

The Effects of Eye Tracking in a VR Helmet on EEG Recordings

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Abstract

Since scalp EEG recordings are measured in microvolts, electrical signals may easily interfere during an experiment. As Spehlmann discusses, such interference may be introduced through the lights in the recording room, a nearby television, or even a computer monitor [Spehlmann, 1991]. Thus, when we consider performing EEG/EP/ERP experiments within a virtual reality helmet containing an eye tracker, electrical interference becomes a real possibility. We tested the effects of wearing a VR4 virtual reality (VR) helmet containing an ISCAN eye tracker while asking subjects to do a continuous performance task. The results of this task were then analyzed in the frequency domain and compared to results from the same experiment while looking at a computer screen in two different environments. Results indicate that in an environment with other computers, the vertical refresh from the back of a nearby row of computer monitors added more noise to the signal than wearing the VR helmet and eye tracker. Even in an environment without other computers, the noise while wearing the VR helmet and eye tracker is not significantly different from the noise obtained while viewing a laptop computer screen in the same location.

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1 Introduction

The use of virtual reality (VR) and eye tracking during EEG experiments promises to be beneficial. Virtual reality can provide dynamic and controllable experimental environments and eye tracking allows a comparison between cognitive behavior as associated with eye movement and through the EEG signal. While [Nelson *et al.*, 1997] recorded EEG signals in a virtual environment, the environment in question consisted of a large screen in front of the subject. This screen posed less of a problem with noise than we assumed a virtual reality helmet sitting on the head of a subject would.

Since scalp EEG recordings are measured in microvolts, electrical signals may easily interfere during an experiment. As discussed in [Spehlmann, 1991], such interference may be introduced through the lights in the recording room, a nearby television, or even a computer monitor. Thus, when we consider performing EEG/EP/ERP experiments within a VR4 virtual reality helmet containing an ISCAN eye tracker, electrical interference becomes a real possibility. Many algorithms exist for reducing known artifacts from a recording (see [da Silva *et al.*, 1986], [Sadasivan and Dutt, 1995], [Berg and Scherg, 1994], and [Jung *et al.*, 1997] for a sample of methods), but in order to reduce the artifact it is helpful to first know what kind of artifact exists.

We tested the effects of wearing the VR helmet with the eye tracker while asking subjects to do a continuous performance task. The results of this task were then analyzed in the frequency domain and compared to results from the same experiment while looking at two different kinds of computer screen in two different environments. In the “noisy” environment, other computers were present and they were absent in the “quiet” environment. Results indicate that the vertical refresh from the back of a computer monitor in a nearby row added more noise to the signal than wearing the VR helmet and eye tracker. Even in an environment without other computers, the noise while wearing the VR helmet and eye tracker is not significantly different from the noise obtained while viewing a laptop computer screen in the same location.

2 Experiments

Electrodes were placed on the subjects using the International 10-20 system with a linked mastoid reference. Figure 1 shows the electrode placement for both subjects. Electrode impedance was below 20 kohms on all channels and the signal was amplified using Grass amplifiers. The analog frequency range was from 0.3 Hz to 300 Hz. While this is a rather large range, our interest in examining noise justifies the range. A Neuro Scan Acquisition system was then used to digitally record the signals at a rate of 1000 Hz.

Discovered in the 1960’s [Sutton *et al.*, 1965], the P300 is an easily evoked positive waveform around 300 ms after infrequent task relevant stimuli. Using a visual oddball paradigm, the task for both subjects was to click a mouse button upon seeing an “E” on the screen they were viewing and to do nothing when seeing an “S”, “O”, “W”, or “X”. E’s occurred 15% of the time. The Neuro Scan Stim visual continuous performance task program was used both to flash letters on the screen and to trigger the EEG acquisition

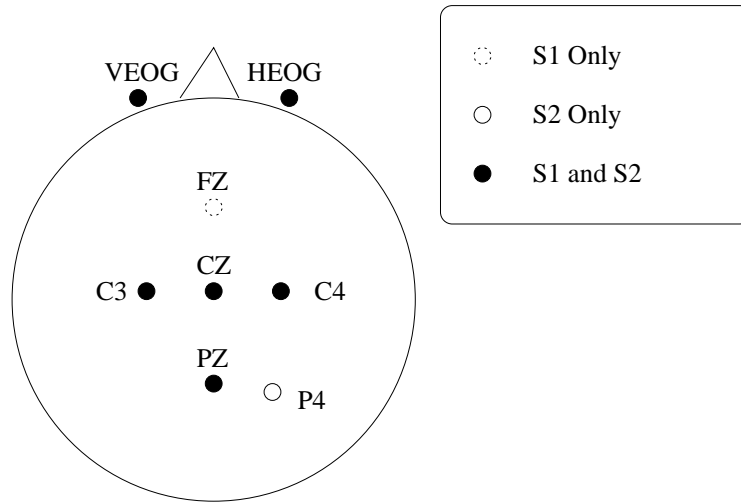


Figure 1: The electrode placements for both subjects using the International 10-20 system with a linked mastoid reference.

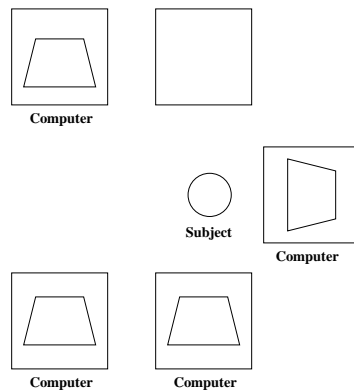


Figure 2: The environmental setup for the first subject. Notice how the backs of the monitors in a nearby row face the subject.

system to record only signals occurring between 100 ms before the stimulus and 1000 ms after the stimulus was presented. The interstimulus interval was 2 seconds.

For the first experiment, S1 viewed the stimulus from a Hitachi SuperScan Elite 17 inch monitor. This monitor has a variable vertical refresh, which was 70 Hz at the time of the experiment and the subject sat approximately 1.5 feet away from the monitor. The monitor was located in an environment with other computers (including the EEG signal recording computer) in the setup of Figure 2.

On a different day, the VR helmet was placed on S1's head and S1 repeated the original task while viewing the head-mounted display inside the helmet with the eye tracker turned on and in a different room from the previous experiment where there were no other computers close to the subject. An average of the signal from both types of display is shown in Figure 3. The average frequency spectrum for each type of display over all epochs is shown in Figure 4. As can be seen from the results, a dominant 70 Hz frequency is seen in

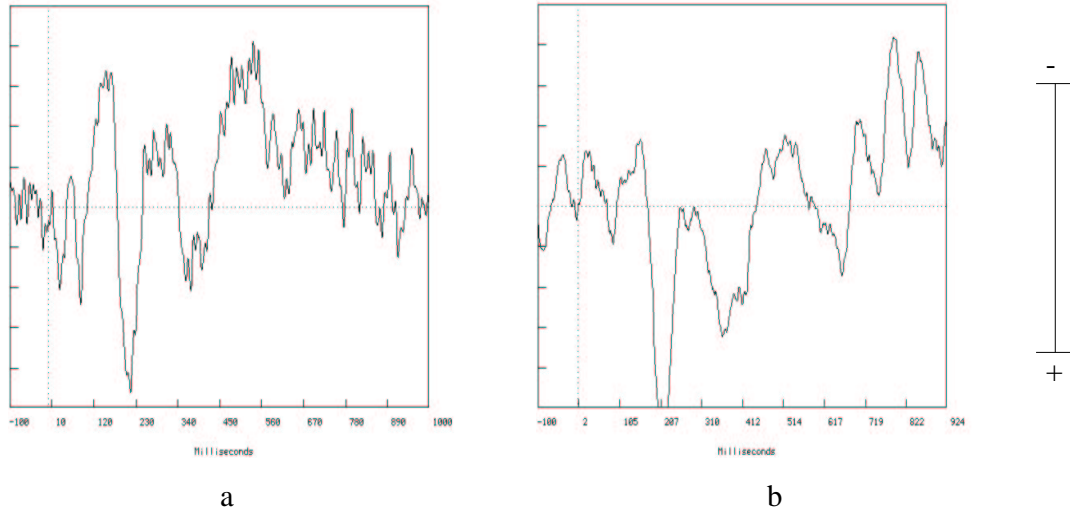


Figure 3: a. The average of the rare (P300) trials recorded with electrode PZ from S1 while viewing a 17 inch monitor in a room with other computers. b. The average of the rare (P300) trials recorded with electrode PZ from S1 while wearing the VR helmet. All signals were low pass filtered at 100 Hz (the usual low pass frequency for P300 experiments) before averaging. Notice that a. appears noisier than b. due to the 70 Hz monitor vertical refresh coming from the back of a nearby computer monitor.

the environment with other computers. This was due to the 70 Hz monitor vertical refresh coming from the back of a computer monitor approximately 2 feet from the subject's head.

While the problem with the signal power of the nearby monitor vertical refresh could not be denied from this experiment, several other problems with the experiment itself arose after careful consideration. First, the two parts of the experiment were done on different days. While the impedance at the electrode sights for both days was below 20 kohms, the impedances were probably not similar enough to be able to directly compare the signal power in the two parts of the experiment.

After carefully reading the manual for the helmet, it was discovered that the helmet signal was sent at a rate of 60 Hz due to use of the NTSC timing format [Systems, 1994]. While recording during the first experiment, the 60 Hz notch filter was on and thus a potential problem with the VR helmet signal was avoided. An experiment using a second subject fixed these problems: the notch filter remained off, both parts of the experiment were done in a room with no close computers and the lights off, and both experiments were done in sequence on the same day.

Subject S2 performed the same task as S1, but at first viewed the task from the 12 inch screen of a laptop computer. Laptop computers have backlit screens and it was reasoned that there would be no possibility of a vertical refresh problem with this type of screen. During the same recording session, the VR helmet with the eye tracker was carefully placed on the subject's head and electrode impedances were rechecked. The image signal from the 12 inch monitor was converted to S-VHS format and piped into the VR helmet. A sample average under both viewing conditions is shown in Figure 5. A frequency analysis of all epochs is shown in Figure 6. The signal power in the frequency spectrum was similar in both parts of the experiment, although the VR helmet had more signal power around 60-70

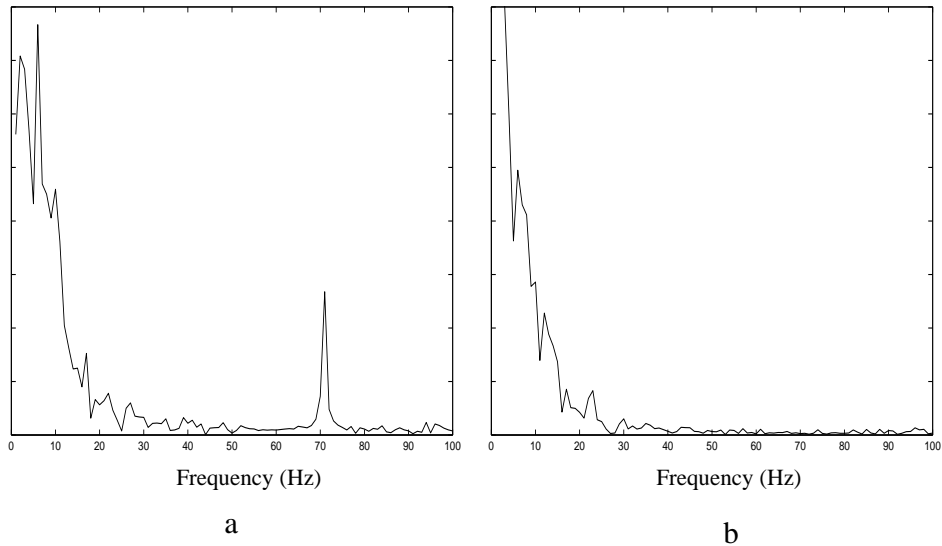


Figure 4: a. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S1 while looking at a 17 inch computer monitor. The 70 Hz signal is due to the vertical refresh from the back of a nearby computer monitor. b. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S1 while wearing the VR helmet and eye tracker. The differences in the low frequency signal power are most likely due to a different quantity of eye movements between sessions. Both graphs are shown at the same scale and are low pass filtered at 300 Hz.

Hz.

Due to the construction of the VR helmet, we found that the band of the helmet going around the head hit against electrode locations P3 and P4. This is why electrode location P4 was recorded in addition to the recorded locations for S1. The average power spectrum for this electrode location is shown in Figure 7. Surprisingly, there isn't much of a difference between the two parts of the experiment. Each epoch of channel P4 was carefully checked and it was found that the electrode did not suddenly move on the head during the time of the recording.

3 Discussion

In this paper we have shown that the vertical refresh from the back of a nearby monitor may contain more noise than wearing a VR helmet with an eye tracker. The overall noise levels while viewing a 12 inch laptop monitor and while wearing the helmet were comparable to one another - indicating that experiments done in the VR helmet while tracking a subject's eye will not be more noisy than sitting in front of a laptop screen. The results of this experiment were mostly positive, but must be tempered with caution in an actual virtual environment.

For instance, the helmet band presses against electrode locations P3 and P4. The subject remained still in this experiment, looking at a static screen. In a real virtual reality environment, the subject will be expected to move his/her head in order to see different

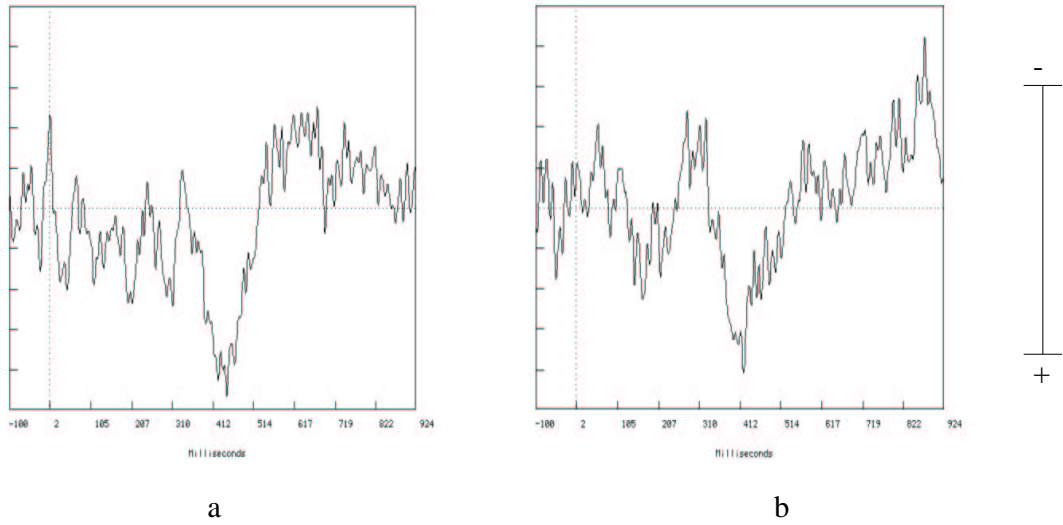


Figure 5: a. The average of rare (P300) trials recorded with electrode PZ from S2 while viewing a 12 inch laptop screen. b. The average of rare (P300) trials recorded with electrode PZ from S2 while wearing the VR helmet. These averages are much noisier looking than S1's averages simply because only 10 rare trials were averaged for a. and b. The signals were digitally low pass filtered at 100 Hz (the usual analog low pass frequency for P300 experiments) before averaging.

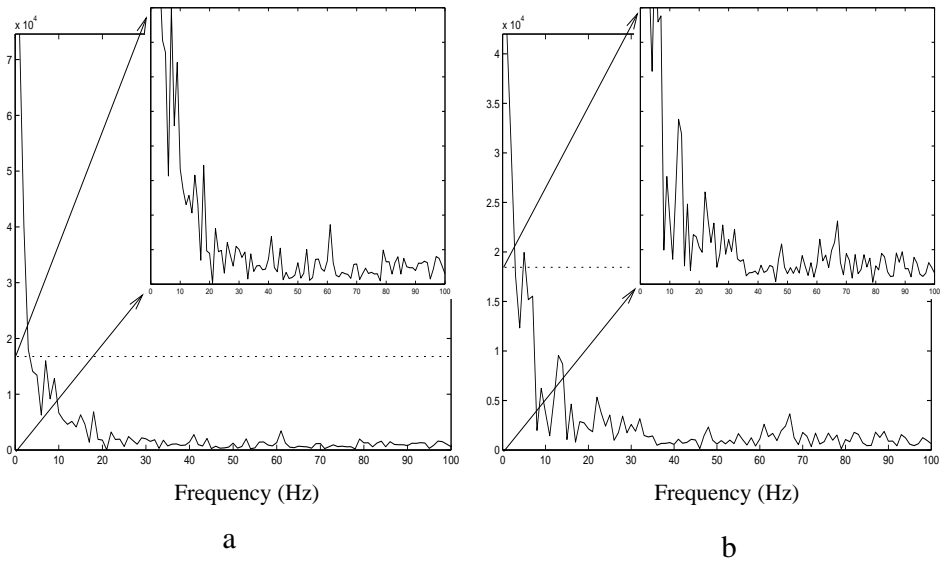


Figure 6: a. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S2 while looking at the 12 inch screen on a laptop computer. b. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S2 while wearing the VR helmet and eye tracker. Slightly more noise exists inside the VR helmet, but the two frequency waveforms correlate at 0.79 ($p < 0.05$) for the data from 20-100 Hz (where most of the noise was assumed to lie). Both plots were calculated directly from the 300 Hz analog low pass filtered data.

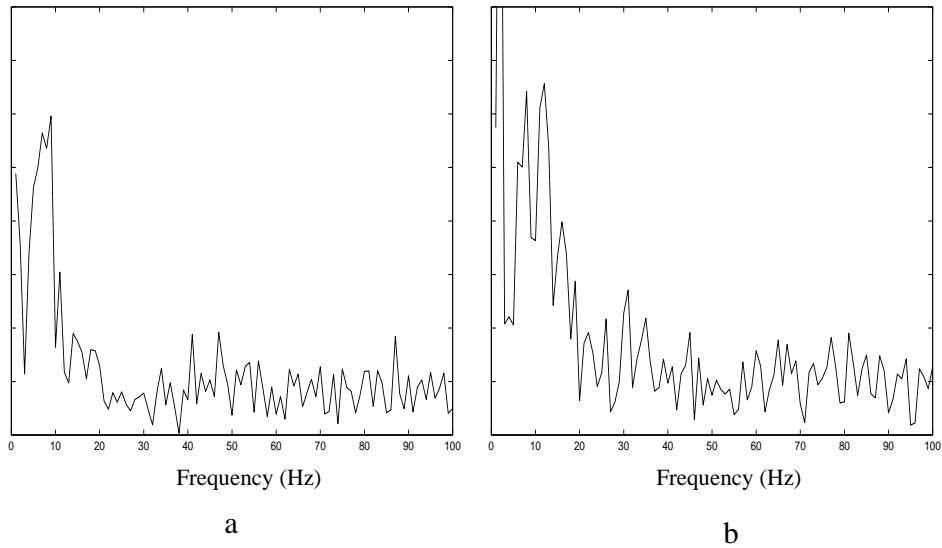


Figure 7: a. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S2 while looking at the 12 inch display on a laptop computer for electrode P4. b. A frequency analysis of the average of the magnitude of the power spectrum signal from each EEG epoch for S2 while wearing the VR helmet and eye tracker for electrode P4. Notice that there is a little more noise overall while wearing the helmet. This may be due to the electrode shifting a little when the helmet was placed on the head. For both a. and b. the impedance fell below 20 kohms. Both graphs are shown at the same scale.

parts of the world. This may cause the P3 and P4 electrodes to shift from rubbing against the helmet if the helmet is not tight enough around the head. In the future, recordings need to be checked for the possibility of shifting electrodes.

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