eXtreme EEG

EEG in a Rollercoaster - eXtreme EEG measured in the Europa-Park, Rust

by Dr. Michael Jachan, Maria Schatt, Patrick Britz and Dr. Achim Hornecker

In earlier eXtreme EEG studies, we showed that it is possible to take EEG measurements from humans while in motion, for example when playing table tennis. Hungarian researchers have even taken our “eXtreme EEG Pack” to the hostile environment of the Himalayas, where they recorded EEGs while mountaineering. We in the Freiburg Software Development Team had the idea of taking EEG measurements under conditions of unnaturally high acceleration, such as occur during a rollercoaster ride. This short pilot study could pave the way toward a new branch of brain research into FEAR, ANXIETY and DANGER!

The Europa-Park in Rust, Baden-Württemberg (*www.europapark.de*), is an amusement park for the whole family. Older children and teenagers enjoy the excitement of riding high-power, high-tech rollercoasters, such as the Silver Star (*www.clipfish.de/video/800851/silverstar-europa-park-rust*) or the Blue Fire (*www.youtube.com/watch?v=AtK72rTL3BM*). We made a two-day appointment with the very welcoming team at the Europa-Park who allowed us exclusive use of the Silver Star on September 14 and the Blue Fire the day after. Of course, to benefit from an exclusive session on a rollercoaster you have to get up early in the morning, and we were therefore probably the first people ever to follow up a quick breakfast with an 8 am rollercoaster ride.

Silver Star Ride

We spent the first session training ourselves on the Silver Star. I can still remember that my whole body was shaking even during our preparations. We mounted the eXtreme EEG on Maria who had never ridden the Silver Star. I, Michael, had already experienced this ride two years previously. We prepared the actiCAP and connected the three devices: The laptop, the FirstAmp, and the actiCAP control box. We stowed these in the rucksack, seated Maria in one of the front seats and mounted a two-channel acceleration sensor on the car. The sensor’s x and y channels corresponded to accelerations in the left/right and up/down directions. We were not able to measure the third component, forward-backward. We could not find any way to mount the camera safely on the car, so we decided to go without it – time was running out… I took the seat next to Maria, leaving Achim as groundstaff to push the safety button, while the official from the crew, sitting in the control cabin, started to winch us up. The Silver Star‘s design uses a passive powering principle: The car is slowly pulled to a height of 73 meters and is then released into almost vertical free fall. OK, it is not completely vertical – but when you are sitting in the Silver Star, it feels like it! The whole ride of 1.6 km is powered only by the kinetic energy gained from lifting the car. Maria and I screamed more than once, especially during the first, and steepest, downward section. After a ride lasting approximately 65 seconds, the car returned to the platform and we checked the equipment. We saw that both channels of the acceleration sensor had gone off – the connectors to the FirstAmp had become loose. For the second ride, we fixed them to the FirstAmp using leucoplast. 3... 2... 1... second ride. Unfortunately, this time all the EEG channels went off after 15 seconds. However, the acceleration sensor yielded a good signal on both channels.

The rest of the working day on Monday was spent examining the data using Analyzer 2. Three of the 16 EEG channels were completely polluted by high-amplitude artifacts. A comparison of these three channels with the acceleration signals from the second ride showed that they seemed to be highly correlated and indicated each curve on the rollercoaster’s path. This might indicate effects due to defective contacts. It has to be admitted that, in general, the data quality was very low because physiological artifacts, most of them muscle artifacts, were superimposed on the EEG. We had repeatedly screamed out loud and our bodies must surely have activated every possible muscle to counteract the external forces. However, no external artifacts, such as 50 Hz mains signal, were present.

Blue Fire Ride

For the second day‘s research, Maria and Achim had the idea of mounting the camera on a biker‘s helmet using copious amounts of Gaffer Tape. During the Blue Fire experiment, Maria wore the helmet while I was responsible for the EEG cap. The Blue Fire is a more modern ride and uses a sophisticated principle to power the car: It is a catapult launch coaster. The car starts out on a horizontal track, where it is accelerated by a 2500 horsepower linear motor which carries it from zero to 100 km/h in 2.5 secoooonds. Achim agreed with the staff that we could have two rides in a row and then take a break to check the equipment before finally taking two more rides. The linear acceleration phase at the start is the most exciting part. Then comes a steep horseshoe-shaped turn with a total height of approximately 40 m followed by a full loop and a total of three screw turns which provide an enjoyable, exciting aerial experience with a maximum acceleration of 3.8G. After a ride of 45 seconds, it is over. Wow! Have you ever ridden a rollercoaster four times in a row without even having to get out and back into the car? Weren‘t we lucky!

During the second day, we did not experience any technical problems except for the fact that the acceleration sensor‘s x-channel came loose again. Even though the data quality was excellent in terms of external influences, there were still a lot of muscle artifacts, in fact too many for the data to be useable for conventional EEG processing. We observed relatively strong external artifacts during the acceleration phase. These were probably caused by the high-power linear motors.

Data Analysis

First, we analyzed the interference caused by the 2500 horsepower linear motors during the acceleration phase. We extracted the 2.5 seconds after the start, a phase which was reflected by a huge artifact in all four rides. We computed the FFT based on 500-millisecond intervals averaged over all channels and all four rides. Fig. 1 illustrates this averaged FFT (logarithmic scale). The artifact can be described as a low-pass noise with decreasing spectral density in the band 0-100 Hz.

We then decided to evaluate the global spectral EEG properties as a function of acceleration. First, the EEG was filtered in the band 0.5 – 32 Hz and the acceleration signals were filtered in the band 0.5-4 Hz using 48dB/Oct filters. Figure 2 depicts the time-domain signature of the acceleration sensor. All four rides yielded very similar patterns. The EEG's Pz channel was excluded because it contained artifacts which might have been due to a defective contact. For the remaining EEG channels, we computed an ICA to perform artifact rejection. The Cz channel contained approximately 14% artifacts and these were discarded. We automatically set markers on the maxima and minima of the acceleration channels. These were then used to generate 38 low-acceleration segments (group A) and 51 high-acceleration segments (group B), each of length 500 ms. An FFT with a Hanning window was applied to both groups and the group averages were computed. The resulting spectra for three example channels (O1, O2, Oz) are shown in Figure 1. It can be seen that the values for high accelerations (green lines) are noticeably higher than for low accelerations. However, we do not claim to have found a significant difference in this simple experiment. We are also unable to say whether this spectral difference is due to the EEG solely or due to sources such as the EMG or due to external electromagnetic interferences.

Conclusion

In this pilot study involving an EEG recorded during a rollercoaster ride, we clearly reached the technical limits of EEG acquisition. We are proud to say that our hardware was able to withstand extreme acceleration forces of up to 3.8G. In the future, it will be an easy task to solve minor problems such as loose connectors by improving the electronics housing. The actiCAP's ability to measure the EEG when active electrodes and, moreover, active shielding were employed meant that external artifacts remained at a very low level. However, when dealing with external power sources of several megawatts, we were able to identify the temporal location of the artifacts in the data.

A video, a part of the recorded data and a report on this eXtreme EEG Project can also be found in our eXtreme EEG Database at *www.brainproducts.com/extreme_eeg.php?tab=2*

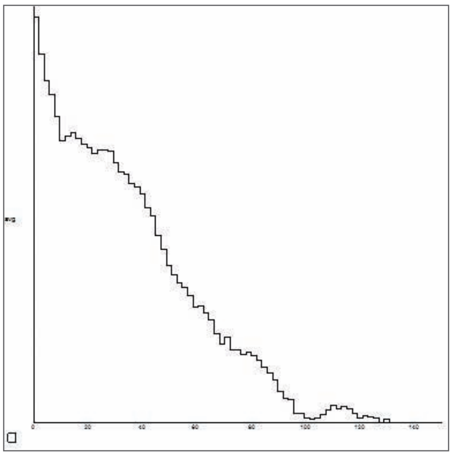

Figure 1

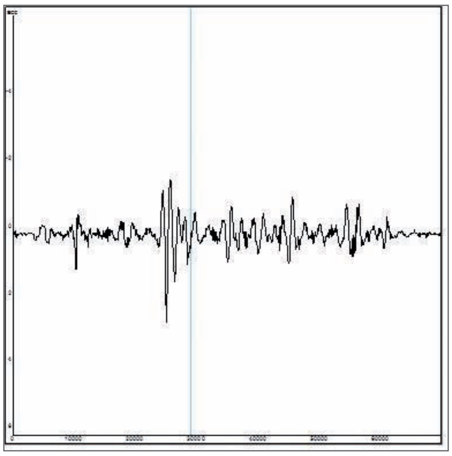

Figure 2

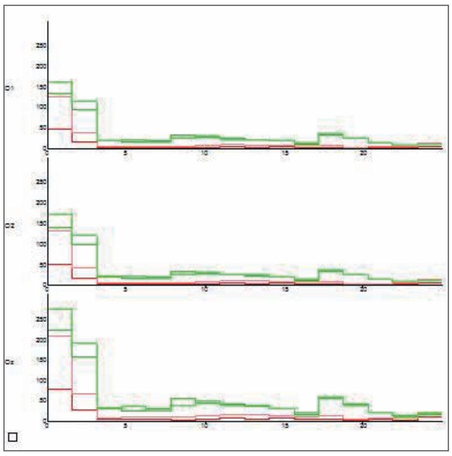

Figure 3

Legend figure 1:
BLACK: Total average FFT spectrum of the 2.5 second acceleration phase. The artifact is 0-100 Hz broad-band noise with decreasing amplitude.

Legend figure 2:
BLACK: The acceleration sensor signal of the first Blue Fire ride. The signals for all four rides are similar.

Legend figure 3:
RED: Power spectral density for group A (low acceleration). The thin line indicates mean value plus standard deviation.
GREEN: Power spectral density for group B (high acceleration). The thin line indicates mean value plus standard deviation.