Evidence for an anomalous anticipatory effect in the autonomic nervous system

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Previous studies investigating autonomic arousal levels prior to randomly selected calm vs. emotional stimuli found that the baseline levels depended on future conditions. Two double-blind experiments involving a total of 98 participants re-examined this anomalous anticipatory effect, dubbed "presentiment." Participants with the most consistent responses to calm stimuli were predicted to show the presentiment effect, and they did ($p = 0.04$). In addition, it was shown that physiological arousal levels prior to the stimuli were positively correlated with independently assessed emotionality ratings ($p = 0.008$). To ensure that the anomaly was not due to subliminal cues, stimulus pictures were randomly selected after the pre-stimulus recording period. To ensure that the effect was not due to statistical anticipation, the picture categories of calm and emotional were randomly selected with replacement. No significant autocorrelations were found in the stimulus sequences, and both pseudorandom and hardware-based truly random number generators were used to generate the stimulus sequences, with similar results. Other potential design artifacts and anticipatory strategies that might have generated the observed results were considered in detail and rejected.

Keywords: skin conductance level, presentiment, intuition, anticipation

[1] This article was written while the author was a visiting scientist at Interval Research Corporation.

INTRODUCTION

It is commonly assumed among neuroscientists that mental concepts such as conscious awareness, memory, and unconscious perception are epiphenomena or emergent properties of the nervous system and brain (Grush & Churchland, 1995; Dennett, 1991; Crick, 1994). This being so, it is taken for granted that the mind is essentially a complex, dynamical system, subject to the same fundamental physical constraints as rocks and stars. In particular, the arrow of time in this complex living system, as in other physical systems, is assumed to point from the past to the future. Thus, it is usually accepted without question that the mind is restricted to perception of the sensory present, intermingled with fading memories of the past.

Given these assumptions, when neuroscientists read reports of ostensibly accurate precognitive dreams, they quite reasonably suppose that the explanation for such reports is some combination of pathology, statistical naivete, delusion and fraud. Precognition implies a reversal of the arrow of time, and backwards-moving time seems to violate both common sense and basic logic.

Within physics, however, an absolute direction of the arrow of time is far less certain (Price, 1996). Dozens of scholarly publications have seriously considered the implications of time-reversed effects as described by the formalisms of general relativity, electrodynamics, and quantum mechanics (e.g., Elsasser, 1969; Tipler, 1974; Rietdijk, 1987; Travis, 1992). The time-reversed solutions to these theories are often assumed to manifest only in exotic realms, e.g., under extremes of gravity, energy, mass or speed, or at very short time-periods. As a result, retrocausality is viewed as possible in principle, but beyond the domain of ordinary biological systems. That is, even if phenomena as strange as time-reversed effects were accepted as real, they are assumed to be inconsequential for the understanding of human psychology and psychophysiology.

However, if retrocausal effects did occur at the human scale, how might they be reported? One way is the experience of perceiving a future event before it occurred. Such experiences, variously called prophesy, premonition and precognition, have been reported throughout history and across all cultures (Rhine, 1969; Radin, 1997a). For nearly a century, researchers have investigated these phenomena under controlled conditions to see whether such experiences are best understood as coincidences or selective memory, or whether some of the experiences might be what they appear to be – perception of non-inferable future events.

In a meta-analysis of one class of "forced-choice" precognition tests, Honorton and Ferrari (1989) found 309 published studies reported in 113 journal articles published from 1935 to 1987. These studies, contributed by 62 different investigators from laboratories around the world, comprised a database of nearly 2 million individual trials generated by over 50,000 subjects. The experimental methods ranged from asking people to guess the outcomes of cards shuffled in the future to guessing computer-generated, randomly presented symbols. Honorton and Ferrari's analysis of a statistically homogeneous subset of these studies, involving some 248 studies reported by 57 investigators, resulted in overall odds against a chance effect of a billion to one. Further analysis showed that the filedrawer problem (i.e., selective reporting) as well as variations in experimental quality could not adequately explain these results. These studies, along with thousands of case studies of apparently precognitive dreams suggest, in spite of common sense, that events from the future can sometimes be perceived in the past.

One possibly precognitive effect is the intuitive hunch, especially hunches reported prior to unexpected emotional events (Moss & Gengerelli, 1968; Bechara et al, 1997). Of particular interest is the hunch commonly described as a foreboding or a "bad feeling," one with no evident cause before an unexpected emotional event. Such pre-feeling or *presentiment* experiences may suggest that some aspect of our perceptual apparatus is continuously scanning the future. Sometimes, if a future event is sufficiently important, novel, or emotional, it may precipitate a change in the present physiological state that is consistent with the future reaction. In the laboratory, we can test this idea by comparing autonomic arousal levels prior to randomly selected emotional vs. calm stimuli. Such a technique would elicit anticipatory responses before the stimulus and orienting responses after presentation of emotional stimuli (Andreassi, 1989; Boucsein, 1992; Kimmel et al, 1979). If presentiment is a genuine effect, then the magnitude of the anticipatory "presponse" should be correlated with the magnitude of the post-stimulus orienting response.

Of course, most hunches do not require exotic explanations like retrocausation; more prosaic explanations like subliminal sensory processing and implicit knowledge are sufficient. Similarly, retrocausal explanations are unnecessary if say, one dreams about failing an examination for which one hasn't studied. Further, hunches occurring as a result of forgotten expertise, such as some remarkable cases of "intuitive medical diagnosis" (Dossey, 1997), may also be attributed to ordinary causes. But hunches experienced minutes or hours in advance of unexpected future events are not so easily explained.

Previous studies

Levin & Kennedy (1975) used a reaction time task to see whether contingent negative variation (CNV), a slow brainwave indicator of anticipation, could be used to differentially detect a future stimulus. Participants were asked to press a key when a green light appeared, but not when a red light appeared. A hardware random number generator determined which light would appear. Significantly larger CNV's were observed just before the RNG selected a green light as compared to just before it selected a red light.

A few years later, Hartwell (1978) reported a similar study, also using CNV. Participants saw a picture of a person of the same sex or the opposite sex. If the picture was of the opposite sex, they pressed a button as quickly as possible, otherwise no response was made. Various forms of warning stimuli were used to alert the subject that a picture was about to be shown, from explicit warnings to prepare to respond, to no warning which served as the precognition condition. Thirteen of 19 planned statistical tests were in the predicted direction, but overall the results were not significant.

Evidence for presentiment effects in the autonomic nervous system were more recently reported in experiments by Radin (1997b) at the University of Nevada, by Bierman and Radin (1997, in press) at the University of Amsterdam, and by Norfolk (1999) at the University of Edinburgh. In these studies, individuals viewed a randomly selected emotional or calm picture while their skin conductance level (SCL) was monitored. SCL measurements were taken five to seven seconds before the picture was displayed and eight to ten seconds afterwards. These experiments observed greater autonomic arousal before emotional stimuli than before calm stimuli.

The superposed epoch analysis in Figure 1 illustrates how presentiment manifests in these experiments. The two curves are mean arousal levels (and one sigma error bars) for changes in SCL before, during and after presentation of randomly selected emotional or calm pictures. Presentiment is observed as a larger mean arousal level during the six seconds before emotional pictures as compared to before calm pictures.

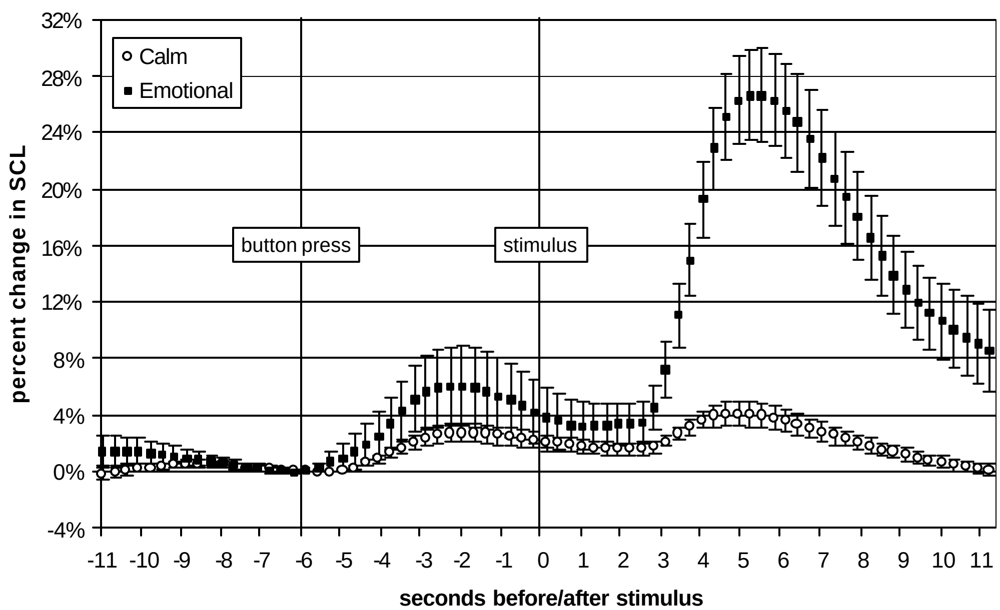

Figure 1. Superposed epoch analysis of one subject's results from Experiment 2 reported in this article. This person viewed 8 emotional and 21 calm pictures, randomly selected from a pool of 150 available pictures. The two curves show percent change in SCL averaged over all calm and emotional trials, with one sigma error bars. The curves are clamped to zero with respect to the moment when the trial was initiated by the subject.

The present studies

The present experiments were designed to investigate ways of optimizing detection of presentiment effects. The first experiment examined three autonomic measures simultaneously (SCL, heart rate and fingertip blood volume), and the second experiment explored the effect (on SCL) of using a higher contrast between the emotionality ratings of emotional and calm targets.

EXPERIMENT 1

Participants

Participants recruited for this study were mostly adult staff, faculty and students from the University of Nevada, Las Vegas. A few volunteers were enlisted from the local Las Vegas community through advertisements seeking people interested in a study on intuitive hunches, and from occasional visitors to the laboratory.

Procedure

Individuals were asked to simply sit quietly in a straight-backed chair and observe a series of randomly selected color pictures displayed on a computer screen. After the participant signed an informed consent form, the experimenter attached 1 cm^2 silver-silver chloride electrodes to the index and second fingers of the left hand to measure SCL.[2] A photoplethysmograph was attached to the tip of the third finger to measure heart rate (average of the last three beats) and fingertip blood volume. The psychophysiological monitor was a J&J Engineering Model I-330, a 4 channel A-D device with 12-bit resolution. The I-330 measured SCL in the range 1 to 100 µS with an accuracy of ±0.5%, and used a constant current of 2.5 µA for excitation. Data were collected at 5 Hz. After attaching the electrodes, the experimenter started a software program that controlled the I-330. The program was written in Microsoft QuickBasic 4.5 and run under the DOS operating system on a 100 MHz desktop PC.[3]

The participant was instructed to press a mouse button using the right index finger to begin each trial at will. After the button-press, as shown in Figure 2, the computer screen remained blank for 5 seconds, then a high-resolution digitized image was shown for 3 seconds. This was followed by a blank screen cool-down period of 10 seconds. At the end of this period, a message appeared on the screen stating that when ready, the participant could press the mouse button to begin the next trial. Data were continually recorded during the testing period, but not between trials.

It was explained that during inter-trial periods if the participant needed to stretch or move he or she should do so and then relax a few seconds to settle down. After running one demonstration trial, the experimenter turned off the overhead fluorescent lights and waited behind an opaque screen. The participant then conducted 40 additional trials at their own pace, unobserved.

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[2] Parker Laboratories "Signa Creme" electrode cream was used to improve skin conduction.

[3] A Super VGA graphics library by S. Balkum and D. Sill was used to extend the display capabilities of QuickBasic 4.5.

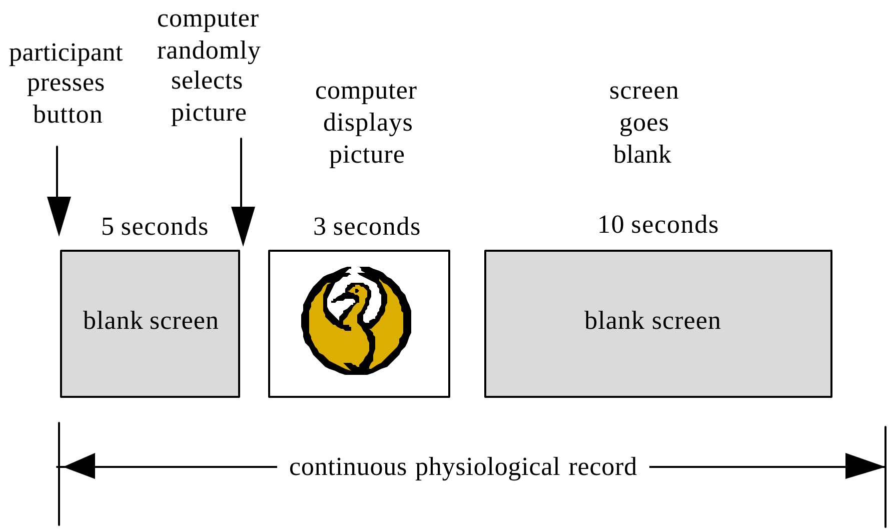

Figure 2. Illustration of the experimental procedure in Experiment 1.

Target selection procedure

Immediately after the participant pressed the button to initiate a trial, the experimental program set the seed-number of the controlling program's pseudorandom number generator (PRNG) algorithm to the present clock time (with 1 second resolution), and the physiological monitor began collecting data. Immediately after the pre-stimulus period, the software created a new seed-number by taking the sum of the computer's current clock time plus the raw values of the most recently recorded physiological measurements. This number was used to re-seed the PRNG, which was used to generate a number from 1 to 120. This number in turn determined the target stimulus to display. See Appendix A for more details about this method of generating random targets.

Target materials

The target pool for Experiment 1 consisted of 80 calm and 40 emotional pictures. This 2:1 proportion was employed to avoid physiological habituation to the emotional pictures, which could occur if participants saw too many emotional stimuli in the same session (Boucsein, 1992, p. 225). The calm and emotional pictures were selected from a collection of high resolution color digital photographs. The calm pictures included landscapes, seascapes, and portraits of people, fruit, trees and animals. Emotional pictures portrayed a range of erotic and violent topics, following the style and content of the "International Affective Picture System" (IAPS, Center for the Study of Emotion and Attention, 1995; Bradley et al, 1993; Ito et al, 1998).

To provide an independent assessment of the emotionality of the targets, five men and five women were independently asked to rate the target pictures, one at a time, on the same dimensions used to rate the IAPS pictures: emotionality (level of arousal) and valence (negative to positive). The rating dimensions in this case consisted of 100 points, and the rating method asked the person to view the picture on a computer screen and move a pointer across a scale to indicate his or her assessment on each of the two dimensions. Each person's assessments were normalized into standard normal deviates (z-scores), and the z-scores per target were combined across all 10 people to provide a two-dimensional distribution of target emotionality and valence in z-score space. This target set resulted in a high correlation between valence and emotionality ($r = 0.89$). For purposes of this experiment, images rated with normalized emotionality scores < 0 were defined as calm and scores > 0 were defined as emotional.

Idiosyncratic responses

Measurement of physiological responses to emotional pictures presents a problem because people can exhibit a wide range of responses to the same picture. For example, a picture of an accident victim, subjectively assessed as highly emotional by an independent panel of judges, may produce no response at all in say, an emergency room doctor who is inured to such images. Another picture rated as calm, such as a dog, may produce an unexpected emotional response if the viewer had lost a much-loved pet. In other cases, participants may experience a momentary lack of attention and fail to notice an emotional target, or may sneeze during presentation of a calm photo and generate an artifact resembling an emotional response.

These idiosyncratic responses can introduce a substantial amount of noise into the evaluation of presentiment effects, so they must be identified and eliminated. However, in assessing which trials exhibited idiosyncratic behavior it is essential to avoid introducing analytical artifacts and post-hoc data selection problems. The approach we took was to separate people into two groups: Those who responded (i.e., post-stimulus) to calm targets most *consistently* and most *inconsistently*. Consistent subjects were those who displayed few or no emotional responses to calm targets, and few or no movement artifacts during calm trials that might have mimicked emotional responses. By contrast, inconsistent subjects displayed more idiosyncratic responses to calm trials, and as a result, their post-stimulus differential (i.e., emotional vs. calm) contrast was diminished or eliminated. Because presentiment is hypothesized to depend on post-stimulus responses, it is necessary to have a strong post-stimulus difference in order to detect a clear pre-stimulus difference. As a result, the formal hypothesis tests were based on data from the group more likely to show these clearer post-stimulus responses, i.e., what we called the consistent responders.

To identify the consistent responders, for each subject we examined the *variance* of his or her SCL percentage difference scores for all post-stimulus samples across all of the calm stimuli they viewed.[4] The 50% of participants with the largest variances were defined as idiosyncratic responders and the remaining 50% with the smallest variances were defined as consistent responders. This median split was used as a straightforward *a priori* method of partitioning the subjects.

[4] Note that this selection criterion is based only upon similarity of responses and does not depend on physiological arousal levels.

Hypotheses

H1: Individuals who respond consistently to calm targets (post-stimulus) will show a larger mean anticipatory arousal before emotional stimuli than before calm stimuli. This is a differential hypothesis.

H2: The consistent responders will show a mean positive correlation between their pre-stimulus level of arousal and the independently assessed emotionality ratings of the targets. This hypothesis is a generalization of H1, predicting a functional relationship between the magnitude of the anticipatory arousal and the emotionality of the future response.

Analyses

Physiological measurements

To evaluate Hypothesis 1, normalized measures of differential presponse and response arousal levels were required per participant (i.e., a within-subject analysis). For the physiological measurements we were interested not in absolute measures, but in how physiology *changed* from the moment a given trial was initiated (e.g., Ben-Shakhar, 1985). To do this, each sample in each trial was transformed into a percentage difference score (Δ) relative to the physiological measurement at the moment the participant pressed a button to initiate each trial.

Each trial consisted of 5 + 3 + 10 = 18 seconds × 5 samples per second = 90 measurements. If the first sample is called s(1), then for n = 1 to 90, the transformed samples for that trial are $\Delta(n) = [s(n) - s(1)] / s(1)$. By definition, the first percentage difference score in a given trial is always zero ($\Delta(1) = 0$).

Superposed epoch analysis

To provide a convenient visual indicator of the overall outcome, the percentage difference scores may be examined as superposed epochs of average calm and average emotional curves, with one sigma error bars, as illustrated in Figure 1 for SCL. However, because superposed epoch curves are averages, they tend to skew the average towards larger-magnitude values more than smaller changes. This means that epoch curves involving data pooled across subjects will reflect the performance of labile or highly-reactive individuals more than stabile or low-reactive individuals. Thus, the epoch graphs alone cannot be relied upon to form accurate statistical assessments across subjects.

Randomized permutation analysis

To determine the statistical significance of the differences between emotional vs. calm curves during the presponse period, randomized permutation analysis (RPA) was applied separately to each individual's data (Diaconis & Efron, 1983; Efron & Tibshirani, 1991; Good, 1994; Hjorth, 1994). The outcomes of the RPA were two standard normal deviates, or z scores, per person. The differential presponse (pre-stimulus) was called z_{pre}, and the differential response (post-stimulus) was called z_{post}.[5] RPA is an appropriate statistical technique for comparing average difference curves involving physiological data, as this method takes into account autocorrelations inherent to physiological signals and their underlying non-normal distributions (Blair & Karniski, 1993). See Appendix B for details on the RPA method.

Results: Experiment 1

Participants

Data were collected from 50 participants from April 1996 through March 1997. Difficulties with the computing hardware occurred during two of the 50 participants' sessions, making it necessary to discard those two datasets. Thus, rather than collecting the planned 2,000 trials (40 trials $\times$ 50 people) a total of 1,920 trials were collected. Participants included 26 women and 22 men, ages ranging from 18 to 72.

Superposed epoch analyses

Before examining the results of the specific hypothesis, it is instructive to examine the superposed epoch analyses for SCL, BVP and HR, for all data combined across all subjects (Figures 3 - 5). These graphs indicate that the post-stimulus changes in SCL, BVP and HR were in accordance with the expected orienting reflex (Siddle et al 1983), and that the anticipatory rises (for SCL and HR) and drop (for BVP) before the stimulus were also consistent with a "signal stimulus," i.e., "those stimuli which evoke a reaction in anticipation of external agents likely to appear in the future" (Sokolov, 1963, p. 163). In addition, the graphs indicate, as predicted by the presentiment hypothesis, that for BVP anticipatory arousal before the emotional targets was higher than before calm targets (as indicated by a larger drop in fingertip blood volume), and for HR anticipatory arousal was higher (as indicated by a larger increase in heart rate).

[5] While Hypothesis 1 only involves z_{pre}, it is useful to calculate z_{post} to confirm that the emotional manipulation occurred as expected.

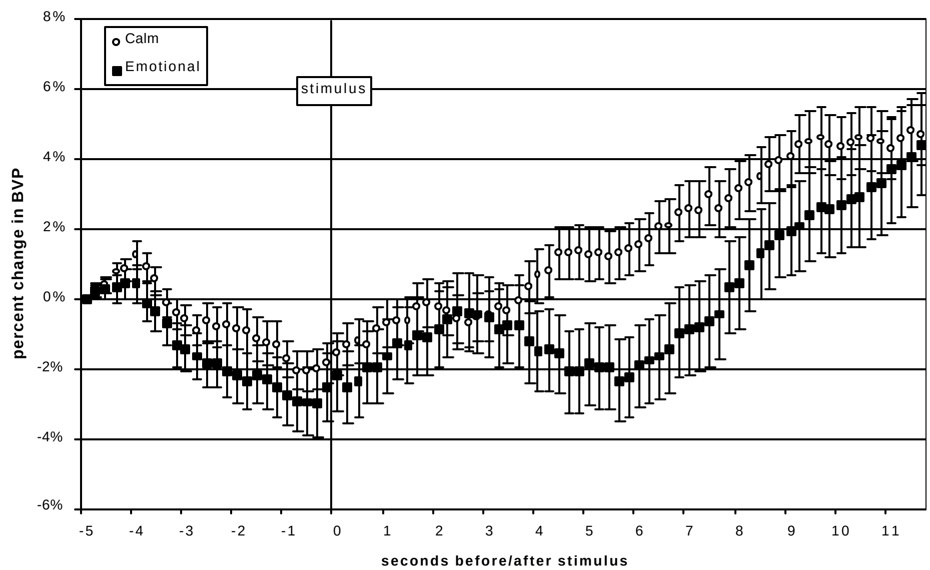

Figure 3. Superposed epoch analysis for change in BVP, all trials for all 48 subjects, with one standard error bars. Negative percent change in this graph reflects a drop in fingertip blood flow.

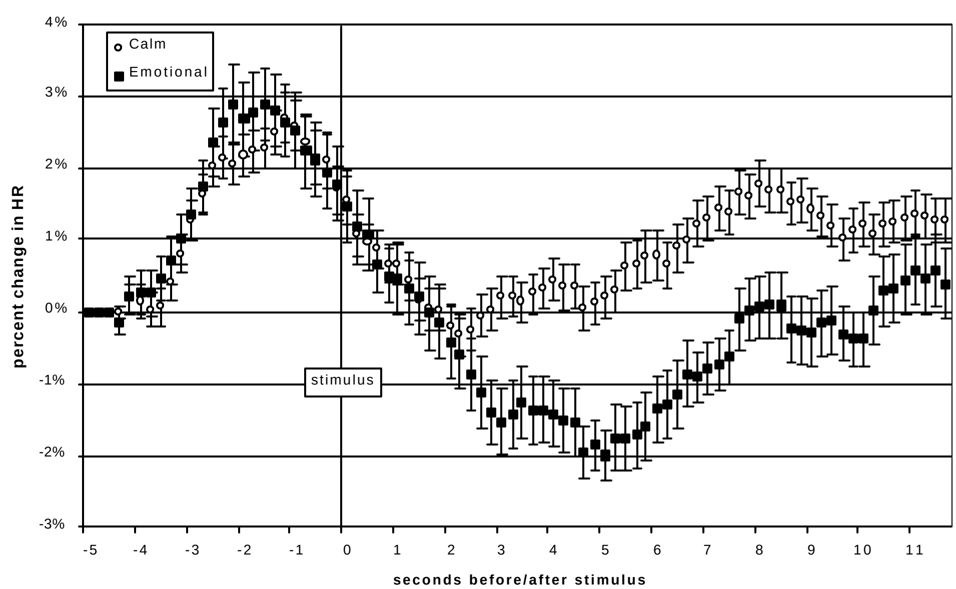

Figure 4. Superposed epoch analysis for change in HR.

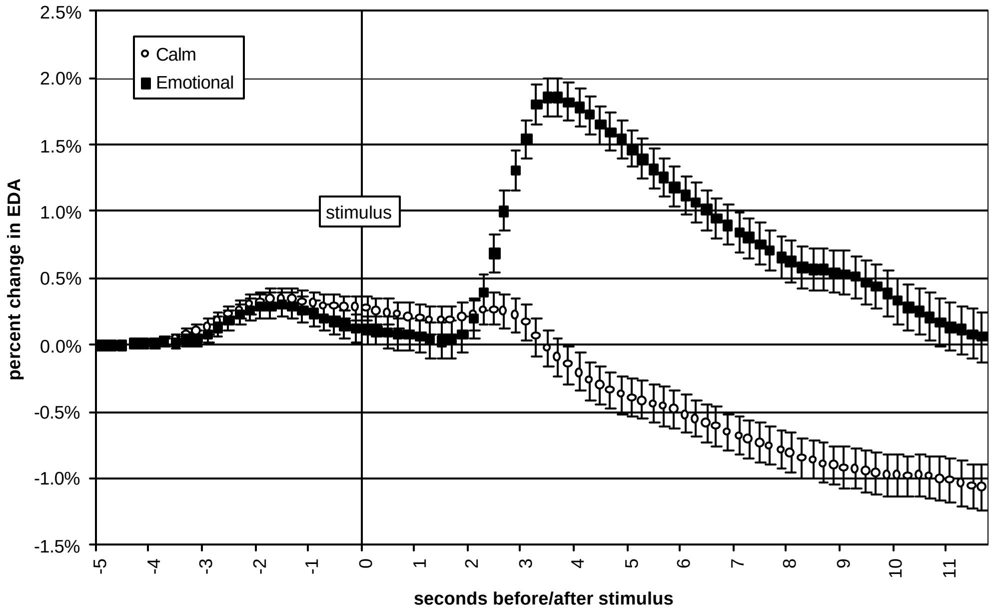

Figure 5. Superposed epoch analysis for change in SCL.

Table 1 shows the RPA results for the three physiological measures across all participants. The presponse differential z scores (z_{pre}) for SCL and HR did not significantly differ from chance, but in accordance with the presentiment hypothesis, BVP significantly dropped before the emotional targets (p = 0.05).

Experiment 1	Z_{pre}	p(1-tail)
SCL	-0.23	0.59
BVP	-1.68	0.05
HR	0.21	0.42

Table 1. Combined random permutation analysis results for all 48 participants in Experiment 1.

Hypothesis 1

This hypothesis predicted that z_{pre} from the "consistent responders" would show a presentiment effect. Figure 6 shows the resulting superposed epoch analysis graph for SCL, and Table 2 summarizes the associated z_{pre} scores for SCL, HR and BVP. We see that the results for SCL and HR increased in the direction predicted by the presentiment hypothesis, but only the result for BVP remained marginally significant.

Experiment 1	Z_{pre}	P (1-tail)
SCL	0.57	0.29
BVP	-1.61	0.05
HR	0.30	0.38

Table 2. Summary of results for the 24 most consistent responders in Experiments 1.

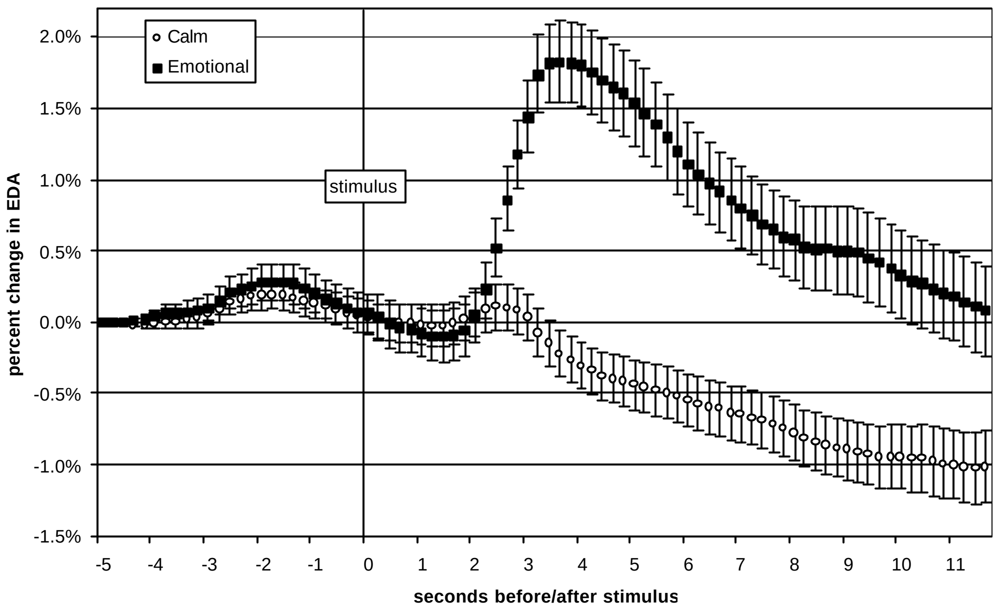

Figure 6. Results for SCL in Experiment 1, for the 24 most consistent responders.

Hypothesis 2

This hypothesis generalized the above differential hypothesis, predicting that consistent responders would show a mean positive correlation (for SCL and HR, mean negative for BVP) between the independently assessed target emotionality ratings vs. the pre-stimulus physiological arousal levels during the presponse period. To help clarify the nature of this test, Figure 7 shows the correlation for SCL for the group of consistent responders at the beginning of the fourth second post-stimulus, where one would expect to see a positive correlation between emotionality ratings and physiology. While small in magnitude, this correlation (r = 0.23) is statistically highly significant.

In Figure 8, this same correlation is graphed for SCL as a mean point estimate with one standard error bars, along with similar correlations for all samples from 5 seconds before the stimulus to 11 seconds afterwards. Figures 9 and 10 show the same correlations for BVP and HR.

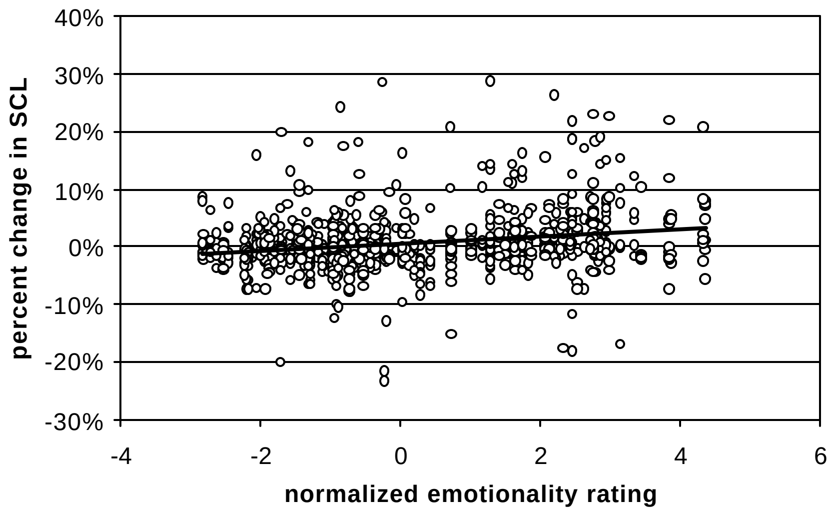

Figure 7. Correlation between percent change in SCL vs. normalized emotionality ratings, for samples measured four seconds after the stimulus in Experiment 1. The observed correlation is r = 0.23 (N = 960). There is no question that this correlation is non-zero, t (958 df) = 7.27, $p = 3.6 \times 10^{-13}$.

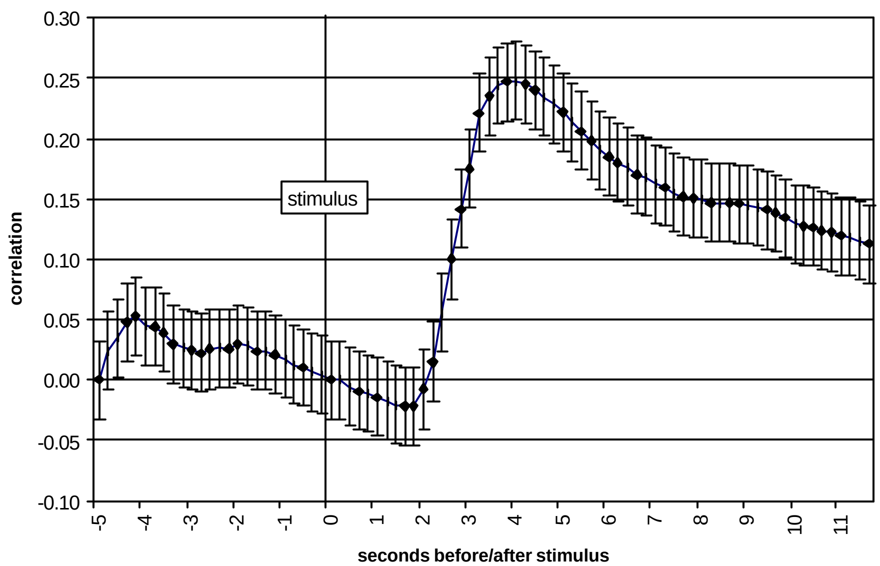

Figure 8. Correlations and associated one standard error bars between independently assessed target emotionality ratings vs. percent change in SCL, from 5 seconds before the stimulus to 11 seconds afterwards, for the 24 consistent responders in Experiment 1. Note that the post-stimulus correlations are in alignment with the orienting reflex, and that all *pre-stimulus* mean correlations are greater than zero, as predicted by the presentiment hypothesis.

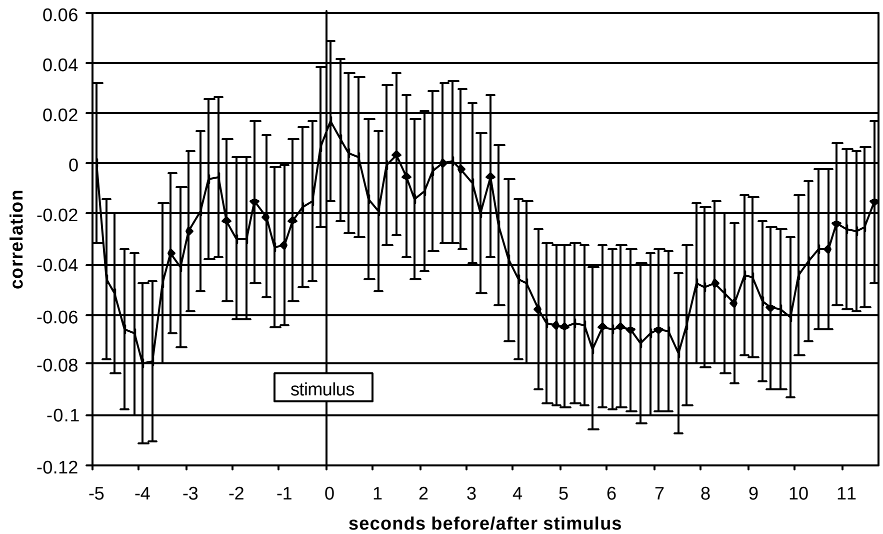

Figure 9. Correlations and standard error bars for BVP. Note that all pre-stimulus correlations are less than zero, as predicted by the presentiment hypothesis. Larger autonomic arousal is reflected as a drop in BVP.

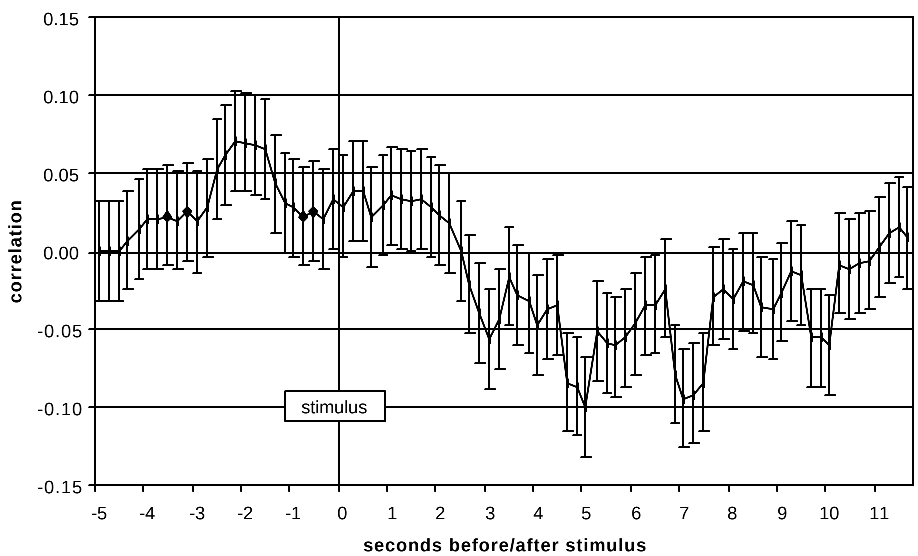

Figure 10. Correlations for HR. Note that all pre-stimulus correlations are greater than zero, as predicted by the presentiment hypothesis. Higher autonomic arousal is reflected as an anticipatory rise in HR.

Randomized permutation results shown in Table 3 (see Appendix C for details) indicate that the mean presponse correlations (indicated as $z_{pre\text{-}r}$) for these physiological measures again increased in the predicted directions; BVP was significant at $p = 0.01$. The composite direction of these results suggest the presence of an underlying functional relationship between the emotionality of the targets and the predicted physiological arousal levels.

Experiment 1	Z_{pre-r}	P (1-tail)
SCL	1.23	0.11
BVP	-2.18	0.01
HR	0.51	0.31

Table 3. Summary of mean correlation test results for consistent responders in Experiment 1.

<u>Summary</u>

Overall results of Experiment 1, primarily for BVP, suggested that autonomic arousal levels may have "presponded" in accordance with the presentiment hypothesis. As predicted, subjects who responded consistently to calm targets performed marginally better than all subjects pooled, and there was suggestive evidence for a functional relationship that depended on the future emotionality of the target stimuli. If the functional relationship observed here reflected a genuine presentiment effect, then it should be possible to enhance the effects observed in Experiment 1 by using a stimulus pool with a very high degree of emotional contrast between the emotional and calm categories. In addition, a genuine effect should not depend on specific hardware or software implementations. These predictions were tested in Experiment 2.

EXPERIMENT 2

This experiment was a replication of Experiment 1, using new hardware and software, a new picture pool with higher emotional contrast, and a new subject population. Also, rather than running 40 trials per participant, 30 trials were used to alleviate fatigue and accommodation observed in some participants' data in Experiment 1 (the first of the 30 trials was used for demonstration/instructional purposes and was discarded from further analysis).

Participants

The study was planned for 50 adults. Volunteers were recruited from visitors and staff at Interval Research Corporation, and from participants at seminars held in Port Antonio, Jamaica and at Esalen Institute in Big Sur, California.

Equipment, Procedure and Targets

A new controlling program was written for this experiment in Microsoft C++ version 6.0. Some trials were run on a 233 MHz laptop PC, others on a 300 MHz desktop PC, both using the Windows NT4.0 operating system. The psychophysiological monitor was a J&J Engineering Model I-330C2, a 6 channel A-D device with 12-bit resolution. The I-330C2 measures SCL in the range 1 to 100 µS with an accuracy of ±0.5%, and uses a constant current of 2.5 µA for excitation. Only SCL measurements were systematically monitored in this study (at 10 Hz). The program was written to allow continuous data collection, thus in this study the epoch analysis graphs could be drawn to display data 5 seconds before the trial was initiated. The program also provided for a 6-second pre-stimulus period, in contrast to the 5-second period used in Experiment 1.

The target pool was the 80 most calm and the 40 most emotional pictures from the standard IAPS stimulus set, where "calm" and "emotional" were defined by the emotionality ratings (averaged across gender) that accompany the IAPS pictures. To further enhance contrast between the emotional and calm targets, participants wore headphones which played one of 20 randomly selected noxious sounds during presentation of emotional pictures (i.e., screams, sirens, explosions, etc.), otherwise the experiment was conducted in silence.

Data collection

Data were collected from January through June 1999. Of the 50 planned participants, all were run by the author, and all planned trials 1,450 (29 trials x 50 people) were successfully obtained. Participants included 27 woman and 23 men, ages ranging from 29 to 60.

Results

Table 4 shows that the overall differential effect for the *post-stimulus* responses in Experiment 2 (z_{post} = 17.02) was significantly larger than the post-stimulus responses in Experiment 1 (z_{post} = 6.23). This was expected, as Experiment 2 used stimuli with a high emotional contrast as well as sound stimuli during the emotional stimuli. However, while the overall z_{pre} measure (for SCL) in Experiment 2 was somewhat higher than that for SCL in Experiment 1, there was no evidence for presentiment in SCL for the two studies combined. The overall epoch analysis for SCL in Experiment 2 is shown in Figure 11.

	Experiment 1	Experiment 2	Combined
z_{pre}	-0.23	0.31	0.06
z_{post}	4.43	17.02	15.26
N subjects	48	50	98
p_{pre} (1-tail)	0.59	0.38	0.48

Table 4. Combined results for SCL for all participants from Experiments 1 and 2. The p-values are only shown for z_{pre} because the probabilities associated with the z_{post} scores are for all practical purposes zero.

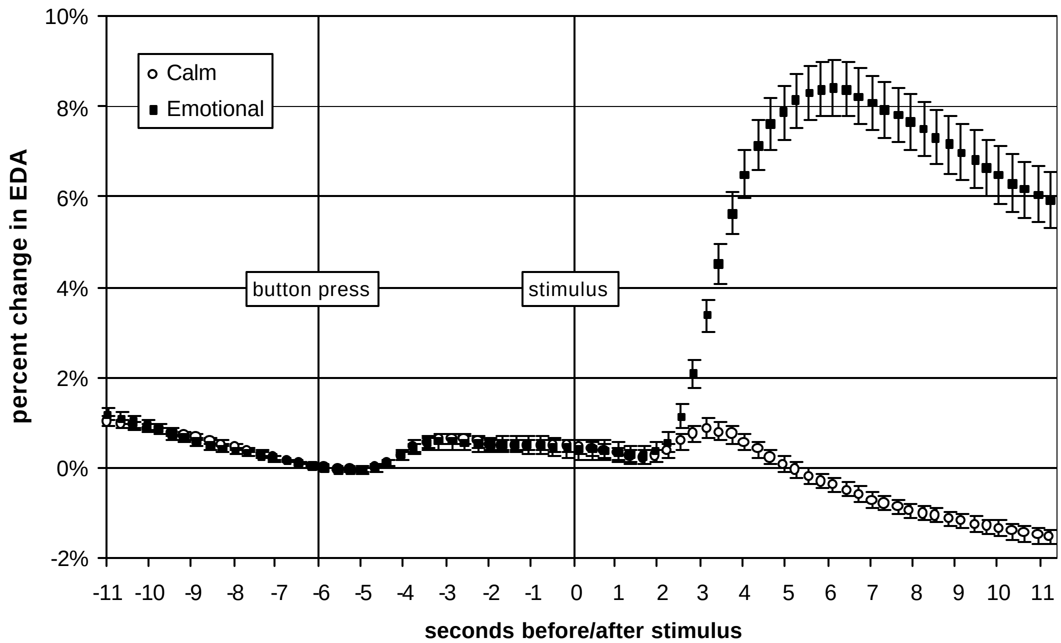

Figure 11. Superposed epoch analysis for SCL for all 1,450 trials in Experiment 2, with one sigma error bars. The button press used to initiate each trial occurred in this experiment at 6 seconds before the stimulus. Data were recorded between trials in this experiment, thus data is also displayed five seconds before the initiation of the trial.

Hypothesis 1

This hypothesis predicted that the combined pre-stimulus differential presponse (z_{pre}) from the consistent responders would show a presentiment effect. Figure 12 shows the SCL results graphically, and Table 5 shows the results for SCL in both experiments separately and combined. The overall presentiment for SCL from the consistent responders was now significant (p = .03) in Experiment 2, confirming the prediction that a higher-contrast set of target pictures would produce a larger presentiment effect. Combined across both experiments, SCL z_{pre} = 1.65, p = .04

	Experiment 1	Experiment 2	Combined
SCL z_{pre}	0.57	1.95	1.78
N	24	25	49
p (1-tail)	0.29	0.03	0.04

Table 5. Summary of results for consistent responders in Experiments 1, 2, and combined.

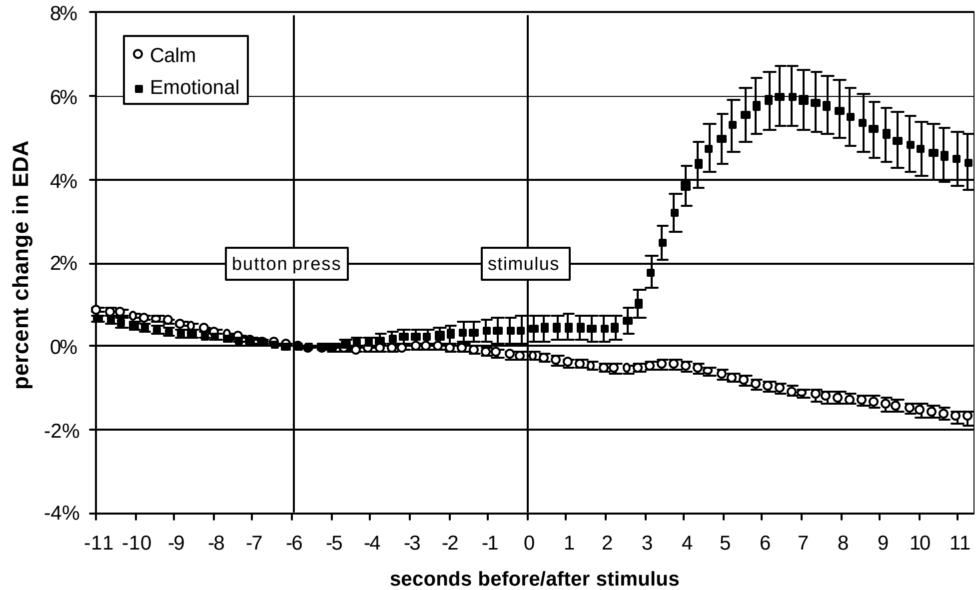

Figure 12. Results for SCL in Experiment 2, for 25 most consistent subjects.

Hypothesis 2

This hypothesis predicted that the consistent responders would show a mean positive correlation between the independently assessed target emotionality ratings vs. pre-stimulus change in SCL. Figure 13 shows the time-course of these correlations.

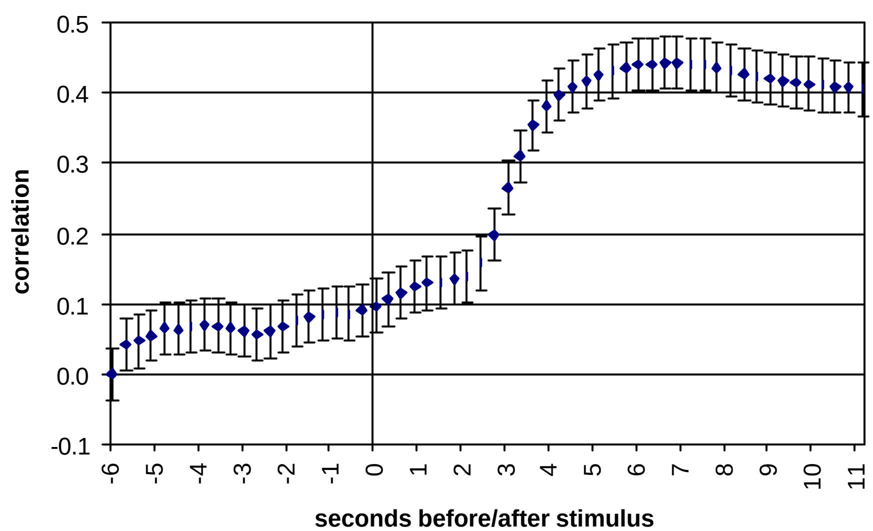

Figure 13. Correlations (with one standard error bars) between independently assessed target emotionality ratings vs. percent change in SCL, for the 25 consistent responders in Experiment 2. RPA shows that the probability that the mean of the

pre-stimulus correlations is less than or equal to zero is p = 0.01 (combined z = 2.19).[6]

Randomized permutation results shown in Table 6 confirm that the average presponse correlation in Figure 13 is significantly positive: $z_{pre\text{-}r}$ combined is associated with p = 0.01. Overall, the combined $z_{pre\text{-}r}$ results confirm the predicted positive relationship between the emotionality of the targets and the physiological arousal levels prior to the stimulus, p = .008.

	Experiment 1	Experiment 2	Combined
$z_{pre\text{-}r}$	1.23	2.19	2.42
N	24	25	49
p (1-tail)	0.11	0.01	0.008

Table 6. Summary of mean correlational results for consistent responders for SCL, in Experiments 1, 2, and combined.

DISCUSSION

In summary,

a) Hypothesis 1 predicted that a subset of pre-defined "consistent responders" would show evidence for a presentiment response. The prediction was confirmed (p = 0.01) for SCL combined across both experiments, and marginally confirmed (p = 0.05) independently for BVP in Experiment 1.

b) Hypothesis 2 predicted that the group of consistent responders would show a mean positive correlation between independently assessed emotionality ratings and physiological arousal levels observed during the presponse period. The prediction was confirmed (p = 0.008) for SCL combined across both experiments, and confirmed (p = 0.01) for BVP in Experiment 1.

Post-hoc variance analysis

After examining the results of these experiments, it appeared that the larger rise in autonomic arousal before emotional vs. calm targets was associated with larger autonomic variability before emotional vs. calm targets. To test this observation, RPA was used to determine the differences in presponse *variance* for emotional vs. calm trials for SCL in Experiments 1 and 2 combined, and for BVP and HR in Experiment 1. Results shown in Table 7 confirm that for both SCL and BVP *across all subjects* (not just the subset of consistent responders) physiological variance before emotional targets was greater than before calm targets.

Measure	Z_{pre}	P (1-tail)
SCL	1.70	0.04
BVP	1.73	0.04
HR	-0.23	0.59

[6] In this graph, the underlying distribution of emotionality variables are bimodal by design (i.e., high-contrast) rather than uniformly distributed, so the error bars can only be used for illustrative purposes. The probability of the mean presponse correlation in this graph is determined by permutation analysis.

Table 7. Summary of variance test results for all data in Experiments 1 and 2.

Personality correlates

Presentiment is hypothesized to be an unconscious perceptual effect. As such, it is not unreasonable to expect that the magnitude of the effect would be modulated by personality, personal experiences, defense mechanisms, and so on. If so, then we may predict that individuals who rely upon or are open to intuitive hunches may show larger presentiment effects than individuals who are closed to these possibilities. As an exploratory measure, 45 of the 48 participants in Experiment 1 were asked to respond to the following seven questions, each on a seven-point scale. The higher the score summed across all seven questions, the more we could presume that the individual was comfortable with the notion of intuition. The seven questions were as follows:

1. experience with intuitive hunches (never → to frequent)
2. decision making style (logical → feeling)
3. experience with mental or physical disciplines (never → daily)
4. family experience with psychic experiences (never → often)
5. personal precognitive experiences (never → frequent)
6. belief in existence of psychic phenomena (impossible → certain)
7. preference for order (maintain status quo → spontaneous)

If presentiment is modulated through these unconscious factors, we could predict a positive correlation between the sum of the answers to these questions vs. the z_{pre} scores for EDA and HR, and a negative correlation associated with BVP. Results in Table 8 show that the prediction was confirmed for BVP, but not for EDA and HR. Given that for all data combined in Experiment 1 only BVP independently showed a significant effect for presentiment, this may not be surprising. While caution is advised because three correlations were tested (and no Bonferroni correction was applied), this BVP correlation provides weak secondary support for the notion of an unconscious presentiment effect.

	BVP	EDA	HR
r	-0.25	-0.02	0.00
t	-1.68	-0.12	0.01
N	45	45	45
p (1-tail)	0.05	0.45	0.50

Table 8. Correlations between belief questions vs. z_{pre} for 45 participants in Experiment 1, and associated t-scores and one-tailed p-values.

Low consistency responders

Given that there was better evidence for presentiment from the consistent responders, one wonders how the inconsistent responders performed? Examination of the raw data revealed that in most cases, the inconsistent responders were so labeled because one or two of their calm trials had exceptionally large within-trial variances (i.e., variance of the physiological measure from the moment of the stimulus to the end of the cool-down period). Because of this observation, as a post-hoc test we examined the mean presponse correlation for SCL for each inconsistent responder, after removing the *one* calm trial with the most extreme within-trial variance.

Table 9 shows that the effect of removing this single trial from each of the total of 49 inconsistent responders (across both experiments), indicated as I* in the Table, dramatically changed the overall results.[7] All data from all subjects combined resulted in a nonsignificant $z_{pre\text{-}r} = 0.03$, whereas removing the single highest-variance calm trial from each of the inconsistent subjects (leaving 98.5% of all data) resulted in a combined significant $z_{pre\text{-}r} = 2.99$ for SCL. That is, based upon 100% of the data (C + I in Table 9), we see no evidence for presentiment, but with 98.5% of the data (C + I*) we see significant evidence for a functional relationship between the pre-assessed picture emotionality and change in SCL during the presponse period. This post-hoc observation implies that special effort must be applied in future studies to objectively identify and eliminate idiosyncratic responses, as they appear to play a major role in determining whether or not presentiment is detected.

Type of Responder	Study 1 $z_{pre\text{-}r}$	Study 2 $z_{pre\text{-}r}$	Combined $z_{pre\text{-}r}$	p (1-tail)
C	1.23	2.19	2.42	0.01
I	-1.79	-1.56	-2.37	0.99
I*	0.97	1.58	1.81	0.04
C + I	-0.40	0.44	0.03	0.49
C + I*	1.56	2.67	2.99	0.001

Table 9. Mean presponse correlation test ($z_{pre\text{-}r}$) for the consistent responders (C), inconsistent responders (I), inconsistent responders minus their single largest variance calm trial (I*), and combined (C+I and C+I*).

Alternative explanations

Sequential distribution of targets

If the sequence of calm and emotional targets in this experiment were predictable, this could have influenced participants' expectations. This in turn could have driven their physiological state to mimic the observed results. To check whether the target sequence generated by the PRNG was adequately random, autocorrelations from lag 1 to 15 were determined for the sequence of calm and emotional trials observed in Experiments 1 and 2. The results, shown in Figure 14, indicate that the target sequences were adequately random, and thus there were no sequential biases available to provide statistical clues about the upcoming target categories. In addition, Figure 15 shows that the sequence of pre-assessed target emotionality ratings was also adequately random.

[7] The magnitude of a linear correlation can be significantly affected by a single outlier.

Thus, it is unlikely that the results can be explained as a result of non-random patterns in target sequences.

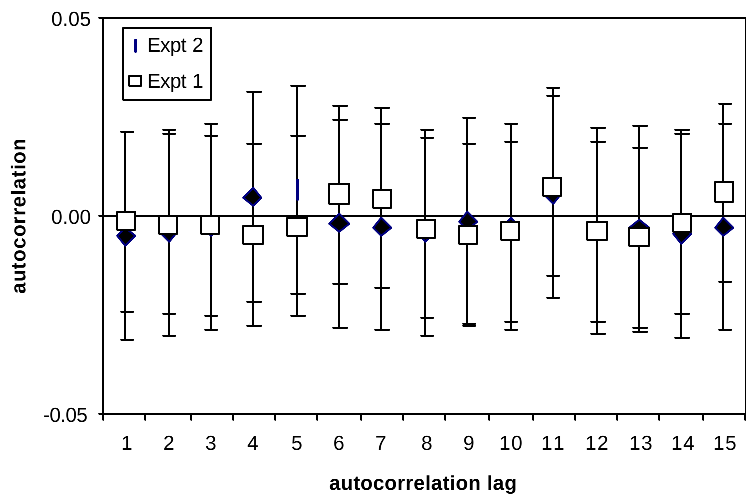

Figure 14. Autocorrelations and one sigma error bars up to lag 15 for the sequence of calm and emotional targets in Experiments 1 and 2. All autocorrelations are within chance expectation.

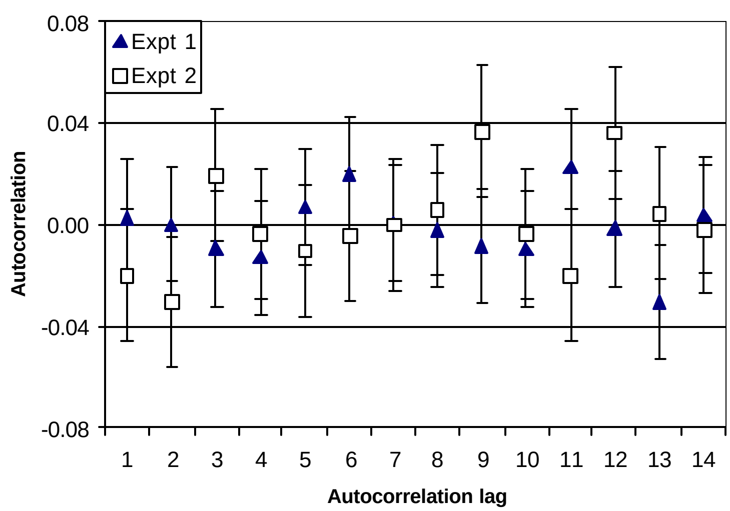

Figure 15. Autocorrelations and one sigma error bars up to lag 15 for the sequence of pre-assessed target emotionality ratings in Experiments 1 and 2. All autocorrelations are within chance expectation.

<u>Anticipatory strategies</u>

Despite the lack of sequence autocorrelations, one may argue that after a few trials, participants might have noticed fewer emotional targets than calm targets. This may have resulted in a conscious or unconscious strategy leading to progressively increased anticipatory arousal after each successive calm target until an emotional picture appeared. At that point, the "statistical counter" in the person's mind would reset to zero, and their arousal level would drop accordingly.

A Monte Carlo simulation was used to study the effects of such a strategy. In the simulation, fifty subjects each observed a sequence of randomly selected emotional and calm trials. As in the actual experiments, trials were randomly selected with a 2:1 calm to emotional ratio. The baseline arousal level in the simulation was set to 0. On each successive trial it was increased by 1 until an emotional trial was randomly selected, at which point it was set back to 0.[8] The difference in average emotional vs. calm arousal levels, for sequences of 14 to 112 targets in a single session, is shown (with one sigma error bars) in Figure 16.

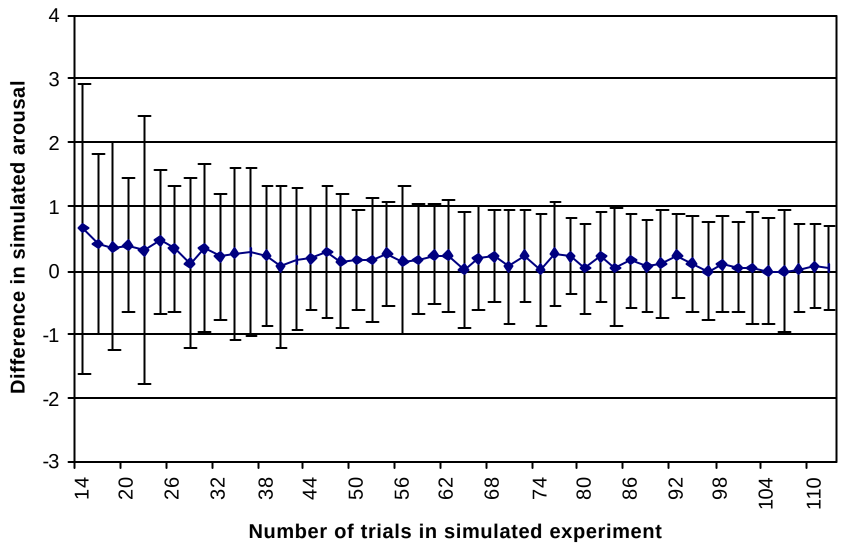

Figure 16. Results of experiment simulating a statistical anticipation strategy. The simulation is based on 50 subjects, each of whom observed from 14 to 112 trials. The ordinate shows the emotional-calm difference in arousal levels.

The results indicate a tendency – under a worse-case scenario – for the average emotional-calm difference to be slightly positive, especially for shorter sequence lengths. However, the error bars indicate that these differences are well within chance expectation, thus it seems unlikely that even a perfectly applied progressive arousal strategy could explain the observed results.

Another way of testing whether this strategy was used is to examine the actual arousal levels observed in these experiments. For example, Figure 17 shows a segment of data from a participant in Experiment 2. This individual showed an independently significant presentiment effect (the same individual's data is shown in the superposed epoch analysis in Figure 3). Figure 17 shows the raw SCL (in μSiemens) recorded over a sequence of 10 trials during this person's session. There is no evidence of systematic arousal occurring in the first nine calm targets. Then,

[8] This simulated strategy is a worse-case ideal, because actual autonomic arousal levels cannot rise indefinitely, nor are arousal levels likely to increase systematically or linearly.

as the tenth, emotional trial begins, a much larger magnitude presponse occurs. This suggests that in this individual no progressive anticipatory strategy was employed.

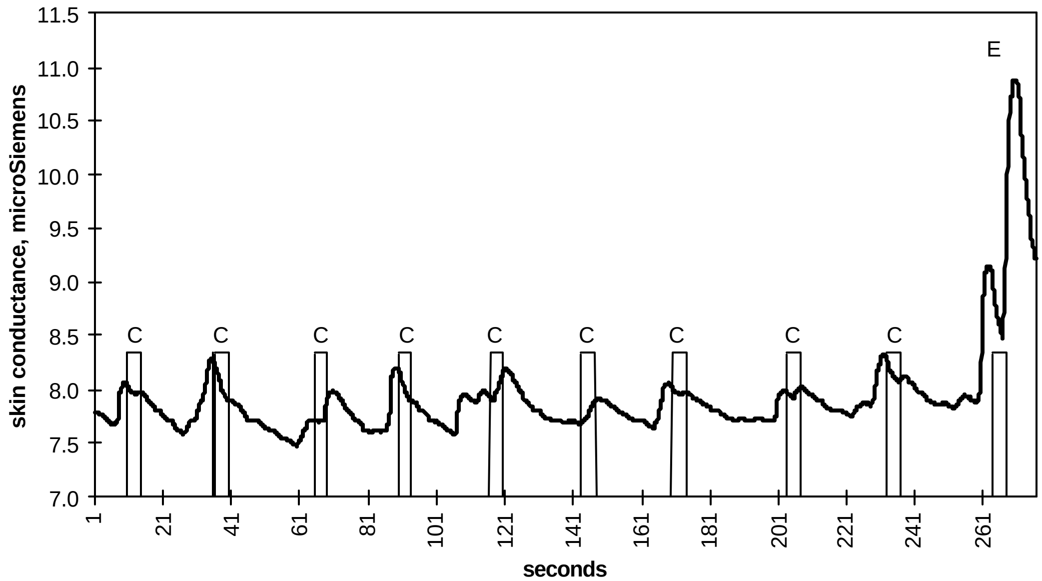

Figure 17. SCL in µSiemens continuously recorded over a sequence of nine calm and one emotional trial, for one individual in Experiment 2. The bars indicate when the stimulus pictures appeared; these are labeled as calm (C) and emotional (E). The large rise in arousal prior to the one emotional target is an example of possible presentiment.

A third way to explore for potential sequential strategies is to examine the mean percentage-change values for SCL in the pre-stimulus period for sequences of targets in the order calm-calm-calm-emotional. To ensure the greatest likelihood of detecting a strategy, only those sessions resulting in independently significant presentiment effects were examined (as measured by $z_{pre} > 1.64$). This included 3 sessions from Experiment 1 and 4 sessions from Experiment 2.

Progressive arousal strategies would predict a monotonic increase in arousal levels, peaking at the emotional target. Figure 18 shows the resulting average arousal levels, indicating that in both experiments no progressive arousal strategy was used, even in participants who showed independently significant evidence for presentiment. Note that in both cases the largest positive arousal levels occurred on the last – emotional – trial.

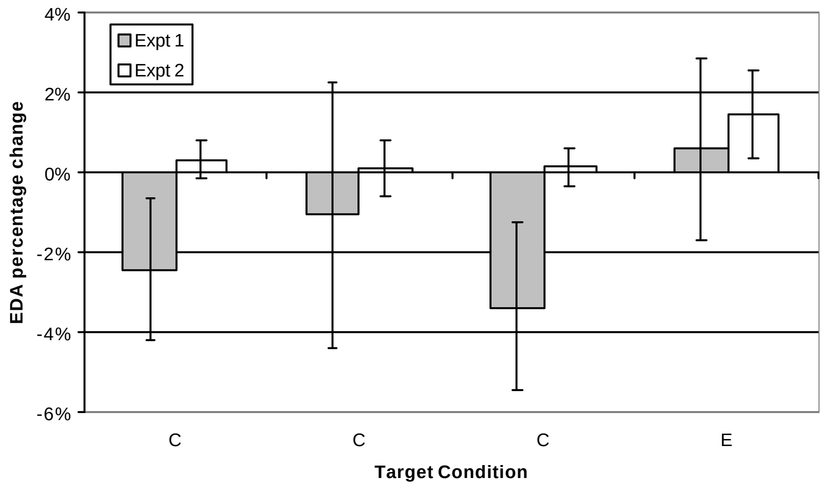

Figure 18. Average pre-stimulus arousal levels, and one sigma error bars, for three individuals in Experiment 1 who showed significant presentiment effects, and for four such individuals in Experiment 2. The arousal levels in the three calm targets prior to the emotional target do not monotonically increase, indicating that a progressive anticipation strategy was not systematically used.

Sensory cues

Sensory cues about the identity of the upcoming target might have biased a participant to respond in the manner observed in this experiment. However, by design the upcoming target was not yet determined during the pre-stimulus period, and thus there was no sensory information available to bias the presponse. In particular, there were no hard-disk-access or other computer activities of any kind before presentation of the stimulus picture.

Dependencies in pseudorandom number generation

It may be argued that because the PRNG seed-number was determined by a combination of momentary physiological values plus the time of the system clock, this might have introduced a dependency between physiology and the random target selection. However, as noted earlier, there were no significant autocorrelations among the sequence of calm vs. emotional targets, or among the emotionality ratings of the targets, and there was essentially a zero correlation between the PRNG seed-numbers and the subsequently generated pseudorandom numbers. Still, one may argue that participants unconsciously learned the relationship between their bodily state, the time they pressed the button to begin a trial (because the current system clock time was also part of the seed-number), and the subsequent target numbers.

There are two arguments against this likelihood. First, there is evidence (Hypothesis 2) that consistent responders' arousal levels were in accordance with the emotionality ratings of the future targets. To produce these results by artifact would have required the participant to learn not only the value of the PRNG seednumber and the numbers generated as a result, but also the relationship between those numbers and the actual target identities along with the emotionality ratings of the selected target, and then to physiologically respond accordingly. And all this has to be accomplished between the last presponse sample and the presentation of the stimulus, a gap of 200 milliseconds in Experiment 1 and 100 milliseconds in Experiment 2. Such a scenario seems most unlikely.

The second argument is that 21 of the 50 trials in Experiment 2 were run using a commercial hardware random number generator (RNG) based on electronic noise.[9] This device has passed Marsaglia's "DIEHARD" suite of randomness tests, one of the "gold standards" used to demonstrate adequate randomness.[10] As shown in Table 10, the results on those trials were similar to the results obtained with the PRNGs. Thus, the precise method of randomization used in these studies apparently did not significantly influence the outcome.

	N	z_{pre}	z_{post}
PRNG	29	-0.19	12.71
RNG	21	0.70	11.33
z difference		0.63	-0.98

Table 10. Comparison of outcomes using pseudorandom (PRNG) and hardware-based truly random number generators (RNG) in Experiment 2.

CONCLUSION

Combined results of two experiments investigating an anomalous anticipatory effect, using different hardware, software, stimuli, and subject populations, confirmed the findings of previously reported studies. Special attention was paid to possible artifactual explanations and no suitable conventional candidates could be found.

If this anomalous anticipatory effect continues to be successfully replicated in future studies, it would suggest that autocorrelations in psychophysiological signals may reflect more than the usual assumption of forward-time causal dependencies. In addition, some form of backwards-time dependencies may also be present. This would imply that the time symmetries commonly described by physicists may occur not only in the rarified realms of exotic physical theory, but also in the more intimate realms of the human psyche.

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[9] Orion random number generator web page: http://valley.interact.nl/av/com/orion/home.html

[10] Marsaglia DIEHARD tests: http://www.csis.hku.hk/internet/randomCD.html

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APPENDIX A: RANDOM TARGET SELECTION

While the time of the initiatory button press combined with the momentary physiological condition were used to determine a PRNG seed-number, without (1) knowledge of that seed-number, (2) knowledge of the PRNG algorithm, (3) a computer, and (4) the relationship between the target numbers and the associated pictures, a participant would have no way of determining the upcoming targets. To further illustrate the lack of a predictable relationship between a given seed-number and the resulting output for the PRNG used in Experiment 1, the PRNG was seeded with an integer, then it was instructed to generate a random number from 1 to 120 (i.e., to simulate uniform random selection of target numbers). This was repeated for seed-numbers ranging between 1 and 5,000, then the correlation was determined between seed-numbers and the subsequently generated target numbers. The resulting correlation was, as expected, essentially zero ($r = 7 \times 10^{-4}$).

After the target picture was randomly selected, it was immediately retrieved from the hard disk and displayed for 3 seconds. Note that through this procedure, from the moment a trial began to just before the stimulus was displayed, the target *was not yet determined*. Therefore, there were no sounds (due say, to movements by the computer's hard disk as it retrieved the digitized target), or electromagnetic changes in the computer monitor display, or any other state-changes prior to display of the stimulus that could have provided sensory cues about the identity of the upcoming target.

In addition, even though participants did not know the exact frequency of calm and emotional targets in the target pool, the picture categories were randomly selected with replacement to prevent statistical hints about the future targets from accumulating over the course of the experiment. To avoid repeating specific target pictures over the course of a session, if the next target selected had already been shown, its category (emotional or calm) was retained and another picture from the same category was randomly selected and displayed. In this way, the *a priori* probability of seeing either a calm or an emotional target was held constant throughout the experiment, and no targets were repeated.

APPENDIX B: RANDOMIZED PERMUTATION ANALYSIS FOR DIFFERENTIAL EFFECTS

To illustrate the RPA method, say that one individual's experimental session of 40 trials resulted in a randomly ordered presentation of 25 calm and 15 emotional targets. For each trial, first we determine percentage difference measures (Δ), as described above. Then for each of the 90 samples (in Experiment 1), we calculate the average of the Δ values across the 15 emotional trials, then do the same across the 25 calm trials. Let's call these average difference values Δ_E and Δ_C. Now we determine the difference between each of the 90 Δ_E and Δ_C values during the pre-stimulus period, i.e., $\delta = \Delta_E - \Delta_C$, and then sum these differences. Call this summed difference $\sum\delta_o$, where the "o" refers to the observed summed difference.

Next, we scramble the original calm vs. emotional target assignments to create 25 new "pseudo-calm" and 15 new "pseudo-emotional" trials. That is, the original data stays the same, but the assignments of which trials were calm and which were emotional are randomly scrambled, retaining the original proportion of 25 calm and 15 emotional. Now we evaluate the data exactly as before, creating average emotional and calm curves, determining the difference between the curves, and forming a summed difference value, $\sum\delta$.

Now we repeat this process to build up a distribution of randomly permuted $\sum\delta$ values. After each new permuted values is generated, we update the mean (μ) and the standard deviation (σ) of the distribution along with a standard normal deviate measure, $z = (\sum\delta - \mu)/\sigma$. The permutation process is repeated until this z score no longer changes at the third decimal place.

This z score, a measure of the difference between emotional and calm physiological responses, can be determined for the pre-stimulus presponse period and for the after-stimulus response period. We will refer to these per participant pre-stimulus differential z score as z_{pre} and to the post-stimulus z score z_{post}. These z scores can now be combined using the Stouffer Z method to provide an overall assessment of pre-stimulus differential presponse or post-stimulus orienting response across subjects (Rosenthal, 1978).[11]

APPENDIX C: RANDOMIZED PERMUTATION ANALYSIS FOR CORRELATION

Hypothesis 2 requires that we determine the statistical significance of the (linear) correlation between pre-assessed emotionality ratings and physiological presponses. To do this, RPA was again used. For each individual, first the correlation was determined between the pre-assessed target emotionality and the SCL percentage difference measure (Δ) for the first physiological sample. Let's call this correlation value $r\Delta_1$. Then the same correlation was determined for the second physiological sample, the third, and so on. Let's call these correlation values $r\Delta_N$. Now we sum the $r\Delta_N$ values for all samples in the presponse period. Call this summed correlation $\sum r\Delta_p$, where the "p" refers to the presponse period.

Next, we scramble the order of the original target emotionality assessments. That is, the original Δ values stay the same, but the emotionality assignments used to determine the $r\Delta_N$ correlations are randomly scrambled. Now we re-evaluate $r\Delta_N$ as before. We repeat this process to build up a distribution of randomly permuted $\sum r\Delta_p$ values, and we continually update the mean (μ) and the standard deviation (σ) of the distribution along with a standard normal deviate measure, $z = (\sum r\Delta_p - \mu)/\sigma$. The permutation process is repeated until this z score no longer changes at the third decimal place.

This results in one per-participant z score for presponse correlation, which we call $z_{pre\text{-}r}$. The same process can be used to determine one z score for post-stimulus correlation, $z_{post\text{-}r}$. These z scores can now be combined using the Stouffer Z method to provide an overall assessment of correlational presponses and responses across subjects.

[11] The Stouffer Z is a standard normal deviate formed by summing z scores and dividing by the square root of the number of summed scores.