Exploring the Viability of Utilizing Smart Home Devices in Aiding Communication with Patients with LIS

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Background information on Locked in Syndrome (LIS):
LIS patients are conscious and awake, yet have complete body paralysis except for a few muscles, usually associated with the eyes. The main cause of LIS is brainstem lesions, more specifically to the pons, a part of the brainstem that contains nerve fibers that relay information to other areas of the brain and subsequently the rest of the body. LIS affects about 1% of stroke victims and can be caused by anything from poisonous animal bites to traumatic brain injuries.

3 Types of LIS:
- **Incomplete:** Patients have the ability to control some voluntary muscles in addition to eye movement
- **Standard:** Patients only have control of eye movement
- **Complete:** Patients have no control over any voluntary muscles, including eyes

Why spend so much time and effort on such a rare disease?
While LIS is a rare disease, it completely upheaves the lives of patients and their families. Because patients are completely aware of their situations it is imperative to provide them with an effective means of communication. Of those who have recovered, almost all have credited the ability to communicate with doctors and family members as one of the main steppingstones on the road to recovery.

What are the plans for the future to aid those that suffer from LIS?
Understanding of the disease has increased over the years, but there is still much to learn. In terms of communication, the most important breakthrough is the introduction of the **Brain Computer Interface (BCI)** to the treatment process. This technology is the focus of this research and will be explored in depth.

Brain Computer Interfaces

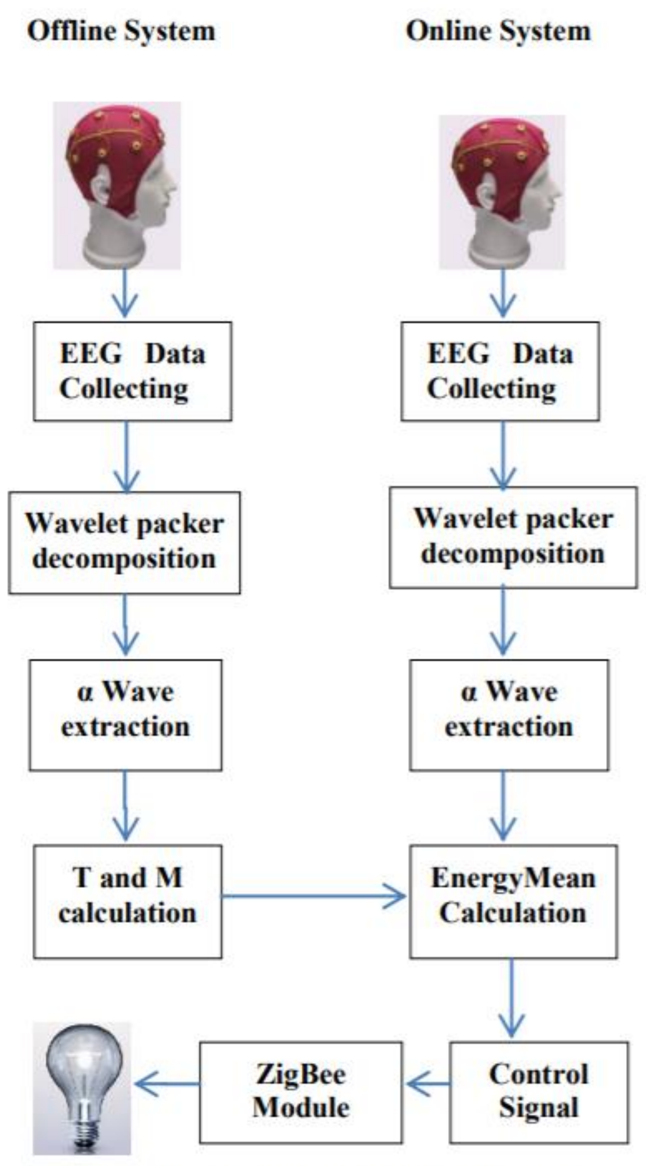

Figure 1. The overall structure of BCI

Eye controlled BCIs

Brain Computer Interfaces (BCIs) utilize a patient's specific brainwaves through the patient's electroencephalogram (EEG). The EEG measures the electrical activity of neurons. As can seen by Figure 1 the EEG is non-invasive and uses dry electrodes placed around the head. The data is then transferred to and calculated by the BCI. In one study (Zhang G. et al.), a BCI utilized alpha brain waves to turn a smart home light on and off. As can be seen in Figure 2 the amplitude of alpha waves increase when a patient's eyes are closed. By using the BCI and the connection seen in Figure 1, the BCI essentially gives the patient a binary choice. The 5 patients tested were able to use this device with an average of 15 minutes of training with an average accuracy of 85%. While this experiment shows the ease of implementation and high accuracy, it relies on a patient's ability to control eye movement, which patients with CLIS do not have.

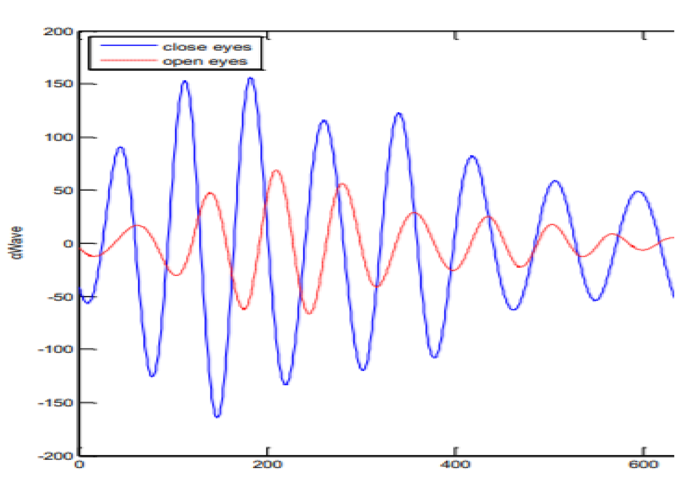

Figure 2: Amplitude of Alpha Waves

Subject	Eyes Opening times	Command Accuracy (Open)	Eyes closing times	Command Accuracy (Close)	Average accuracy
P1	10	90%	10	80%	85.0%
P2	15	86.70%	5	80%	83.4%
P3	8	87.50%	12	91.70%	89.6%
P4	4	75%	16	87.50%	81.3%
P5	10	90%	10	80%	85.0%
Average	**9.4**	**86%**	**10.6**	**84%**	**85%**

Figure 3: Accuracy Results of Experiment

mindBEAGLE and CLIS BCIs

The mindBEAGLE BCI utilizes similar technology to other market BCIs, but it has a very important distinction: it does not require any motor control, meaning it can be used to communicate with patients with CLIS. The mindBEAGLE system uses vibrotactile stimulation, as seen in Figure 5, which involves placing vibrating nodes on each of the patient's wrists.

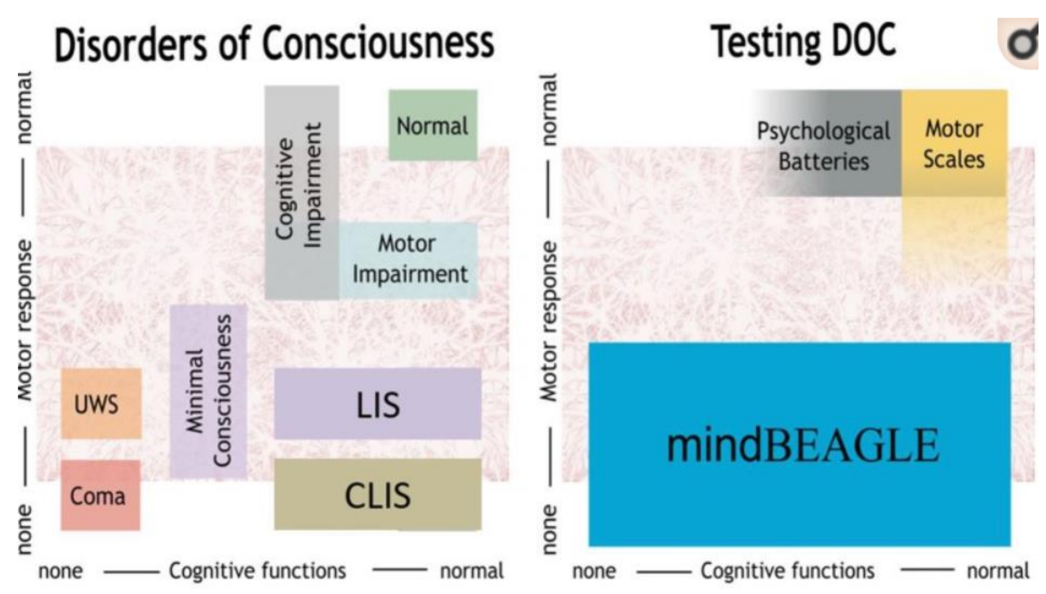

Figure 4: Disorders of Consciousness

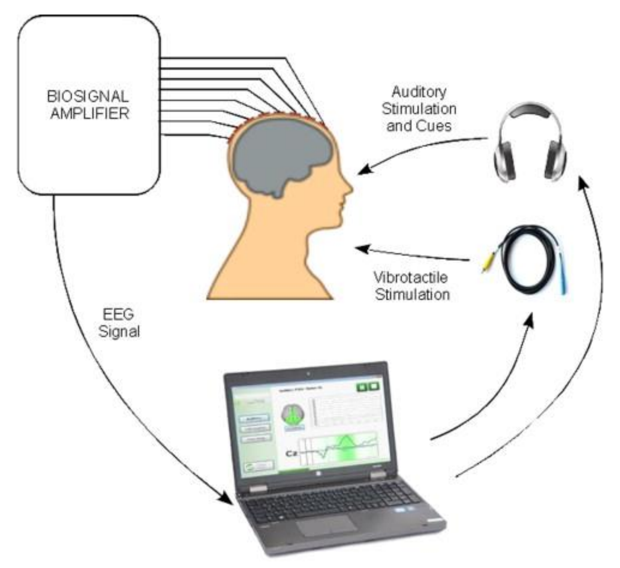

Figure 5: Schematic of Experiment Set Up

These nodes are stimulated at random for a set time. The patient is then asked to count the number of times their left wrist was stimulated, thereby causing a spike in brain activity and creating data for mindBEAGLE's P300 system to use. The process is repeated for the right wrist, and the mindBEAGLE system now has two distinct brain signals, allowing the patient to answer a binary question without need for motor control of any muscle. In a study from 2017 (Guger C. et al.), mindBEAGLE was used on 12 LIS patients, 3 of whom were classified as CLIS patients. The accuracy for standard LIS patients was comparable to the eye controlled BCIs and of the 3 CLIS patients, 2 were able to communicate with an average accuracy of 70%. Similarly, the average training time was 15-20 minutes and was non-invasive.

References:
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Edlinger G., Holzner C., Guger C. (2011) A Hybrid Brain-Computer Interface for Smart Home Control. In: Jacko J.A. (eds) Human-Computer Interaction. Interaction Techniques and Environments. HCI 2011. Lecture Notes in Computer Science, vol 6762. Springer, Berlin, Heidelberg

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Smart Home Devices and their Applicability

The next step in communication for patients with LIS seems to be the integration and utilization of SmartHome devices. SmartHome devices are those that use the internet and various non-physical switches to function. For example, the popular Amazon Alexa enables its users to activate connected devices by voice and motion controls. While many available and popular SmartHome devices and systems are not currently suited to enable BCIs such as the P300, there are certain characteristics which certain off the shelf products can emphasize to potentially allow this connection. In an experiment which tested a virtual reality environment (Edlinger G. et al.), patients used a BCI to control a virtual SmartHome. This environment was entirely virtual but has opened the door to the possibility of enabling physical SmartHome applicability. This represents the crux of the research conducted in this presentation.

Existing SmartHome Devices

As stated previously, the integration of physical SmartHome environments has been few and far between, but that does not mean that certain off the shelf devices are not on pace to change that. Accessibility has been a key feature that has been emphasized more in recent years in the SmartHome industry. The ability to control devices within your home without the need of physical movement is an important step in aiding those with severe disabilities.

This report looked into the accessibility features of 4 SmartHome Devices: Amazon Alexa, Google Home, Samsung Smartthings Smart Hub, and the Apple Watch. As can be seen in Figure 6 , each device was given an accessibility rating and a price (based off the listed price online). An overall applicability rating is based on these two criteria in addition to the features' ability to be utilized by patients suffering from LIS or CLIS.

Device	Price	Accessibility (out of 10)	**Applicability (out of 10)**
Amazon Alexa	£119.99	7.5	**6**
Google Home	£99	5	2
SmartHub	£150	8	5
Apple Watch	£399 - £499	7	3

Figure 6: Table of Applicability Ratings of SmartHome Devices

The main advantage of Alexa lies in its ability to integrate with a plethora of smart home devices from many different companies. While the price is steeper than some other smart home devices, "routines" can be programmed when certain actions are taken place, enabling more choice and options to the patient instead of a binary decision. Because of this I suggest that research should focus on the Amazon Alexa in the future