

Anomalous Anticipatory Skin Conductance Response to Acoustic Stimuli: Experimental Results and Speculation About a Mechanism

EDWIN C. MAY, Ph.D.,¹ TAMÁS PAULINYI,² and ZOLTÁN VASSY, M.Sc.^{3*}

ABSTRACT

Objectives: The primary aim of this study was to conduct a replication, simplification, and extension of similar previous studies that claimed anomalous anticipatory skin conductance responses prior to various stimuli and to provide sufficient protocol and analysis details in order to foster additional replications. A secondary aim was to provide a testable model in order to understand the observed results.

Design: We used standard skin conductance measures and techniques to search within 50 participants for responses prior to 1-second duration, 97-dB acoustic stimuli, compared to prior to silent controls. We used an interstimulus interval randomly and uniformly distributed between 30 and 50 seconds.

Outcome measures: The dependent variable was the difference between proportions of 3.5-second pres-stimulus intervals prior to acoustic stimuli and prior to silent controls that contained a fully formed, nonspecific skin conductance response (ns-SCR). The null hypothesis was that the proportion difference should be zero.

Results: We found a significant proportion difference of 0.032 ($Z = 2.08$; effect size = 0.077 ± 0.037 ; $p(1t) = 0.0018$), which is a replication of earlier similar studies.

Conclusions: We examined and ruled out a number of potential artifacts that might have accounted for this finding. To understand these results, we demonstrated, by Monte Carlo techniques, that a possible explanation is that experimenters may have used their own intuition to initiate experiment runs to somehow sort otherwise random nonspecific skin conductance responses into appropriate bins in order to mimic physiological responses. We found experimental evidence to support this idea as an operational mechanism. If this speculation is confirmed in prospective studies, then this intuition-based mimicking of effects may profoundly impact the interpretation of results from complementary and alternative medical studies that use statistical inference to assess outcomes.

INTRODUCTION

Vassy conducted what he conceived of as a classical, but remote, conditioning experiment in the 1960s, which was reported much later.¹ In that experiment, a sender, who was sensorially isolated from a receiver, was shown a randomly determined light flash as a signal to “transmit” a telepathic warning message (i.e., a putative conditioned stimu-

lus) to the receiver that he or she was about to experience a mild electric shock (i.e., unconditioned stimulus) in their left hands, while their skin conductance was monitored continuously in their right hands. The stimuli timing was such that if there were to be a conditioned response to the telepathic conditioning stimulus, it would appear before the unconditioned stimulus and a few seconds before the well-known unconditioned response.² Using manual and graphi-

¹Laboratories for Fundamental Research, Palo Alto, CA.

²Szintézis Szabadegyetem, Budapest, Hungary.

³Aion Foundation, Budapest, Hungary.

*The author order is alphabetical, and the research and its successes were contributed equally by all.

cal methods of analysis, Vassy analyzed 10 sender-receiver sessions and found that six pairs were individually significant at the $p < 0.01$ level. While impressive, these results were obtained with visual meter readings and not with state-of-the-art equipment and techniques. However, the experiment was repeated in 2002 with 50 sender-receiver pairs and showed significant evidence ($p < 0.01$), in the first of three series, of what appeared to be a telepathically conditioned response.³ Subsequent series, however, with some changes of equipment and protocol, did not produce significant effects. Another interpretation of such significant effects might be that receivers may have been responding in advance (i.e., anticipation) to future electroshock stimuli.³

Radin and Bierman began investigating and observing significant anticipatory differential orienting effects in skin conductance responses prior to emotional and neutral photographic stimuli.⁴⁻⁶ Radin coined the term *presentiment* to describe this type of orienting effect.

More recently, significant anticipatory effects were observed not only with skin conductance measures but also with electroencephalogram and electrocardiogram measures.^{7,8}

We believe there may be a complication that might confound the interpretation of all of the presentiment results—photographic, cognitive stimuli can elicit idiosyncratic responses. For instance, a photographic stimulus that has been previously rated as having a low average affectivity may have, for some individual participants, a large affectivity, and vice versa. This reduces the contrast between arousing and calming presentations and constitutes an unwanted source of variance in these designs.

May and Spottiswoode adopted a different approach to remedy this possible confounding. They replaced the emotional visual stimuli with acoustic startle stimuli and vastly simplified the analysis. Their dependent variable was the difference of proportions of prestimulus intervals that contained fully formed, nonspecific skin conductance responses (ns-SCR) prior to acoustic stimuli, compared to prior to silent controls. The null hypothesis was that these proportions should be equal. The first 105 participants of 125 reported later⁹ were considered a pilot study. After trying a number of different approaches and parameters, they found mean proportions of 0.099 and 0.064 before acoustic stimuli and silent controls, respectively. Instead of an expected ratio of 1.0, they found a ratio of 1.53 ($Z = 2.84$; effect size = 0.086 ± 0.030 ; $p(1t) = 0.002$).*

In a 100-participant formal follow-up study,[†] they reported proportions of 0.162 and 0.087 prior to acoustic and control stimuli, respectively, for a ratio of 1.87 ($Z = 5.08$; effect size = 0.162 ± 0.032 ; $p(1t) = 1.79 \times 10^{-7}$).

The results of these anticipatory studies imply a particular mechanism; individuals somehow appear to be able to respond psychophysiological, in advance, of cognitive arousing or acoustic startle stimuli. However, we suggest an alternative interpretation that involves an anomalous anticipatory effect in such a way as to mimic physiological responses.

METHODS

Our approach was a modification of standard skin conductance methods that were used in the previous acoustic prestimulus response studies.

Skin conductance and other hardware

We used an SC5-SA skin conductance monitor (Contact Precision Instruments, Boston, MA). This unit is specified to have an absolute accuracy of $\pm 0.1 \mu\text{Siemens}$, a DC excitation voltage of 0.5 V, a constant sample rate of 40 samples per second, a 24-bit precision, and a relative accuracy of $5.96 \times 10^{-6} \mu\text{Siemens}$. The unit contains a hardware low-pass filter with an upper cutoff frequency of 10 Hz to prevent aliasing.

The electrodes used were 12-mm Ag/AgCl (Med Associates St. Albans, VT TDE-022SN) and were applied with an electrode paste of 0.5% saline in a neutral base (Med Associates TD-246). The electrode surface, which was surrounded by a 2-mm-high Teflon rim, was covered with a film of electrode paste even with the rim, and the electrodes were fastened to the distal phalanges of the first and second fingers of the nondominant hand by a loop of adhesive skin tape. The electrode cables were secured to the palm by a third piece of tape to minimize any mechanical motion being transmitted to the electrodes.

We used high-quality, active, noise-canceling headphones.[‡]

Stimuli

Unlike earlier studies, no acoustic stimulus was repeated throughout the run. A few examples included: air raid signal; ambulance; machine gun; and white noise.[§]

The acoustic startle stimuli were examined with an audio editing program and adjusted to provide an approximate 97-dB intensity with a 1-second duration. Controls (i.e., null stimuli) were markers placed into the skin conductance data stream and did not have an associated audio file. To eliminate possible extraneous sources of stimuli, the participant wore sound-isolating headphones during the trial, ensuring a low background sound level during the experiment sessions.

At the start of the data collection code, a list of 20 possible stimuli was randomly ordered and each successive acoustic stimulus was taken, in turn, from the randomized list. In this way, we assured that no acoustic stimulus would be repeated and that each participant would receive a personalized order of stimuli.

*The effect size is defined here as the proportion Z-score divided by the square root of the number of acoustic stimuli.

†May EC, Spottiswoode SJP. Anticipatory Effects in the Human Autonomic Nervous System. In preparation.

‡Sony Model MDR-NC5.

§Full stimuli details are available from the authors.

In this study, the interstimulus interval (ISI) was uniformly and randomly distributed between 30 and 50 seconds for a mean ISI = 40 seconds, using the Marsaglia (FSU, FL) pseudorandom number generator.¹⁰ The total number of stimuli for each participant was 30, and no attempt was made to counterbalance the types.

At the end of a particular ISI, the stimulus type was determined by electron-shot noise within a nonalgorithmic, nondeterministic random number generator that was developed in the physics department at Ulm University in Ulm, Germany.¹¹ This device, and its associated driver software, passed the "Gold Standard" for random number generators—The DieHard tests.⁹ If this generator returned a binary one, an acoustic stimulus was presented; if it returned a binary zero, a silent marker into the skin conductance data stream was generated.

Software

The data collection code, which ran on a Sony VAIO laptop, was coded in Microsoft's Visual Basic language. Skin conductance data were transferred from the serial port buffer into the computer memory at each stimulus opportunity. After the data were stored in memory, the hardware generator described above determined the stimulus type of the next stimulus. The analysis software was coded in the Research Systems, Inc., 4th generation, vector-processing computation language, IDL.¹² The next acoustic stimulus file was loaded in memory during the poststimulus period of the previous acoustic stimulus.

Analysis

The dependent variable was the difference between proportions of the number of 3.5-second prestimulus regions prior to future acoustic and control stimuli (i.e., p_a and p_c , respectively) that contained a single ns-SCR.

The standard relation for the Z-score for the difference between two proportions is given by¹¹:

$$Z = \frac{p_a - p_c}{SD}$$

where the standard deviation, SD, is given by:

$$SD = \sqrt{p(1-p) \times \left[\frac{1}{N_a} + \frac{1}{N_c} \right]}$$

and p is given by:

$$p = \frac{p_a N_a + p_c N_c}{N_a + N_c}$$

¹¹Details on this generator may be found at <http://hlhp1.physik.uni-ulm.de/~freitag/spinoffs.html>

⁹See <http://stat.fsu.edu/~geo/diehard.html> for information and source code of these tests.

¹²Details of interactive Data Language can be found at www.rsinc.com

For this type of analysis to be valid, the proportions, p_a and p_c , must be random variables; that is, they must be statistically independent. Even though ns-SCRs within a given participant arguably might not be independent, the necessary random element is provided by the stimuli timing and stimulus type. So, regardless of any putative lack of statistical independences owing to the ns-SCRs, the proportions are independent, and the proportion difference is not artifactually different from zero under the null hypothesis.

ns-SCR definition and detection

Figure 1 shows a ns-SCR from an acoustic prestimulus sample from one of the participants in our study.

Using the cubic spline routine from the Research Systems, Inc. IDL library, we downsampled the data by a factor of five and constructed a spline approximation to that data. Then, using the same routine, we upsampled the resulting spline and created a final spline approximation shown as the solid line in Figure 1. One property of a cubic spline is that the first derivative is well behaved. Therefore, we used standard calculus techniques to determine minima and maxima within a given prestimulus region.

Conservatively, we specified that the following conditions must be met before we would declare that a ns-SCR had been detected.

- A single minimum must be followed by a definitive maximum. That is, the first derivative of the skin conductance data must be zero at the maximum.
- The amplitude of the ns-SCR must meet or exceed a given participant-dependent threshold.

To determine the threshold, a participant's total skin conductance record was scanned for ns-SCRs; however, an in-

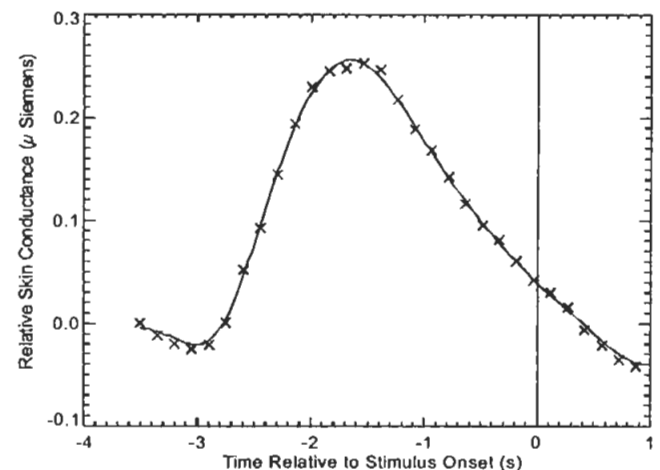


FIG. 1. Example of data smoothing and cubic spline fit. The ×'s represent every fifth data point and the solid curve is the spline approximation.

terval between -7 and $+10$ seconds was excluded around each stimulus marker. The threshold was set at 10% of the average of all ns-SCRs above a floor of $0.005 \mu\text{Siemens}$. The 10% value was arbitrary, but earlier studies demonstrated that the results were independent of the threshold, and, as we will show below, the results of this study were also independent of the threshold choice.

Data inclusion criterion

Because the stimulus types were random but not counterbalanced, we required that a participant's data would not be included if either stimulus type exceeded 20 (i.e., 20 of one stimulus type of 30 is significant at $p = 0.049$).

Participant selection

All participants were recruited as volunteers from the student body of the Szintézis Szabadegyetem ("Synthesis" Free University) in Budapest, Hungary. This school specializes in the study of various parapsychological, and more esoteric, phenomena.

Trial protocol

All trials were conducted in the school's laboratory facility. The laboratory is acoustically isolated from the control room and is often used in sensory isolation experiments.

A participant entered the facility and was offered refreshments and pleasant conversation. Then one of the two experimenters (i.e., Vassy or Paulinyi) invited the participant to rinse their hands in water (no soap), dry them thoroughly, and enter the laboratory. While the skin conductance electrodes were being applied to the subdominant hand (see above), the experimenter described the upcoming session in detail. The participant was shown their skin conductance changes resulting from rapid deep breaths and a surprise hand clap. In addition, they were given a sample sound (not from the set of experimental stimuli) through the headphones and given the opportunity to quit if the sound was too uncomfortable. They were advised on the use of a "panic" button to exit the run if necessary. The experimenter emphasized in this way that participants were in charge of the session and could quit at any time.

All of this activity was designed to last approximately 10 minutes to allow the electrode and electrode cream to nor-

malize with the participant's skin. The participant was advised to keep his or her eyes closed during the session; that they would hear a voice message informing them when the session was complete; and that the run would automatically begin 2 minutes after the session was initiated by the experimenter. The experimenter left and secured the door to the laboratory.

At the end of the session, the participant was immediately shown the statistical results, individual stimuli examples, and their poststimulus responses. These data were discussed in the best possible terms.

RESULTS

We conducted the experiment with 50 self-selected participants, of which 33 were female. Ages ranged from 17 to 74 years, with a mean and median of 38.4 and 37.0 years, respectively. We excluded no individuals from this study.

Table 1 shows the results of the primary analysis.

The null hypothesis was that the proportions should be equal (i.e., a ratio of 1.0); but as Table 1 shows, we observed a ratio of 1.39 (Proportion difference $Z = 2.08$; $n = 725$; effect size = 0.077 ± 0.037 , $p(1t) = 0.0018$). The effect size was defined as the proportion difference Z-score divided by the square root of the number of acoustic stimuli. In this experiment, Vassy was the experimenter for 21 people with a total of 302 acoustic stimuli (Proportion Z-score = 1.33; effect size = 0.0766 ± 0.0575), while Paulinyi was the experimenter 29 people with a total of 475 acoustic stimuli (proportion Z-score = 1.59; effect size = 0.0775 ± 0.0486). Thus, the overall result was equally contributed by the two experimenters, Paulinyi and Vassy (difference t -score = 0.0122; $df = 773$; $p = 0.495$).

At the participant level, the Stouffer's Z for the 50 sessions was 2.017, leading to a session effect size of 0.285 ± 0.141 .

DISCUSSION

We compared this result to the original 105-pilot dataset, because those participants were unselected and the experimenters were new to this type of study. This parallels the

TABLE 1. FORMAL STUDY RESULTS

Interval type	Number of intervals containing an ns-SCR response	Number of prestimulus intervals	Proportion with an ns-SCR response
Before a control	63	775	0.081
Before a stimulus	82	725	0.113

ns-SCR, nonspecific skin conductance responses.

TABLE 2. STUDY COMPARISON

Item	105-Pilot	50-Budapest
Number of stimuli	1106	725
Intervals with ns-SCRs	109	82
Proportion with ns-SCRs	0.0986	0.1131
Number of controls	994	775
Intervals with ns-SCRs	64	63
Proportion with ns-SCRs	0.0644	0.0813
Ratio (MCE = 1)	1.53	1.391
Proportion Z-score	2.84	2.08
Effect size	0.086 ± 0.030	0.077 ± 0.037
p-value	0.0002	0.0018

ns-SCR, nonspecific skin conductance responses.

results reported in this study, as one of us (May) was not an experimenter, and Paulinyi and Vassy were also new to this type of study.

Table 2 shows the results for the two datasets.

The difference between the two study effect sizes is not significant ($t = -0.188$; $df = 1829$; $p = 0.575$). The study reported in this article is a conceptual confirmation of the results from the pilot study. Table 3 outlines the protocol differences between the two studies.

Possible alternatives to the primary hypothesis

In this section, we examine a number of possible artifacts that might account for the observed deviation from chance expectation.

Expectation. Possibly the most obvious artifact might be that of a participant's expectations. The acoustic stimuli could be experienced as unpleasant aversive stimuli. That is, as the session may evolve with long periods of silence, a participant might produce more ns-SCRs from anxiety over time and somehow skew the counting statistic. Given an acoustic stimulus, if the distribution of times to the next acoustic stimulus were statistically identical to the distribution of times to the next silent control, no expectation artifact, regardless of type or magnitude, could contribute to the differential outcome measure.

Figure 2 shows the distribution of times to the next acoustic stimulus and the next control stimulus.

Given an acoustic stimulus, the mean of the distribution of times to the next acoustic stimulus was 80.89 sec and to the next control was 82.04 sec (Mann-Whitney $U Z = 1.045$; $p = 0.148$). The distributions of these times were statistically equivalent (Kolmogorov-Smirnov, $p(1t) = 0.398$). Thus, an expectation artifact could not have produced the observed results.

However, this argument does not consider whether there was an expectation bias. To address this question, we computed the probability of a ns-SCR as a function of time to the next acoustic stimulus and separately to the next control. Figure 3 shows a graphical result for the probability of a ns-SCR prior to an acoustic stimulus as a function of time since the last acoustic stimulus.

The slope of the weighted best fit line was $(1.38 \pm 2.78) \times 10^{-4}$. Similarly, the slope of the weighted best fit line for the probability of a ns-SCR prior to a control as a function of time since last acoustic stimulus was $(2.33 \pm 3.37) \times 10^{-4}$. We note that a zero slope (i.e., no expectation bias) is well within the standard errors. Therefore, as the distribution of times to the next acoustic stimulus and to the next control from the last acoustic stimulus were statistically equivalent and, thus, rendered an expectation bias moot, the results shown in Figure 3 and their associated analyses show there was no bias present.

Stimulus type generator. In this study, there were 725 acoustic stimuli and 775 controls (Binomial Z-score = 1.29; $p = 0.098$, effect size/stimulus = 0.033 ± 0.0259). A possible artifact might arise if there were sufficient information in the actual stimulus sequence to allow a participant to infer the next stimulus.

We address this question first by computing the autocorrelation of a 1500-bit representation of the actual in-sequence stimuli type where a 1.0 represented an acoustic stimulus and a 0.0 a control. The result is shown in Figure 4.

We computed the autocorrelation for ± 30 lags because that is the only amount of stimuli presented to a single participant. The largest correlation occurred at lag = 30 ($r = 0.069$; $df = 1498$; $p(2-t) = 0.0056$) and the smallest at lag = 23 ($r = -0.0711$; $df = 1498$; $p = 0.0058$). Two lags in 30 produced a significant $p \leq 0.05$ correlation (Binomial $p = 0.446$).

A second approach was to compute the informational entropy in the 1500-bit sequence. We found that the informa-

TABLE 3. PROTOCOL COMPARISON

Item	Pilot	Budapest
Number of participants	105	50
Interstimulus interval	60 ± 20 Seconds	40 ± 10 Seconds
Stimuli	White Noise	Nonrepeating acoustic
Experimenters	May/Spottiswoode	Vassy/Paulinyi
Culture/participants	American	Hungarian
Study duration	79 days	10 days

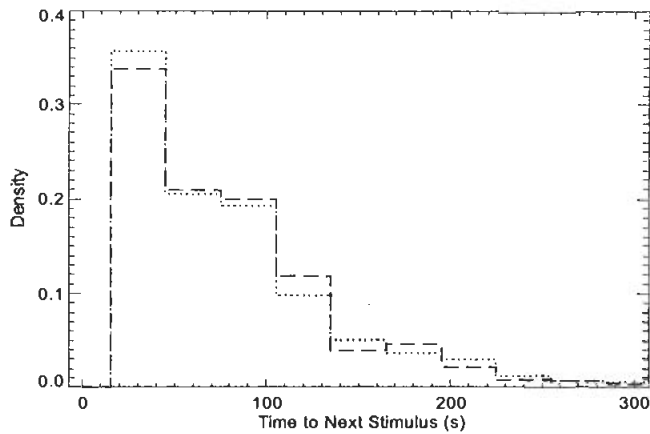


FIG. 2. Distribution of times to the next stimulus. The dotted curve is the distribution of times to the next acoustic stimulus and the dashed curve to the next control.

tion was 0.992 bits/bit. That is, it nearly took a single bit to describe each bit in the sequence. This result, coupled with the autocorrelation shown in Figure 4, precludes the stimulus generator as a possible source of artifact.

Choice of threshold for ns-SCR detection. Based upon previous work,⁹ we used a threshold of 10% of the mean amplitude of all ns-SCRs above a floor of 0.005 μ Siemens far from all overt stimuli. It is possible that this choice of participant-dependent threshold might have been fortuitous. We examined the proportion difference effect size as a function of the threshold percentage from 1% to 50%. The results are shown in Figure 5.

The vertical solid line shows the value used in this study. By inspection, our choice of 10% for the threshold did not induce an artifact.

Two competing hypotheses for the results

The primary hypothesis for this study was that an individual's autonomic nervous system responds, in advance, more to future acoustic startle stimuli than to silent controls. However, a second hypothesis is more subtle.¹²

To understand Decision Augmentation Theory (DAT), we begin with a hypothetical, yet simple, idea. Consider a coin flipper that consecutively flips a fair coin 1 million times. By definition of a random binary sequence (i.e., heads or tails), there will be subsets of the million flips that appear not to be random. For example, a run of 10 heads in a row is half as likely as nine in a row, and so on. Runs of heads of various lengths will be randomly positioned in the million-flip sequence. Suppose now that one is asked to *decide*, by physically looking at the whole coin-flip sequence, when to start counting the next, say, 1000 coin flips such that there would be significantly more heads than expected.

In this example, one would only need to find 27 excess heads (over the expected 500) to locate a significant sequence, and the decision of where to start counting would be reached by physically examining the data.

DAT holds, in general, that people might somehow use their intuition (instead of looking at the data) to statistically bias their decisions toward favorable outcomes. If DAT were possible, then drug trials—or any experiments that use statistical inference to assess results—might contain a researcher-induced component that would mimic the desired outcome. In random, controlled drug trials, for example, an improper randomization of patients—such as not randomizing on severity of disease—might erroneously lead to the conclusion of the efficacy of a test drug; whereas, all that was happening was an unfortunate statistical grouping of the ill patients into the placebo control group, and the healthier patients into the treatment group, and that statistic would mimic an efficacious drug that actually was not.¹³ In this second example, DAT proposes that some form of intuition on the part of an experimenter may induce a weak statistical systematic bias into the patient-selection process to mimic drug and/or treatment efficacy.¹⁴

In the skin-conductance experiment reported in this paper, ns-SCRs are quite rare. The overall most likely lability (i.e., probability of observing a single ns-SCR in any 3.5-second period) was 0.031. Additionally, the stimuli were also relatively rare, with an ISI = 40 ± 10 seconds. If an experimenter's intuition was subjected to DAT, then it might be "easier" to initiate a run to avoid a ns-SCR in the pre-stimulus window than to capture one, because so much of the skin conductance data was devoid of ns-SCRs. This speculation was confirmed by extensive Monte Carlo simula-

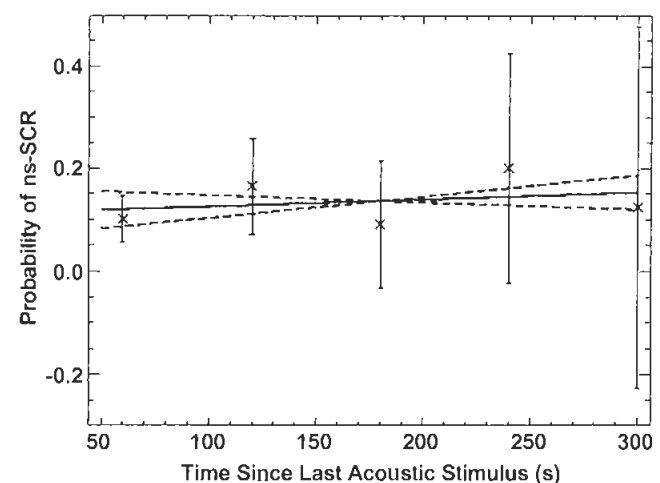


FIG. 3. Probability of a ns-SCR as a function of time since last acoustic stimulus. The solid line is the weighted best fit to the data, and the dashed lines are the one standard error in the slope. The one standard error for each of the data points are shown as error bars. ns-SCR, nonspecific skin conductance responses.

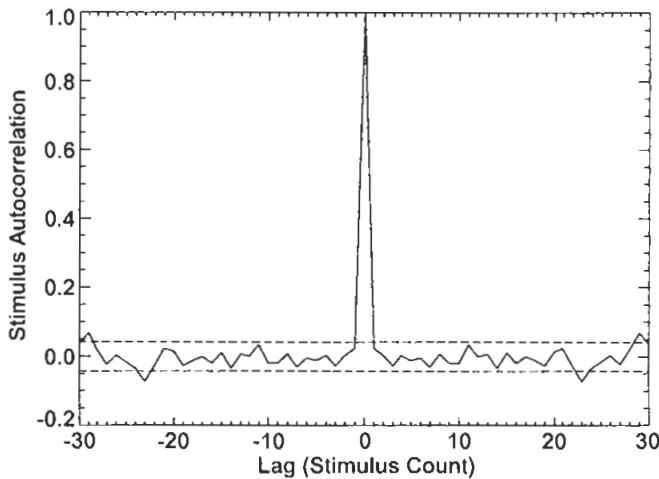


FIG. 4. Autocorrelation of stimulus type as a function of stimulus count. The dashed lines are the critical value for a significant correlation (i.e., $r = 0.0425$; $df = 1498$).

tions. If this form of DAT were present in actual experimental data, it would predict that the significant proportion difference in the anticipatory skin conductance experiment reported above would contain a component that the rate of ns-SCRs in control periods would be *below* that of the rate of the general background ns-SCR rate.

To check this, *post hoc*, we computed an average background ns-SCR rate for each participant as follows. We defined eight 3.5-second intervals near each silent control stimulus. These included four intervals post silent control and four intervals prior to the actual prestimulus interval. The average background rate was computed over $8 \times$ the number of silent controls. Thus, for each of the 50 participants

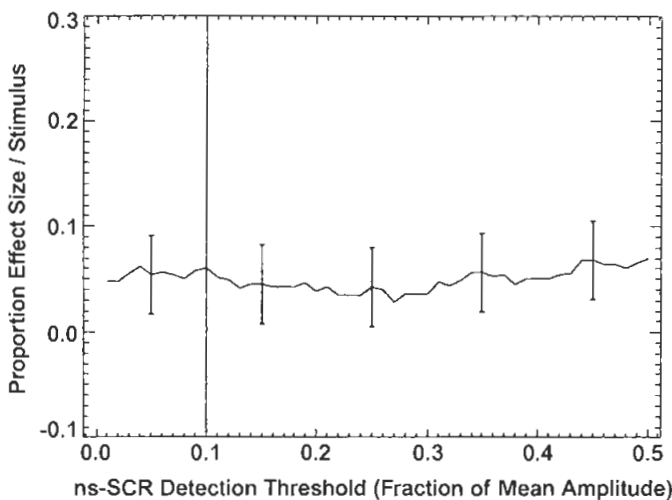


FIG. 5. Threshold sensitivity. The error bars are the one standard error of the equivalent effect size. ns-SCR, nonspecific skin conductance responses.

we computed: p_1 , the ns-SCR rate prior to an acoustic stimulus; p_0 , the ns-SCR rate prior to a control; and p_b , the background rate described above.

We computed paired t tests between p_1 and p_b and between p_0 and p_b . The preacoustic ns-SCR rate was statistically indistinguishable from the background rate ($t(49) = 0.163$; $p(1t) = 0.436$); however, the precontrol rate was significantly below the background ($t(49) = -2.87$, $p(1t) = 0.003$). This result appears to verify the DAT prediction above.

In contrast, we might expect a physiological model to give the reverse: $p_1 > p_b$ and $p_0 \approx p_b$. That is, an individual would be reacting, albeit in advance, to a stimulus and not reacting to a nonstimulus or control.

It seems unlikely that a physiological interpretation could account for a depletion of ns-SCRs prior to null stimuli. This would require not only for an experiment participant to use intuition to know when a randomly determined and uncued control stimulus was about to occur but at the same time, willfully, either consciously or unconsciously, inhibit a ns-SCR for 3.5 seconds in anticipation of the control.

CONCLUSIONS

We successfully replicated the earlier work with regard to acoustic stimuli prestimulus response. That is, there is clear evidence for an anomalous preferential anticipatory skin conductance response prior to acoustic stimuli, compared to prior to controls. However, the primary hypothesis that individuals are responding in advance to startle stimuli is unlikely to be the case. Rather, there is suggestive experimental and circumstantial evidence that experimenters use their own intuition to sort random ns-SCRs in order to mimic a physiological response—Decision Augmentation on the part of the experimenters. If the significant result from this rather straightforward psychophysiology experiment can be explained by intuition on the part of the experimenter rather than physiological responses on the part of the designated experiment participant, then, so also, should any statistical inferential results from any study, including those of interest to alternative and complementary medical investigations, be questioned, at least with regard to interpretation. A prospective study is needed to settle the question definitively with regard to DAT and prestimulus response.

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Address reprint requests to:

Edwin C. May, Ph.D.

Laboratories for Fundamental Research

415 Cambridge Avenue

Suite 3

Palo Alto, CA 94306

E-mail: May@LFR.ORG