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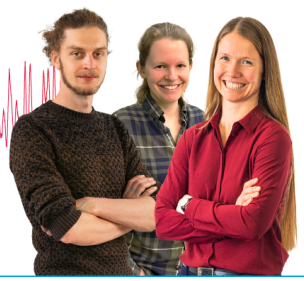

Prediction of Truly Random Future Events Using Analysis of Prestimulus Electroencephalographic Data

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Abstract. Our hypothesis is that pre-stimulus physiological data can be used to predict truly random events tied to perceptual stimuli (e.g., lights and sounds). Our experiment presents light and sound stimuli to a passive human subject while recording electrocortical potentials using a 32-channel Electroencephalography (EEG) system. For every trial a quantum random number generator (qRNG) chooses from three possible selections with equal probability: a light stimulus, a sound stimulus, and no stimulus. Time epochs are defined preceding and post-ceding each stimulus for which mean average potentials were computed across all trials for the three possible stimulus types. Data from three regions of the brain are examined. In all three regions mean potential for light stimuli was generally enhanced relative to baseline during the period starting approximately 2 seconds before the stimulus. For sound stimuli, mean potential decreased relative to baseline during the period starting approximately 2 seconds before the stimulus. These changes from baseline may indicated the presence of evoked potentials arising from the stimulus. A P200 peak was observed in data recorded from frontal electrodes. The P200 is a well-known potential arising from the brain's processing of visual stimuli and its presence represents a replication of a known neurological phenomenon.

INTRODUCTION

Experimental work on physiological retrocausality appears to be obtaining positive results (1). To better understand the nature of physiological retrocausality, we are conducting an experiment on electrocortical evoked potentials using EEG. If the human brain responds to truly random stimuli which occur in the future of a measurement, it could be considered evidence of a retrocausal effect. Because the stimuli are selected using a quantum process, according to standard quantum mechanics no information about the upcoming stimulus should exist prior to the time of wavefunction collapse.

Previous experiments have detected pre-stimulus effects via EEG potential measurements preceding random stimuli (2, 3). To expand on this work we are conducting an experiment measuring electrocortical evoked potentials in the general population using non-selected subjects. Subjects are recruited online with the conditions that they be over 18 years of age and free of neurological disorders. They are told this experiment's purpose is to measure the brain's reaction to light and sound stimuli in order to help create a predictive system. As of this paper, 8 subjects out

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of a planned 50 have been tested. This experiment is designed to establish a baseline measurement in preparation for further experiments measuring pre-stimulus evoked potentials prior to truly random stimuli in both selected populations such as meditators (3) and which use neurofeedback (4). Furthermore, real-time analysis of EEG data may allow quantum events to be predicted in advance, which would affect interpretations of quantum mechanics and our notions of causality.

Our experiment flashes a light in a darkened sound booth or rings a loud buzzer. The selection is based on the output of a quantum random number generator immediately before the stimulus starts. The experimental procedure for the light stimulus part of our experiment was suggested over 55 years ago (5).

Hypothesis

Our hypothesis is that prestimulus physiological data such as EEG can be used to predict random which are mapped to stimuli. The experiment reported here is a preliminary exploratory experiment to be followed by further experimentation studying whether various parameters such as meditation experience or stimulus duration affect the ability to make predictions using prestimulus data.

PROCEDURE

Our experiment is designed such that it is impossible for research subjects to gain knowledge of upcoming stimuli through either inference from sensory information or any other causal strategy. To this end, stimuli are chosen using a quantum random number generator (qRNG), the Quantis manufactured by IDQ Quantique. Light, sound, and null (no stimulus) stimuli are selected with equal probability by the qRNG immediately before the start of the stimulus. Therefore, according to standard physics no information about the stimulus should be expected to exist prior to stimulus selection. EEG recordings (see **Data Recording** section) proceeding each stimulus are analyzed in order to find correlations with the future selected stimulus.

Stimuli and Questionnaire

The monitor of a Lenovo Thinkpad T530 laptop computer is used to display the light stimuli. Light stimuli last approximately 0.6 seconds and change the light before the subject from 0 lux to 16 lux. The computer runs a background program in Qt displaying a white screen throughout the experiment but the monitor is powered off except during light stimuli. The effective monitor size is approximately 34.3 cm wide and 19.1 cm tall. The subject sits approximately 41 cm from the screen.

The same computer controls sound stimuli via use of a relay. Sound stimuli are produced by a buzzer (SV4 manufactured by Velleman) connected in series with the USB-controlled relay (SRD-05VDC-SL-C manufactured by SONGLE) and a 5V USB power-source connected to the stimulus computer. Sound stimuli are triggered by sending a system command to the relay to close the circuit. This causes the buzzer to ring until the end of stimulus is reached and the circuit is opened. The duration of sound stimuli is approximately 1.2 seconds and changes the sound intensity in the experimental area from 32 dBa to 98 dBa for the duration of the stimulus.

Time durations for both light and sound stimuli were arbitrarily chosen but were selected to be different lengths in order to provide a means to distinguish the stimuli in the digital channel recording (see sub-section "*Digital Channel"* under **Data Recording**). Future experiments will explore the effects of different stimuli lengths and intensities.

Stimuli intensity are measured prior to experiment using a Single Range Datalogging Sound Meter and a Visible Light SD Card Datalogger, both manufactured by Sper Scientific.

In order to increase psychological contrast between non-stimulus conditions and stimuli conditions, the research subject sits in a dark and sound-shielded booth ("sound booth"). The sound booth is of interior dimensions 1 meter wide by 2 meters deep. The sound booth is a PRO30 model manufactured by PUMA Soundproofing. Two extra layers of foam (~2.5 and ~3 cm thick) and one layer of acoustic fiberglass panel (~5 cm thick) were placed on two sides of the sound booth to provide additional shielding in the direction of a neighboring tenant. The sound-shielding is tested during pilot tests and during the experiment by asking the tester or subject, respectively, after the sessions whether outside sounds could be heard. If outside noises (sounds other than the buzzer and white noise) could be heard, data is marked as bad. This question is asked if the two experimenters present hear any sounds emanating from outside the laboratory (the experimenters maintain quiet themselves during data-taking). Based on reports from testers and

experimental subjects, outside sounds do not penetrate the sound booth during normal laboratory hours. Background white noise was measured to be 32 dBa.

Two methods can be used to check whether subjects are falling asleep: a questionnaire asking about alertness levels and a check on eye-blink artifacts in the frontal EEG channels. As of the writing of this article, alertness measures and eye blinks have not yet been analyzed.

Timing

The experimental subject sits in front of a monitor inside the sound booth. At the beginning of each of session, a start screen requests a key press to begin the stimulus program. Once a key is pressed, the monitor is powered off and the stimulus program executes. At the end of a session, the computer beeps three times and the monitor is powered back on. Experimental sessions consist of blocks of 20 trials, between which subjects record their alertness level on the questionnaire. Each trial lasts between 28 and 32 seconds, the length being somewhat randomized to reduce any anticipation effects connected to a generic stimulus. There are four sessions in total. Filling out the questionnaire, checking on the subject, and saving the data file takes approximately 2 minutes. The exception is if the BIOPAC AcqKnowledge program which runs the EEG data acquisition fails to start. Then the gap may be several minutes while the experimenters restart the program.

Questionnaire

A questionnaire is presented to the research subject at the beginning of the experiment and immediately after each of the four sessions. At the beginning of the experiment, the subject will write down their age, gender, and estimated hours of lifetime meditation experiment. Studies (2) and (3) showed that gender and mediation experience affect pre-stimulus response. The final analysis will test these previous results after collections of all data.

Data Recording

Acquisition from EEG Electrodes

Experimental subjects are fitted with an EEG headcap (BIOPAC MB-32EEG-CAP-A) with 32 electrodes. This headcap's electrodes use paper-cotton strips soaked in water to make electrical connection with the scalp. Data is taken using a BIOPAC Mobita Amplifier which communicates with the BIOPAC AcqKnowledge analysis program running on a Windows 7 HP ENVY desktop computer. The acquisition rate is set to 250 samples/second. No filtering was used for any results reported in this paper.

Digital Channel

The Mobita amplifier contains a digital channel. The digital channel is used to mark the durations of stimuli via use of analog voltage signals. Since sound stimuli have longer durations than light stimuli, stimuli were identified by digital signal length in addition to being recorded by the stimulus control program. The digital channel records the voltage arising from Monocrystalline solar cells (7.2V / 100mA manufactured by OSEPP) during light stimuli in order to measure their durations. In order to measure the duration of sound stimuli, the digital channel also measures the voltage in parallel across the buzzer circuit. The digital signal representing the null stimulus is also created using monocrystalline solar cells. The solar cells and computer monitor used for the null channel signal are a copy of the light stimulus set-up but placed in a location hidden from the research subject (the subject cannot see light from the computer). The length of the null stimulus is much longer (approximately 2.15 seconds) compared to the light stimulus (approximately 0.6 seconds) so the analysis program can mark time epochs surrounding a null signal as control data.

The mastoid position (behind the ears) is used as the reference for EEG data. The ground channel is attached to the subject's wrist via use of a metal ESD wristband.

Artifacts

Glitches in EEG data collection including sudden changes in impedance and electrostatic discharges may create artifacts in the EEG potential. If any electrode records a change of 1 mV over 1 second, the trial is marked as having an artifact and is not included in means of potential or estimates of identification rates.

Data Integrity

Pre-Registration

In order to limit biases arising from optional stopping or mid-course procedural changes, a pre-registration was submitted to the Koestler Parapsychology Unit describing the procedure and specifying the target number of experimental subjects to test (50). As of the writing of this paper 8 out of 50 subjects have been tested. As this is an exploratory experiment, specific analysis procedures or goals were not described in the pre-registration. It is expected that a future confirmatory experiment will be registered with a pre-planned analysis in order to prove effects are robust and not due to p-hacking or other questionable research practices.

Two-Person Control

It is required that two or more experimenters be present at all times during formal data taking and to sign a form testifying to this effect at the end of testing each subject. The purpose is to greatly reduce the potential for experimenter fraud due to improper data deletion, data fabrication, replacement of data, and other fraudulent practices. Furthermore, at the end of testing each subject, the collected raw data is copied on to individual thumb drives held by each of the experimenters present, to be kept solely in their personal possession. By comparing the saved data at the conclusion of the experiment, any data-tampering can be detected.

Sometimes during experimental data taking equipment failures or failure to follow proper procedures by either research subject or experimenters may occur. The experimenters can declare data bad and unusable but this must be done before analysis of the data because of the risk of improper data selection. Even if some data is declared bad, it must not be deleted.

Inanimate Object Test

To detect whether experimental results could be due to procedural flaws or equipment malfunction, the entire experiment, including analysis, is run on an inanimate object, in this case a watermelon roughly the size of a human head.

For this analysis, electrodes were grouped into three regions: frontal (Fp1, Fp2, and AFz), central (Fc1, Fc2, Cp1, andCp2), and occipital (O1, O2, POz, and Oz). The electrodes for inclusion in the three regions were selected before data-taking began. After data taking is completed for all subjects, an analysis will be done using all electrodes in order to find the regions of strongest effect size.

A baseline region was defined for a time interval from -4 to -2 seconds before the stimulus. In order to test whether advance identification of the stimulus (and therefore qRNG output) is possible, a pre-stimulus region was defined from -1.5 to -0.5 seconds. The mean potential across the pre-stimulus was compared to the mean potential of the baseline region. An increase in potential predicts a light stimulus whereas a decrease predicts a sound stimulus (based on (3)). This same check was carried out for a time interval post-stimulus from 0.5 to 1.5 seconds in order to test the correlation between pre- and post-stimulus potentials.

Frontal

The mean average potential for light, sound, and null stimuli were taken for 3 frontal electrodes (Fp1, Fp2, and AFz). A P200 peak was detected arising during light stimuli (see Figure 1). This peak is due to the brain's processing of the visual stimulus and represents a replication of a known phenomenon. The pre-stimulus comparison showed a prediction accuracy rate of 58.0% with Z score of 2.08. Post-stimulus identification rate was 62.7% with Z score of 3.31 (see Table 1). These results show statistically significant binary identification rates for the light and sound

selections from the qRNG. As shown in Figure 1, mean light trial potential is greater than mean sound trial potential after 2 seconds before stimulus onset with the null stimulus potential generally appear between light and sound means.

ANALYSIS AND RESULTS

Table 1: Identification Rates Based on Tests of Human Subjects

Light	Pre-Stimulus		Post-Stimulus	
	Identification Rate	**Z Score**	**Identification Rate**	**Z Score**
Frontal	60.3%	1.81	62.8%	2.26
Central	60.3%	1.81	69.2%	3.40
Occipital	48.7%	-0.23	56.4%	1.13
Sound	**Pre-Stimulus**		**Post-Stimulus**	
	Identification Rate	**Z Score**	**Identification Rate**	**Z Score**
Frontal	56.0%	1.15	62.6%	2.41
Central	49.5%	-0.10	54.9%	0.94
Occipital	62.6%	2.41	53.8%	0.73
Both	**Pre-Stimulus**		**Post-Stimulus**	
	Identification Rate	**Z Score**	**Identification Rate**	**Z Score**
Frontal	58.0%	2.08	62.7%	3.31
Central	54.1%	1.15	61.5%	3.00
Occipital	56.2%	1.62	55.0%	1.31

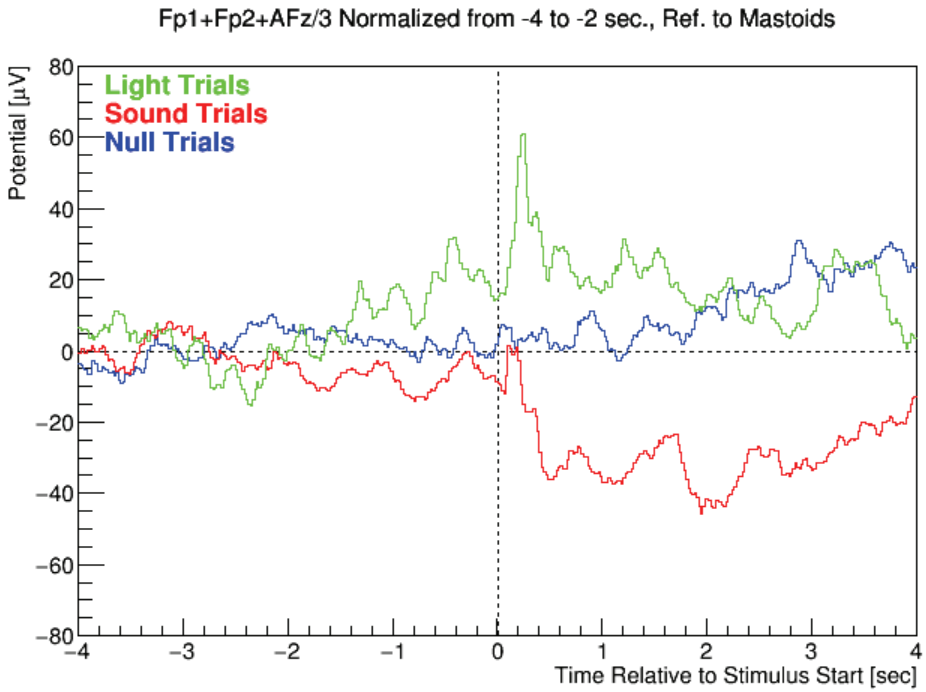


FIGURE 1. Mean potentials measured by electrodes Fp1, Fp2, and AFz for light, sound, and null trials. The mean average potential measured by the mastoid electrodes has been subtracted from the Fp1, Fp2, and AFz mean. The means shown contain data from 78 light trials, 91 sound trials, and 76 null trials. Time = 0 seconds is locked to the stimulus start time as measured by the digital channel for each stimulus type.

Central

The mean average potential from central (Fc1, Fc2, Cz, Cp1, andCp2) electrodes (Figure 2) showed a similar to pattern to that of the frontal electrodes. Mean potential from light stimulus trials was elevated above baseline whereas mean potential from sound stimulus trials was depressed from baseline in the post-stimulus region. In the pre-stimulus region, only the light potential appeared elevated above the null level. The pre-stimulus prediction rate calculated for central region electrodes was non-significant at a prediction rate of 54.4% and Z score of 1.15 (though in the expected direction). The post-stimulus identification rate was found to be 61.5% with Z score 3.00 (see Table 1).

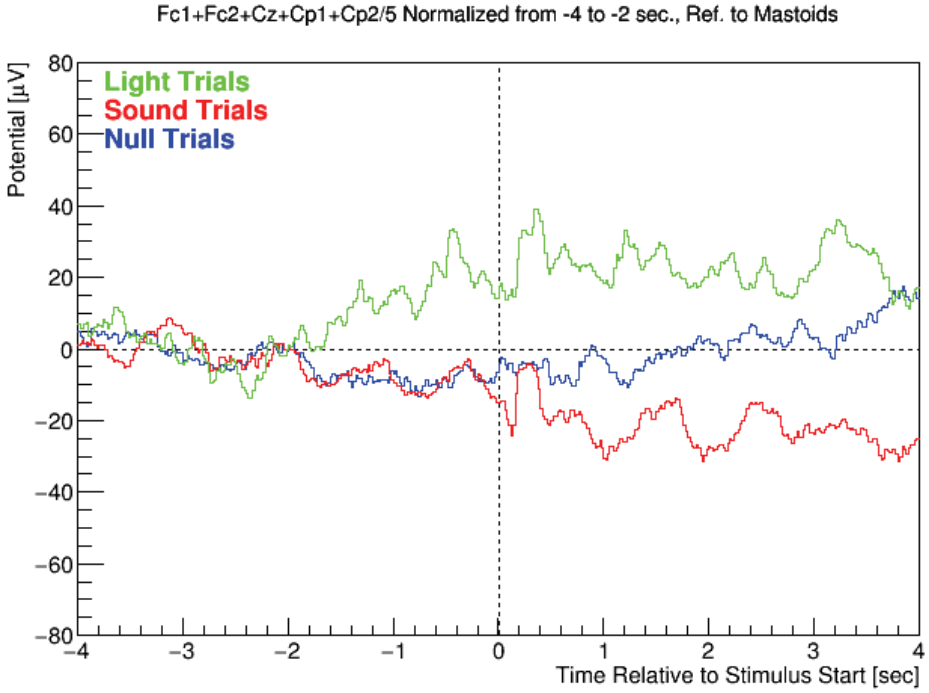


FIGURE 2. Mean potentials measured by electrodes Fc1, Fc2, Cz, Cp1, and Cp2 for light, sound, and null trials. The mean potential measured by the mastoid electrodes has been subtracted from the Fc1, Fc2, Cz, Cp1, and Cp2 mean. The means shown contain data from 78 light trials, 91 sound trials, and 76 null trials. Time = 0 seconds is locked to the stimulus start time as measured by the digital channel for each stimulus type.

Occipital

The mean average potential from occipital (O1, O2, POz, and Oz) electrodes showed a similar to pattern to both frontal and central electrodes with the exception of no appearance of a P200 peak. This is shown in Figure 3. However, both pre- and post-stimulus identifications were non-significant. The pre-stimulus identification rate was 56.2% with Z score 1.62. The post-stimulus identification rate was 55.0% with Z score 1.31 (see Table 1).

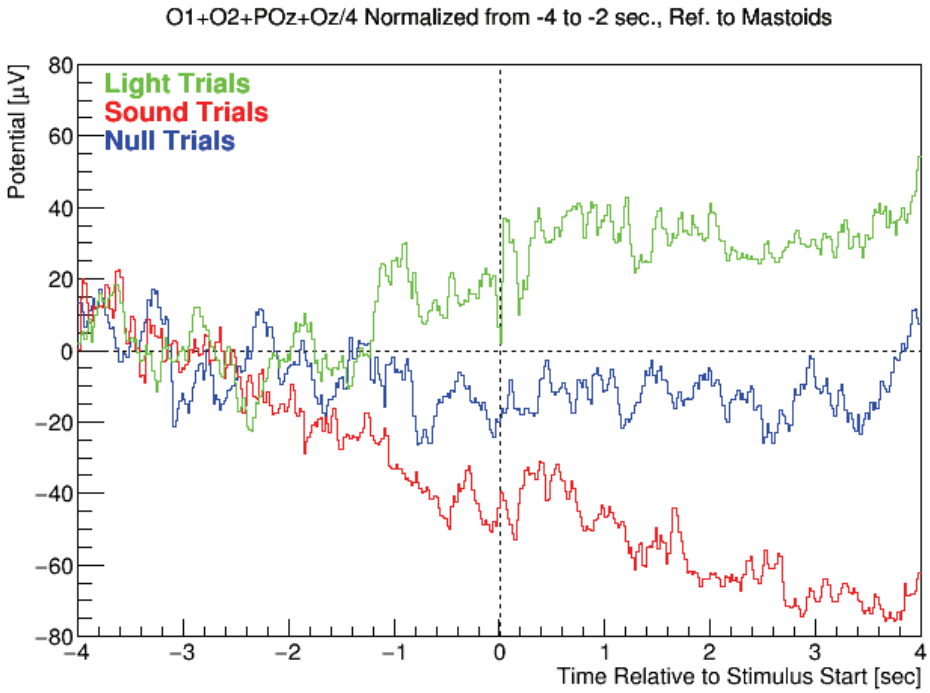


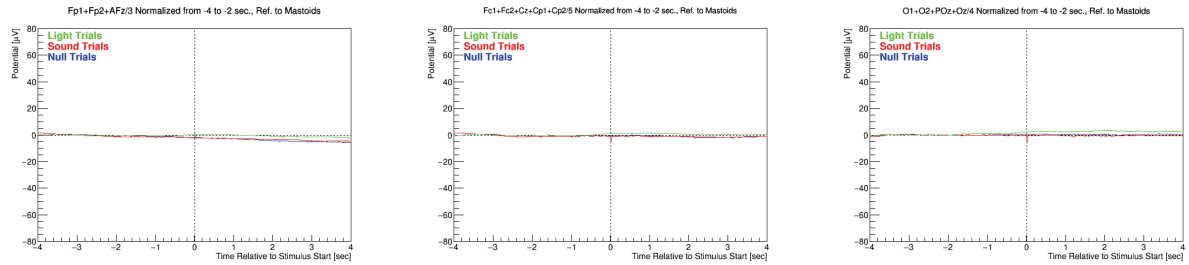
FIGURE 3. Mean average potentials measured by electrodes O1, O2, POz, and Oz for light, sound, and null trials. The mean potential measured by the mastoid electrodes has been subtracted from the O1, O2, POz, and Oz mean. The means shown contain data from 78 light trials, 91 sound trials, and 76 null trials. Time = 0 seconds is locked to the stimulus start time as measured by the digital channel for each stimulus type.

For all regions analyzed, it appeared that mean potential for light stimuli increased over baseline while potential for sound stimuli decrease against baseline beginning at approximately t = -2 seconds relative to stimulus onset with the exception of central region sound epochs. However, statistical strength of the measurements is weak as only 8 subjects out of 50 planned have been tested. It remains to be seen whether the general pattern will hold up after the full data set is collected.

Inanimate Object Tests

When the experiment and analysis was done using the EEG headcap placed on a watermelon, under no conditions was a statistically significant result obtained in either positive or negative directions for combined light and sound trials (see Table 2). The predictions rates for both pre- and post-stimulus periods appear to be at chance levels for combined stimuli. However, in the frontal region, there seemed to be a bias for identifying light and against identifying sound trials. This may be due to an underlying drift in the impedance of the electrodes causing slopes in the measured potentials. Mean measured potentials from the watermelon are shown in Figure 4. A subtle artifact was detected at sound stimuli onset at t = 0 seconds. This artifact may be due to an electrical discharge from the flipping of the electrical relay. It had no effect on prestimulus identification rates.

Table 2: Identification Rates Based on Tests of Inanimate Object				
Light	Pre-Stimulus		Post-Stimulus	
	Identification Rate	Z Score	Identification Rate	Z Score
Frontal	42.7%	-2.84	44.3%	-2.22
Central	45.6%	-1.70	47.2%	-1.08
Occipital	49.1%	-0.36	47.7%	-0.88
Sound	Pre-Stimulus		Post-Stimulus	
	Identification Rate	Z Score	Identification Rate	Z Score
Frontal	56%	2.4	55.8%	2.3
Central	54.5%	1.8	55.5%	2.2
Occipital	52.3%	0.9	52.8%	1.1
Both	Pre-Stimulus		Post-Stimulus	
	Identification Rate	Z Score	Identification Rate	Z Score
Frontal	49.5%	-0.25	50.2%	0.11
Central	50.2%	0.11	51.5%	0.83
Occipital	50.7%	0.40	50.3%	0.18



(a) (b) (c)

FIGURE 4. Mean average potentials measured by electrodes (a) Fp1, Fp2, and AFz, (b) Fc1, Fc2, Cz, Cp1, and Cp2, (c) O1, O2, POz, and Oz for light, sound, and null trials. The mean potential measured by the mastoid electrodes has been subtracted from the means. The means shown contain data from 375 light trials, 400 sound trials, and 389 null trials. Time = 0 seconds is locked to the stimulus start time as measured by the digital channel for each stimulus type.

SUMMARY

Insufficient data has been collected so far to rule out the null hypothesis for prestimulus identification of unpredictable stimuli in the central and occipital regions of the brain using EEG. The identifications using potential data from the frontal region appears statistically significant; however, more data is desired to confirm. Identification of stimulus types based on post-stimulus response is supported by the current data for the frontal and central regions but not the occipital region. A P200 evoked potential has been detected in the frontal electrodes after the stimulus start due to the brain's response to light stimuli, representing a replication of a known phenomenon. Control tests on an inanimate object (watermelon) obtained chance results with no sizable electrical effects, as expected. Due to the partial data set reported here it may be premature to draw a strong conclusion about physiological retrocausality with regards to these light and sound stimuli but data collected so far are consistent with the existence of retrocausality.

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