susceptible to probabilistic influence in the first place.

Another implication of time-reversed effects is that they help make a case for resurrection of Aristotle's “final cause.” Sidestepping the difficult question of whether we should think of causality in terms of force or correlation, most scientists today assume that of Aristotle's four causes the only one worthy of serious attention is “efficient cause.” The *efficient* cause in say, building a chair involves the act of a

hammer hitting a nail into wood, whereas *material* cause refers to the wood and nails involved in making a chair, *formal* cause refers to the design of the chair, and *final* cause refers to the underlying purpose of the chair.

While science has considered material and formal causes to be interesting but irrelevant in understanding the mechanisms of chair construction, final cause is dismissed entirely because teleology is thought (by some) to suspiciously resemble theology. But what if teleologically-inspired guidance were not a gift from the gods, but rather influences from our own futures?

In conclusion, the full epistemological and ontological consequences of time-reversed phenomena have yet to be worked out, but one early implication is that if these phenomena exist then the experimental sciences are faced with a dilemma: Time-reversed effects cannot be prevented by any known experimental designs, including the gold standard double-blind, randomized protocol. This means the best-controlled experiments in any scientific disciplines may be unavoidably flawed. We may take some comfort in assuming that the magnitude of these flaws are miniscule, but in some disciplines, especially highly labile domains such as the life sciences, the flaws may compound and significantly affect the interpretation of results.

It is, of course, a heresy of the first order to suggest that time-honored epistemological assumptions may be defective. But if positive evidence continues to compound in favor of presentiment, then we will eventually have to face this heresy and rethink our epistemologies.

ACKNOWLEDGMENTS

The skin conductance experiments were supported in part by the Bigelow Foundation of Las Vegas, Nevada, USA, the Institut für Grenzgebiete der Psychologie und Psychohygiene of Freiburg, Germany, and by Interval Research Corporation, Palo Alto, California, USA. The slow cortical potential experiments were supported by Richard and Connie Adams, Michael Breland, Claire Russell, Mary Hanson, and by the Institute of Noetic Sciences.

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