EEG MEASUREMENTS IN A LOW-NOISE ENVIRONMENT

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ABSTRACT

Electroencephalographic recordings acquired in the LSBB shielded capsule demonstrate that clean EEG signals can be acquired without the need for notch filtering, and that the broadband noise is also significantly reduced. Those results demonstrate the potential of the LSBB capsule for novel EEG studies.

INTRODUCTION

Electroencephalography which involves the recording and analysis of electric signals generated by the brain has long been used to diagnose various brain dysfunctions and more recently to monitor anesthesia in the operating room and sedation in the intensive care unit. For instance, electroencephalography continues to play a major role in the diagnosis and management of epilepsy. The EEG is generally described in terms of activity in different frequency bands: the delta-band, [0-4Hz]; the theta-band, [4-7Hz]; the alpha-band, [8-12Hz]; the beta-band, [12-30Hz]; and the gamma-band, [30-100Hz]. In the last decade, intra-operative EEG monitoring has become increasingly used to assess the depth of hypnosis of patients in response to hypnotic agents such as propofol.

A particular such monitor is the NeuroSense™, based on wavelet analysis primarily in the gamma-band, see [1] for details of the algorithm. Although this is still subject to debate, the gamma-band has recently been associated with the somatosensory cortex, with a decrease in gamma band activity linked to cognitive decline, and an increased theta/gamma ration associated with memory impairment [2]. Because power line interference will result in significant 50 Hz or 60 Hz corruption of the EEG right in the gamma band, any studies of the gamma band must be performed on an EEG that was first processed though a 50 or 60 Hz notch filter. While effective at removing the resulting EM interference, such a notch filter is also bound to remove some valuable information about the gamma band.

In this pilot study, our objective was to establish whether by acquiring EEG recordings in the LSBB shielded capsule we could do away with notch filters. Secondary objectives were i) to assess the interference from the laptop computer and the NeuroSense patient module; ii) if the data allowed it, to assess the effect of notch filtering on the estimated gamma band activity.

METHODS

A NeuroSense™ patient module PM-701 connected to a laptop running on battery power was used to acquire the EEG of 3 volunteers sitting in a reclined position. The PM-701 is a two-channel (4 electrodes) EEG for bilateral monitoring, has a bandwidth of 0.125-300 Hz, noise less than 2μVpp from 0.125 to 100 Hz, and provides a raw EEG sampled at 900 Hz. No external power source was required by the system. The 900 Hz sampled raw, unfiltered (all filters on the PM 701 were turned off) EEG data were acquired using the NeuroSense NS-701 software running under Windows Vista on a laptop running under battery power and connected to the PM-701 via a USB cable DC-701. The PM-701 is powered by the laptop via the USB cable. The resulting data were then analyzed using MATLAB. The EasyPrep™ EK-701 electrodes were used to acquire bilateral EEG as depicted on Figure 1.

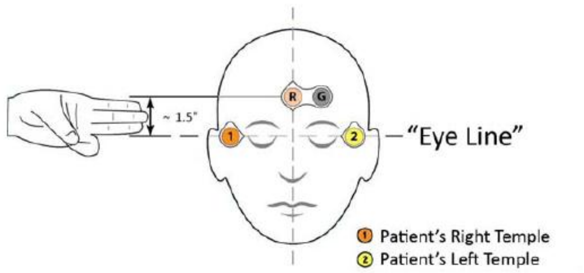

Fig. 1 The montage used to acquire the EEG signals. The electrode "R" is used as reference while the electrode "G" is the ground.

For comparison purposes, EEG were first acquired in a hospital environment, namely the orthodontal surgery suite at the Carémeau University Hospital in Nîmes. EEG was then acquired on the same three subjects in the 1500 m^3 shielded capsule at the LSBB. Three setups were studied: i) subject, PM 701 and laptop in capsule ii) subject, and PM 701 in capsule, laptop outside, iii) subject in capsule, PM 701 and laptop outside. In each setup, the subjects were asked to relax or count backward in 7 under three different conditions: 24 V lights on, 24 V lights off, and total power blackout, i.e. no power nor ventilation in that section of the tunnel.

RESULTS

The first observation is that there was no noticeable difference in the power spectral densities for the three different setups. This indicates that neither laptop nor patient module PM-701 interfered with the acquired EEG data.

Figure 2 displays power spectral densities for one subject for the no-light/counting scenario i) acquired in the surgical suite with and without notch filter and ii) averaged over the three setups in the capsule. In the surgical suite, the presence of both the 50 Hz power line interference and its first harmonic at 100 Hz is striking. Clearly, for assessment of the gamma band activity, notch filtering is required. However, as the results of notch filtering at 50 and 100 Hz show, the filtered signal is distorted with loss of information. On the other hand, EEG acquired in the capsule clearly shows that there is no electromagnetic interference. Also, the EEG from the surgical suite does not display as clearly as the one from the capsule the beta activity resulting from the counting operation.

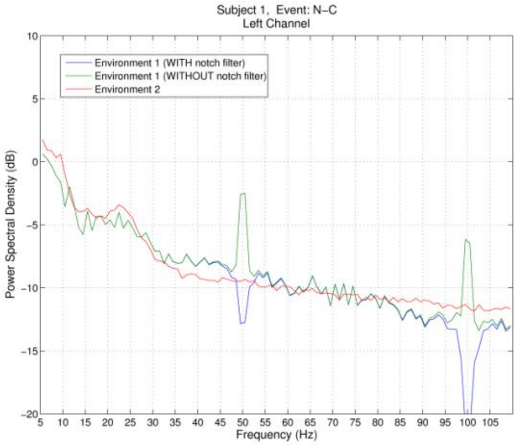

Fig. 2 Comparison of the EEG for subject 1, no-light/counting: i) in the surgical suite with and without notch filtering and ii) in the capsule. Averaged power spectral densities.

Figure 3 shows the power spectral densities for subject 1 for a single event (no averaging) for the different environments. It clearly shows that not only no notch filtering is required for the EEG acquired in the capsule, but also that the background noise over the entire spectrum is significantly reduced in the capsule compared with the surgical suite. The remaining noise could be due either to thermal fluctuations in the amplifier or originate from the electrode-skin interface.

DISCUSSION

Those preliminary findings not only confirm the hypothesis that EEG signals acquired in the capsule do not require notch filtering but also that they are significantly less noisy across the entire spectrum. This study also shows that the patient module does not introduce any noise on the acquired signals. Because it was put together fairly rapidly, this study has some limitations. First, due to the temperature in the capsule, subjects sweated profusively during the experiment, creating artefacts on the signals. Also, the subjects were not sitting very comfortably and thus were not completely relaxed. Because the counting task may not have been sufficient to clearly detect beta waves and the subject were not told whether to open or close their eyes, the expected changes in the EEG between the relaxed state and the counting task were at times not significant. Finally, a subject briefly dozed off during the test.

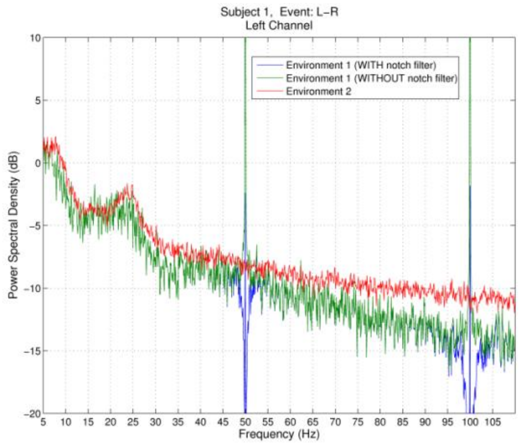

Fig. 3 Comparison of the EEG for subject 1, in the light/relaxing scenario, i) in the surgical suite with and without notch filtering and ii) in the capsule. Single event power spectral densities are shown.

CONCLUSIONS

This first pilot study does confirm the potential of the capsule for novel EEG data studies taking advantage of this unique low-noise environment to detect physiologically-based minute EEG patterns normally buried in noise. More informative studies need to be designed. Also, one might consider using a research-grade rather than a clinical grade EEG system capable of faster sampling as indeed fast (above 600 Hz) brain oscillations may be of interest [3].

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