CIHSPS2004 - IEEE International Conference on
Computational Intelligence for Homeland Security and Personal Safety
Venice, Italy, 21-22 July 2004

Lying and Deception with Visual Evoked Potentials

Evangelia Micheli-Tzanakou, Andy Eugene, Mark Tan, and Kibum Kim
Computational Intelligence Laboratories, Dept of Biomedical Engineering
Rutgers University
cil@rutgers.edu

Abstract *– The recent urgency for counter-terrorism and the fight to protect ones' homeland are of grave concern to nations throughout the world. Finding an efficient process that could have screened passengers prior to boarding a flight or even a train may have derailed many devastating events. Scientific research has continuously proved that there is an explicit marker of neuronal activity that correlates with awareness, past experience, and short-term interactions from the well-known P300 peak of an evoked potential. This study examines the effects of memory recognition to certain key stimuli mixed with irrelevant variables in an effort to identify if a trained terrorist, per se, could not only be identified from a group of subjects, but also validate that the willingness to withhold information is out of the control of the individual; it's simple, one has no control in concealing their brain's activity.*

Keywords *– visual evoked potential, lying, deception*

I. INTRODUCTION

Detecting deception has been a long-standing challenge in society. The lie detector, which bases the deliberate intention to deceive on physiological measurements, is no longer used as the basis for exposing deception. Therefore, other avenues are needed to find a more accurate and concise method to determine whether a person is lying. Many scientists have already begun and had success in measuring deception in electroencephalogram (EEG) recordings.

Lie Detection (Polygraph examination) is designed to look for significant involuntary responses going on in a person's body when that person is subjected to stress, such as the stress associated with deception. But the exams are not able to specifically detect if a person is lying. Polygraphs are no more accurate at detecting lies and there is no significant machine that can detect lies. The 'lie detector' does not measure truth-telling; it measures changes in blood pressure, breath rate and perspiration rate, but those physiological changes can be triggered by a wide range of emotions. To determine whether one is telling the truth or not, other methods are needed to accurately determine whether a person is lying or not. Various experiments have attempted to try to extract information that can be directly correlated with the thinking processes of an individual. The electroencaphalogram (EEG) has undergone multitudes of methods of analysis in order to extract these relevant information, and the need to efficiently and rapidly acquire the visually evoked potentials (VEP) from raw EEGs is present. In this experiment we attempt to develop a method in which deception can be detected from VEPs using an efficient extraction method, called adaptive filtering. Adaptive filtering in comparison to signal averaging can extract signals embedded in noise more efficiently and without the loss of data. From the extracted waveforms, we will use four methods of analysis to determine any differences in the VEPs of 'truthful' and 'lying' individuals: latency, statistical analysis, fractal and wavelet analyses.

II. METHODS

1. **Experimental Protocol:** Protocol is the one of most important steps in detecting deception in VEP. A good protocol produces better VEPs with minimal noise in the waveforms. We spent a lot of time to find out which protocol can best fit our project experiment. MERMER testing (Memory and Encoding Related Multifaceted Electroencephalographic Responses), also known as "brain fingerprinting", was the first idea. It is claimed to be 90-99% accurate, with 0 false-positives or false negatives. Subjects need not utter a word in the MERMER test. They are shown photographs of a crime scene, e.g., and those familiar with the scene show different brain-wave patterns than those who are unfamiliar with the scene. But the problem we met with this test was security. If subjects know why they are being examined, it is hard to obtain good data from such a situation.

   The first set of stimuli used were a set of playing cards. Each subject chose a number from two to six. Each subject was told that in the first three sessions of the experiment, the subject would press a trigger whenever he/she saw the playing card of his or her chosen number. These were the 'truth' sessions. In a following set of three sessions, the subject was told to deliberately press the trigger on a playing card not of her or his chosen number to mimic the attempt to hide information or deceive during a game of poker. These were the 'lie' sessions. This is how the notion of deception was introduced into the experiment. In this experiments the subjects had to press a button in order to indicate that the cards presented as stimuli were not in their possession.

0-7803-8381-8/04/$20.00 (c)2004 IEEE

Stimulus 1

August 17, 1999
Bdaymonth xy, 198z
March 30, 2002
September 28, 1994

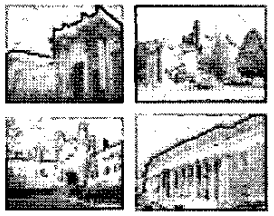
Stimulus 2

Creatine
Positron
Nanobot
Alopex

Stimulus 3

June 9, 2004
December 5, 2004
May 14, 2004
October 23, 2004

Stimulus 4



In the second set of experiments, instead of having the subjects pressing a trigger, they subjects are just staring at a screen where different types of stimuli with "innocent" and "target" pictures were shown. For the "Guilty" subjects, all three where handed a test protocol that outlined a story to concerning a plot to commit and illegal act at a specific date. This included a code-word and had a color picture of the target building on the bottom of the instructions. After the Guilty subjects read the instructions, the following page asked them to recall both the date and password presented on the previous page and also required the Guilty subjects to draw a sketch of the target building. The instructions then asked them to go back to the previous page, re-read the story and recall the information to then re-sketch the image of the target building. From this, the bottom of the page asked them to write and sign their names and include both the current date and their date of birth.

The Innocent subjects were simply asked their date of birth; this was done to establish a baseline for long-term memory across all subjects. Though it was assumed that the Innocent subjects had no prior knowledge of the test, two of the three seemed a bit informed. Moreover, the results clearly showed that the non-Rutgers student's Event Related Potentials showed that he was indeed "Innocent" of any knowledge of the plot to commit the crimes. Similarly, the Guilty subjects, behaviorally, appeared to be very anxious to see their results and this ruined their EEG recordings.

2. **Data Recording and Analysis:** Data were recorded from electrodes placed at positions O1, Fz and FPz. These locations were chosen since they are located at the prefrontal and frontal cortices of the brain, the locations at which high-level thinking occurs. The visually evoked potentials (VEPs) were extracted using signal averaging and adaptive filtering. Although there were three sessions of 15 presentations of a playing card, which totals to 45 periods of the EEG for each type of session ('truth' or 'lie'), only 42 were averaged as a result of the BIOPAC's failure to record the first period of each session. The VEPs that were extracted using signal averaging and adaptive filtering were compared to test the viability of adaptive filtering as a more efficient means of VEP extraction.

Latency, statistical, fractal and wavelet analyses were applied in the attempt to reveal differences between the VEPs during the 'truth' and 'lie' sessions. Differences would signify the deception of the subject. Latency analysis was performed by determining the time at which different amplitude peaks occurred, such as P100, N200, and others peaks. Statistical analysis determined the standard deviation and mean of the evoked potentials for different initial time periods, that is for the first 512, 256, 128, 100, 75, and 64 ms of the presentation of a playing card, the onset of the ON period. Fractal analyses determined the fractal dimension that characterized each of the VEPs using an m-file authored by

R. Kozma. The algorithm was developed by T. Higuchi. The m-file **fraclav.m** was first applied to the variable xx, which contains the VEP signal. Then, the fitlav.m was then applied to the results of the first m-file to produce the low, high, and average fractal dimensions with their corresponding error values.

Wavelet Coefficients can be the method to detect a deception in VEP. An advantage to the Wavelet Coefficient is that the basis functions can be selected to fit the particular application. In Fourier analysis complex exponentials are used as the basis functions to represent all functions. The Daubechies wavelet was used to decompose the VEP responses and the frequency ranges that correspond to the level 4 in this study. Finally, each truth and lie synthesized signals data were collected. Wavelet Coefficient analysis determined the average of coefficient difference in each truth and lie data signals.

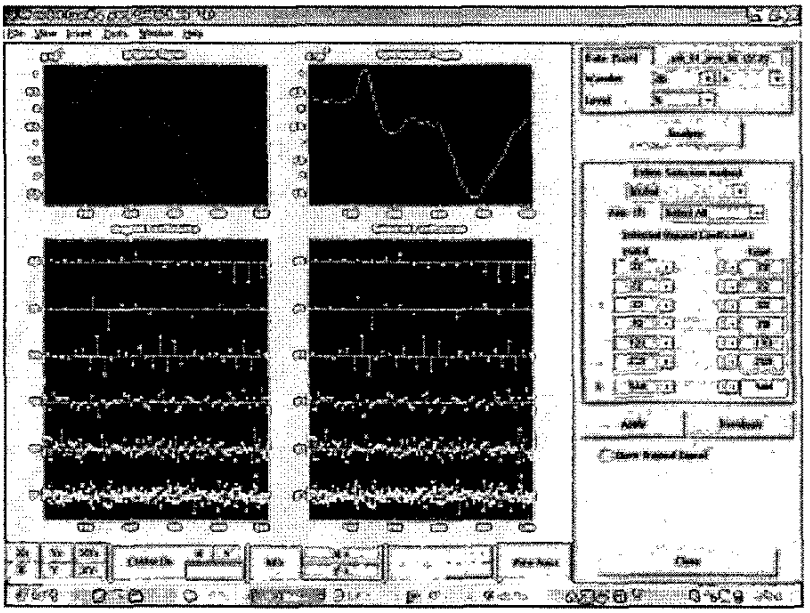
Fractals have the three following properties: self-similarity, dimensionality, and iterative formation. Self-similarity refers to the property in which a subcomponent of a shape will always be similar to the whole shape. However, this is not the only characteristic of fractals, for there are many shapes that are self-similar but are not fractals.

A property of fractals is their dimensions. Finally, every fractal can be formed through iteration by adding self-similar shapes to every side or length of the fractal. Fractals surprisingly are present in all aspects of nature from the shape of the coastline to the electroencaphalogram (EEG). Therefore, fractal analyses on VEP signals therefore can be used to determine their fractal dimensions, and differences between the dimensions of the VEPS of individuals can be compared.

III. RESULTS AND DISCUSSION

The different analytical methods successfully revealed consistent differences between the VEPs recorded during the two different types of sessions, the 'truth' session and the 'lie' session, within a single subject. However, many variables contributed to this difference, which cannot only be attributed to the deception of the subject. One particular variable of importance is the order in which the 'truth' and 'lie' sessions were recorded. The 3 'truth' sessions were almost always recorded first followed by the 3 'lie' sessions. This variable can be observed by the fact that the 'truth' sessions did produce noisier signals as a result of the subject's reaction to novel stimuli. At the presentation of the three 'lie' sessions, the subject's brain started to habituate to the stimuli, decreasing the amount of noise within the VEP. In the same way, this variable may have also contributed to the differences evident in the analysis of the VEPs from each session. Future work should mix the order in which each type of session is presented to the subject, so that noise levels or habituation effects would not affect the VEP analysis.

Visual inspection of each subject's averaged VEPs did not present conclusive differences in the amplitude peaks or latency, some consistent and some inconsistent. FPz and Fz should provide better data since they record signals nearer to the area of interest in the brain. The VEPs recorded at Fz for the three subjects had different characteristics. The 'truth'

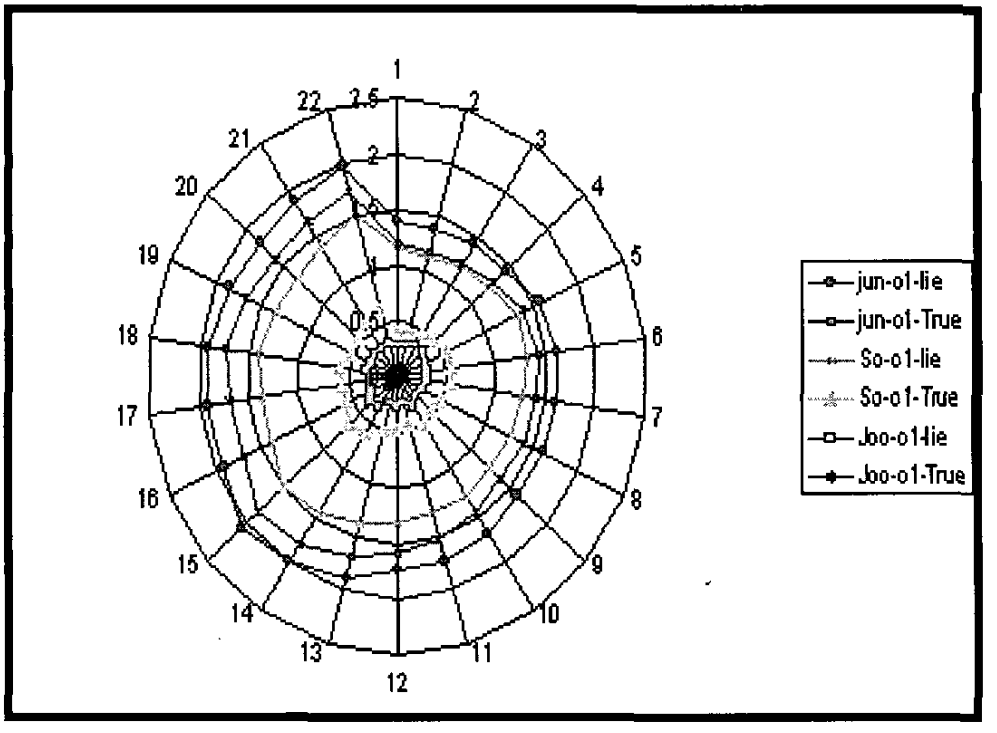


session had a larger first peak than that of the 'lie' session at around 400 to 500 ms. However, in another subject, the 'lie' session had the larger peak. In contrast, at FPz, relatively consistent data were found in the first peaks. In all subjects, the 'lie' sessions had larger amplitudes than that of the 'truth' session during the ON period. Unfortunately, during the OFF period, the relative amplitudes between the 'lie' and 'truth' sessions vary from subject to subject.

The latency analysis proved difficult to utilize. The number of amplitude peaks varied from subject to subject and from session to session. Thus, determining corresponding peaks between the 'truth' and 'lie' sessions is subject to multiple interpretations and can lead to various conclusions regarding the different times at which a particular peak occurred. Such variability would not suffice as an analytical method to extracting the presence of deception in the VEP.

The statistical analysis provided relatively consistent data. Further acquisition of data is required to confirm the reproducibility of these results. Perhaps, it can be clarified whether FPz does reliably exhibit decreased values in the STD and mean as a result of lying. FPz is the location of the prefrontal cortex, a place where high-level thinking may be required for the subject to deceive. However, the decrease in values may suggest that the subject has decreased activity in high-level processing. This also may due to the fact that the individual has habituated to the skill needed to press the trigger at certain times. In contrast both the 'truth' and 'lie' session provided the subject relatively new skill sets. Initially the subject had to concentrate on pressing the trigger at his or her presented card in the 'truth' sessions. Subsequently, the subject then needed to press the trigger at the presentation of another card and skip his or her card in the 'lie' sessions. Mixing the order in which the 'truth' and 'lie' sessions occur may rule out this variable from the results in future experimental work.

The fractal analysis provided clear differences in the VEPs of the 'truth' and 'lie' sessions. However, negative values of the fractal dimensions do not seem to make sense. Such values are studied under the heading of latent fractal dimensions. More studies regarding this must be done. In regard to the evaluation of the actual values produced by the program, one can simply use the program as another way of analysis, whatever its algorithm is attempting to do. Different values produced by the program would still be useful in extracting information if the values resulted from the unique characteristic of each particular VEP signal. A trend of increasing values of the averaged fractal dimensions from the 'truth' to 'lie' sessions was observed for all three subject except at O1. Further subjects must be tested to verify the reproducibility of this data. If it is proven that the fractal dimension does increase for brain signals in deception, this may be very useful method for detecting deception.



Despite the results, the protocol chosen to detect deception may not apply well on the practical level. At the most, questions could be posed instead of cards at each presentation in the ON periods at which the subject will press the trigger to indicate 'yes' and do nothing to indicate 'no'. A more viable method, in which the subject does not need to provide any input to the recording system, may be more promising. The brain signals would simply be the marker for measuring information. Many experiments have already been done in regard to this method and have proved to be very successful in revealing information about the subject's past experience in certain locations.

Wavelet analysis showed consistent results as shown in the figure below. The coefficients from Innocent subjects are consistently smaller than those of the guilty ones.

REFERENCES

[1] Rosenfeld, J. P., "Event-Related Potentials in Detection of Deception," *Running Head: Countermeasures to P300 Deception Institute*, Northwestern University Department of Psychology, August 31, 1999, For Handbook of Polygraphy, ed. By Murray Kleiner, New York: Academic Press, 2000.

[2] Boaz, T. L., *et al*, "Detection of Guilty Knowledge With Event-Related Potentials," Journal of Applied Psychology, 1991, Vol. 76, No. 6, 788-795.

[3] Miller, A. R., *et al*, "False Memory: P300 Amplitude, Topography, and Latency," *Running Head: P300 and False Recognition*, Northwestern University Department of Psychology, jp-rosenfeld@nwu.edu, *date unknown*.

[4] Novak, D., *et al*, "EEG and VEP Signal Processing," Czech Technical University in Prague Department of Cybernetics, *date unknown*.

[5] Rosenfeld, J. P., *et al*, "Simple, Effective Countermeasures to P300-based Tests of Detection of Concealed Information," *Running Head: Countermeasures to P300 Deception Institute*, Northwestern University Department of Psychology, Department of Defense Polygraph Institute, January 06, 2003.

[6] Kalouptsidis, N., "Signal Processing Systems: Theory and Design," John Wiley & Sons, 1997.

[7] Uyeda, E., Wojnicki, P. and Micheli-Tzanakou E. "Visual Evoked Potential Study of Attention." SPIE (2002).

[8] http://kel.otago.ac.nz/CBIS/Objective1/Resources/Fractal/Fractal.html