Field Study of an fNIR-Based Brain-Computer Interface for Communication

M. M. Jackson[1], K. Ozawa[2], K. Kido[3], I. McClendon[1], R. Kerwin[1]
[1]*Georgia Institute of Technology;* [2]*Tokyo Woman's Christian University;* [3]*Hitachi Ltd*

Correspondence: Melody Moore Jackson, 85 Fifth St NW, Atlanta GA 30303. E-mail: melody@cc.gatech.edu

Abstract. Functional Near Infrared (fNIR) Brain-Computer Interfaces use light in the infrared spectrum to determine activity levels in the brain by detecting hemodynamic changes. Hitachi Japan developed the Kokoro-Gatari device, a simple fNIR-based communication system for people with locked-in syndrome. Following a successful study in Japan, we performed a year-long U.S.-based study in the home environments of 30 people with ALS, to determine the long-term effectiveness of the Kokoro-Gatari as a communication device. Accuracy ranged from 32% to 100% with an average of just under 70% overall. We also examined average usage (compliance with the study), regional differences, and learning effects.

Keywords: Functional Near Infrared Imaging; Assisstive Communication, ALS

1. Introduction

People with locked-in syndrome cannot speak or move their muscles, and have little or no ability to communicate with their families and caregivers. Restoring communication can be key to improving quality of life for this population, and Brain-Computer Interfaces (BCIs) are a promising solution. However, most BCIs are complex and require extensive training to use, making them difficult for a home scenario. The Kokoro-Gatari (K-G, "Teller of Hearts" in Japanese) device was developed by Hitachi Japan as a simple BCI for home use [Naito et al., 2007]. The K-G is intended to provide augmentative and alternative communication (AAC) for people with Amyotrophic Lateral Sclerosis (ALS), which is a chronic and progressive disease that can cause locked-in syndrome. The K-G device is based on functional Near-Infrared Imaging (fNIR), which utilizes light in the infrared spectrum to detect areas of activation in the human brain generated by mental imagery or tasks. We performed home visits, setting up the K-G system and training 35 people with ALS and their families to operate it. We automatically collected data from the K-G devices over the span of a year in nine states: New Jersey, New York, North Carolina, South Carolina, Georgia, Florida, Alabama, Pennsylvania, and California. Participants were allowed to keep the device after the study if they wished.

2. Material and Methods

The Kokoro Gatari system consists of three components: a headband, an fNIR signal-processing device and a personal computer. Light emitters and a detector are installed in the headband. The light sources are LEDs with the wavelength of 770 nm. The detector is a Si PIN photodiode (PD) located 30 mm away from the LEDs [Sagara et al., 2009]. The emitter of the headband is placed over the left eyebrow of the subject, as close to the temple as possible without contacting the hair (see Fig. 1). This allows language imagery to activate Broca's area (in right-dominant subjects). Suggested imagery included reciting poetry, singing a song, or sub-vocal counting. The device analyzes the blood volume changes in cerebral cortex accompanied by change in brain activity. When ALS patients are asked a question, they answer 'yes' or 'no' by performing a language imagery mental task to activate their brain. The blood volume change is then detected with near infrared light (NIR). When light sources are focused on the patient's head the light penetrates the brain, scatters there and then returns to the surface of the brain. The use of the brain is detected by measuring the intensity of the returned light. When the blood volume, and thus the amount of hemoglobin, is increased during brain usage absorption of the incident light by hemoglobin decreases and the intensity of returned light decreases also.

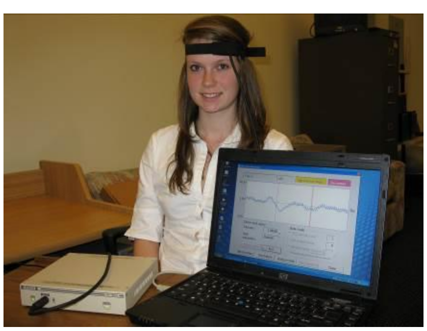

Figure 1. The Kokoro-Gatari

2.1. Experimental Procedure

Researchers visited 30 subjects' homes throughout the U.S., setting up the K-G device and training the subjects to use it. The study protocol consisted of a calibration session, where the subjects were asked to perform mental language tasks to say "yes" and to think of a nonsense syllable (such as "la") to deactivate their Broca's area to say "no". Subjects were asked to generate a "yes" two times and a "no" two times, which allowed the researchers to set device parameters customized for each subject. After the initial calibration, subjects were prompted by the K-G system to generate a "yes" or a "no" in a randomized sequence for a total of ten answers. The data were automatically sent to the research team in Georgia. Subjects agreed to practice with the K-G at least twice a week for a month; at that time they could continue if they wished.

3. Results

3.1. Effectiveness

Of the 30 subjects, only four (13%) were not able to use the device. The average length of participation was 13.6 weeks, over three months. The average number of sessions per week was 1.92, very close to the promised twice a week. Average accuracy overall was just under 70%, with a range of 32% to 100%. Standard deviation was 9.05. The presence of the investigators (who followed up with most of the subjects) had an effect on the accuracy – with 5% greater accuracy when the investigator was present. Regional culture also had an effect, with western states achieving the best accuracy at 75%, and northern states averaging 61%.

3.2. Learning Curve

As expected, we observed a learning trend in the first few months that leveled off as subjects became proficient at operating the K-G device. Figure 2 shows that early learning fluctuated, and then experienced an increase, which leveled off. The increase after month eight reflects the most successful subjects who used the K-G device longer.

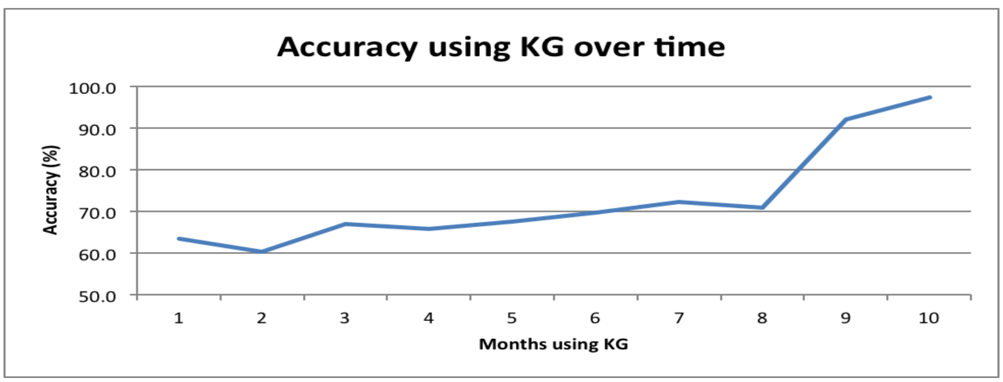

Figure 2. Longitudinal performance averages of all subjects.

4. Discussion

Compliance with this study was impressive from most of the subjects, as evidenced by the nearly twice a week average for practicing with the system. Chronic diseases such as ALS can produce fatigue and illness, so motivation was high for the subjects to be that consistent. The subjects that produced accuracies of less than 50 percent may have had "inverse data"… the calibration of yes and no may have been reversed. A consistent accuracy of 30% may actually be 70%, which could affect the cumulative averages. Overall, 87% of subjects had 60% or higher accuracy.

Acknowledgements

The authors would like to thank Hitachi Japan for their support and funding for this project.

References

Naito M, Michioka Y, Ozawa K, Ito Y, Kiguchi M, Kanazawa T. A communication means for totally locked-in ALS patients based on changes in cerebral blood volume measured with near-infrared light. *IEICE Trans Inf Syst*, E90-D No. 7:1028-1037, 2007.

Sagara K, Kido K, Ozawa K. Portable single-channel NIRS-based BMI system for motor disabilities' communication tools. *Proceedings of the IEEE Engineering in Medicine and Biology Society*, 602-605, 3-6 Sept., 2009.