Independent BCI Use in Two Patients Diagnosed with Amyotrophic Lateral Sclerosis

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Abstract

A P300 based brain-computer interface (BCI) application for creative expression was implemented at the homes of two artists diagnosed with amyotrophic lateral sclerosis (ALS). Here we present data of independent BCI home use for up to 23 months. Our findings indicate that a P300 BCI can be used in the patients' daily life with high satisfaction and gratification for both BCI end-users.

1   Introduction

To date BCIs have hardly been established at the patients' homes. To our knowledge there exist only 3 studies presenting independent BCI use [1-3]. The current study aimed at demonstrating proof-of-principle of independent BCI use and investigating usability of independent BCI use in severely disabled patients. A P300 BCI for creative expression, *Brain Painting*, was implemented at the patients' homes. Here we present data within two patients, who used the BCI at their homes for several months. The study covering data of the first 14 months (200 sessions) for the first patient is published in its extended form in [4]. In this paper we present follow-up data and also data of a second patient, who has been participating in the study for 5 months.

2   Method

For a detailed description of methods the reader is referred to [4].

2.1   Patients

Both patients (one female), aged 73 and 74, were diagnosed with ALS. Both are artists and with progress of disease related paralysis were no longer able to paint. Patient 1 is in the locked-in state with preserved eye-movements. Patient 2 is tetraplegic, able to talk and to move his head.

2.2   Easy to use BCI and set-up

Electroencephalography (EEG) was recorded with 8 active electrodes (gamma cap, g.tec, Graz) from electrocde positions Fz, Cz, Pz, P3, P4, Po7, Po8, Oz. *Brain Painting* [5] was facilitated for

independent home use [4], in the way that *Brain Painting* can be started within a few clicks and BCI parameters, such as calibration data, are loaded automatically. In an initial meeting including two consecutive days, BCI was calibrated and the family and/or assistants were trained in setting up the BCI system. BCI is used independent of the help of BCI experts. BCI data is automatically transmitted to a remote-server to the BCI lab. BCI use is monitored and supported in case of e.g. technical problems using a remote desktop application. Patient 1 was visited in further meetings for e.g. improvement of the system or recalibration. At date of submission, patient 1 has been using the BCI for 23 months and patient 2 for 5 months. Both studies are ongoing.

2.3 Face valid measures of BCI use and evaluation

A BCI session was considered valid, if the end-user painted for at least several seconds. Total painting time is the summed painting time of all runs excluding beaks per session. After every BCI session end-users indicated their satisfaction and frustration with the BCI session on visual analogue scales (VAS) ranging from zero (not at all satisfied/ frustrated) to 10 (very satisfied/ frustrated). BCI users could comment on the sessions in a comment line. Subjective level of BCI control was rated by the BCI end-users within four classes (percentage of correct selections): (1) zero (0-50%), (2) low (50-70%), (3) medium (70-90%) and (4) high (90-100 %).

3 Results

3.1 Face valid measures of BCI use

In 23 months patient 1 painted in 271 sessions, with a total painting time of 403.48 hours with a mean painting duration of M=89.33 (SD=52.87) minutes. Patient 2 painted with the BCI in 58 sessions within 5 months, resulting in a total painting time of 64.60 hours with a mean painting duration of M=66.82 (SD=34.56) minutes.

3.2 Subjective level of BCI control

In most sessions subjective level of BCI control was rated as *medium*, in 94 sessions for patient 1 and 35 sessions for patient 2. *Low* was indicated in 75 and 12 sessions, *zero* in 51 and 1 session(s) and *high* in 43 and 10 sessions, for patient 1 and patient 2 respectively.

3.3 Satisfaction with BCI sessions

Overall satisfaction was high in both subjects, M=7.42 (SD=3.21) for patient 1 and M=7.95 (SD=2.0) for patient 2, consequently overall frustration was low, M=2.88 (SD=3.06) and M=3.02 (SD=2.36) respectively, (**figure 1**). Dissatisfaction occurred due to (1) technical problems with software, mostly at the beginning of the study, or with hardware, e.g. malfunctioning of amplifier or EEG electrodes, (2) low BCI control due to e.g. drying electrode gel, shifting EEG cap and (3) personal factors, such as attention issues (fatigue, concentration) and disease factors (e.g. cough), both influencing BCI control too, and satisfaction with painting.
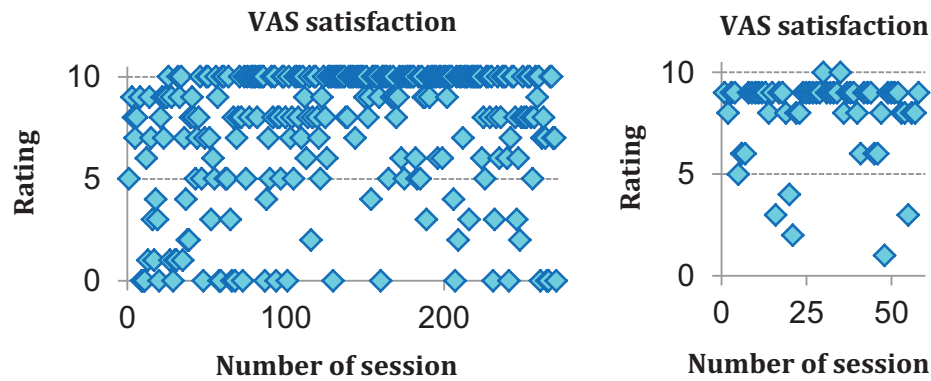
Figure 1: VAS satisfaction for patient 1 (**left**) and patient 2 (**right**) over time (271 and 58 sessions). Zero indicates "not at all satisfied" and 10 "very satisfied".

3.4 Paintings

Patient 1 created more than 120 paintings, patient 2 more than 30. Two paintings are depicted in **figure 2.**
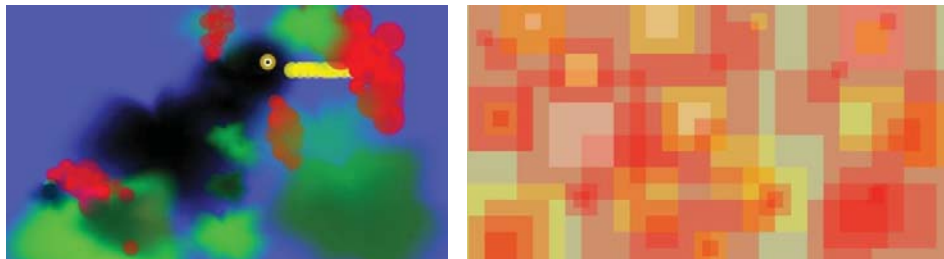

Figure 2: Paintings: *Black bird* by patient 1 (**left**) and *Patchwork* by patient 2 (**right**), with permission of the artists.

4 Discussion

The present study demonstrates that independent BCI use is possible with high satisfaction and gratification for the patients. BCI use was challenged by technical problems, BCI control and personal factors. Technical problems, occurring mostly at the beginning of the study (in patient 1), could be solved and fully removed. Dissatisfaction with the painting occurred also only at the beginning of the study and disappeared with more practice in using the *Brain Painting* matrix. Attentional issues could be reduced through frequent breaks within sessions and time management, e.g. BCI session is not started, if the patient is too tired. Disease related factors, such as cough, however are less likely to be overcome and will remain in daily-life. In most of the BCI sessions end-users rated BCI control as

being *medium*. BCI control depended on the adjustment of EEG cap and electrodes, but also on personal factors (e.g. concentration and cough). Problems on BCI control could be decreased by improvements on hard- and software, e.g. EEG cap and electrodes or an auto-calibration option [6]. Interestingly patients indicated moderate to high satisfaction even if BCI control is moderate and not 100%. Patient 2 states: "*I do not want to focus of my attention on my cough. I have enough time and I refine until I am satisfied with it* [painting]. *This is the way I did it in the past as a* [hand] *painting artist* […]". This shows that, even with low(er) BCI control, the patient can nevertheless be satisfied with BCI as assistive technology. Patient 1 points out: "[…] *Brain Painting makes me happy and satisfied everytime again, if it works - if not, then frustration and disappointment. Fortunately this happens in only few cases. BP completely changed my life. I can paint again and be creative again using colours* […]".

5 Conclusion

BCI controlled painting is accepted well as assistive technology by the severely disabled end-users. *Brain Painting* exactly matches the artists' need for creative expression and positively impacts the quality of life of the patients. P300-BCIs have come of age and can be used independently in daily-life. To replicate our findings, inclusion of more patients is planned.

6 Acknowledges

References

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