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Long-Term Independent BCI Home-Use by a Locked-In End-User: An Evaluation Study

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Abstract. The ERP-BCI controlled application *Brain Painting* was installed at a locked-in ALS-patient's home. BCI was operated by the family independently of BCI experts. In more than 11 months the end-user painted in 140 BCI sessions (and ongoing). The *Brain Painting* was evaluated by the BCI end-user in terms of *satisfaction*, *frustration* and *enjoyment* using a visual analogue scale (VAS). Overall, satisfaction was moderate to high (M = 6.82 of 10, SD = 3.46). The study demonstrates that independent BCI home-use is possible. Moreover, *Brain Painting* has become an important part in the end-user's life (personal statement).

Keywords: Brain Computer Interface (BCI), independent home-use, ERP, user-centered design, evaluation, locked-in state

1. Introduction

Brain-Computer-Interfaces (BCI) enable persons with severe motor impairments, such as amyotrophic lateral sclerosis, to communicate and control their environment. Despite intensive research, BCIs could hardly be established at the patient's home [Sellers et al., 2010]. Main problems are e.g., too complex and not easy to use software and time-consuming set-up. In this study we installed the BCI-application *Brain Painting*, which was successfully tested and evaluated by healthy as well as motor restricted subjects [Münßinger et al., 2010; Zickler et al., 2013], at the patient's home. *Brain Painting* utilizes an ERP-BCI for painting on a virtual canvas by selecting from various painting options (e.g. brush size, color, etc.).

2. Material and Methods

2.1. Subject

One locked-in patient (72 years old), diagnosed with amyotrophic lateral sclerosis (ALS), who used to be a painter, was considered as potential BCI end-user. As she had no existing application for creative expression, *Brain Painting* immediately awoke her interest. Currently, she is using an eye-tracker for communication.

2.2. BCI-set-up and application

The easy-to-use *Brain Painting* application was installed at the end-user's home. An initial calibration was performed once and the family was trained to set EEG-cap and to operate the BCI system. The patient and the family used the BCI independently at home and BCI experts intervened only few times, e.g., when technical problems occurred or parameters had to be changed. This was realized via remote control. BCI data and evaluation reports (see below) were automatically transmitted and stored on a remote server, enabling the experts to follow BCI use and end-user's experience. EEG was recorded with an 8-channel active electrode cap (g.tec, Austria) from centro-parietal regions. After two months the family was visited for a second time, in which a new calibration was conducted. Nine months after start a new *Brain Painting* with Einstein face-stimulation [Kaufmann et al., 2012] was installed and calibrated.

2.3. Evaluation

After every *Brain Painting* session the end-user evaluated the *Brain Painting* session. On visual analogue scales (VAS), ranging from 0 to 10, the end-user rated her s*atisfaction* with the *Brain Painting* session (*0 = not satisfied at all – 10 = very satisfied)*, her experienced *frustration (0 = not frustrated at all – 10 = very frustrated)*, and the level of *enjoyment (0 = not enjoyed at all – 10 = very enjoyed)*. In the initial test phase, only VAS satisfaction was rated (first 8 sessions). After this proof-of-principle phase evaluation was extended (sessions 9 to 140). To evaluate a positive or negative trend over time, Pearson correlations between each scale and time (session) were calculated.

3. Results

The end-user painted in about 140 sessions within 11 months without presence of BCI experts. Setup of BCI equipment took about 20 - 40 min, while setup and operation of the application took approximately another 10 - 20 min. Mean total painting time was $M = 67.54$ ($SD = 41.83$, range: 2 - 198) minutes. After integration of face stimuli, the number of sequences used for stimulation could be decreased from 10 to 5, thereby allowing for faster command delivery. Overall, the end-user was moderately to highly *satisfied* ($M = 6.82$, $SD = 3.46$), showing a positive trend over time ($r = 34$, $p < 001$). Ratings for VAS Satisfaction across all 140 sessions are depicted in Fig. 1. *VAS enjoyment* ratings indicated that the end-user enjoyed the painting in most of the sessions, with an average of $M = 7.37$ ($SD = 3.38$, $r = .30$, $p < .001$). On the other hand, *frustration* was low, with an average over all sessions of $M = 3.19$ ($SD = 3.5$, $r = -.30$, $p < .001$). One of the main reasons for her dissatisfaction and frustration were technical problems, especially in the first BCI sessions. Further sources of dissatisfaction were bad or not good control due to possibly not sufficient electrode gel or bad cap placement, tiredness/bad concentration and loss of control due to drying electrode gel or shifting of cap after 2 - 3 hours of painting.

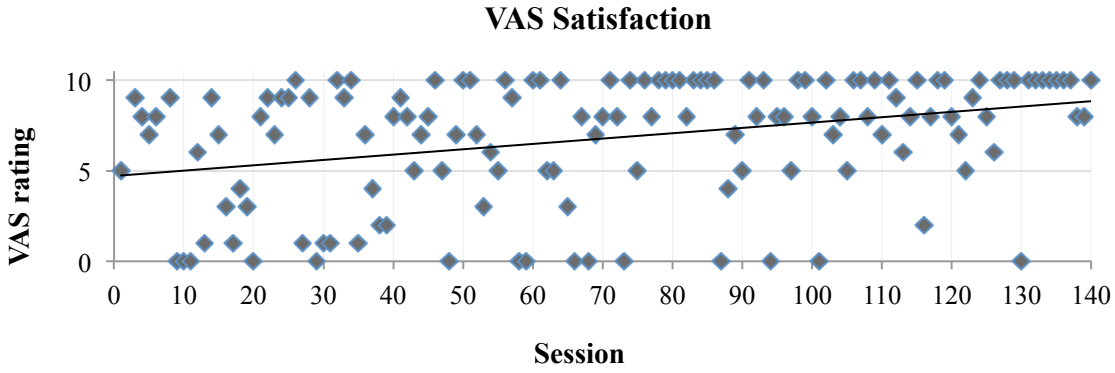

Figure 1. ***VAS Satisfaction****: Satisfaction was rated on a visual analogue scale (0 = not satisfied at all – 10 = very satisfied). Note that ratings in sessions 2 and 7 are missing.*

4. Discussion

Our results demonstrate that expert-independent BCI home-use is possible. However, BCI use is challenged by technical problems and varying BCI control. Nevertheless, a positive trend in *satisfaction* and *enjoyment* is evident. With Einstein stimuli she is able to paint more efficiently. For the end-user *Brain Painting* has become an important part of her life. “I paint three times per week, but if I could, I would like to paint every day” (personal statement of the painter).

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