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Utilization of an alternative Communication Device using the Anal Sphincter (CDAS)

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Abstract—**The purpose of this study was to invent a new communication system for terminal amyotrophic lateral sclerosis (ALS) patients who are in a state of complete motor paralysis with intact sensory and cognitive functions whose speech are disrupted due to the weakness of muscles involved in speaking and/or to tracheostomy and ventilator dependence.**

Keywords—**ALS, anal, anus, communication, sphincter**

I. Introduction

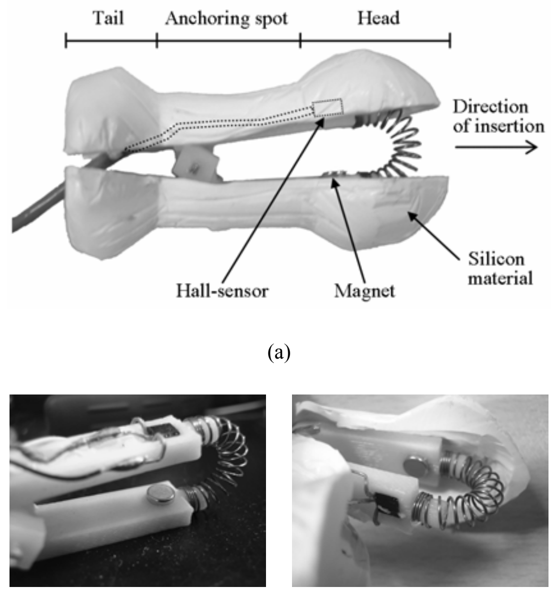
The loss of the ability to communicate with the loss of voluntary motor function is the most feared consequence of ALS patients [1]. They are not able to communicate with caregivers and express their needs and feelings.

A functional motor movement for augmentative communication may be any small movement of a muscle or body part that can be readily control consistently and reliably. As the disease progresses, available body parts are decrease and the available communication devices are limited. Extraocular movements and sphincter continence are usually spared. We will utilize anal sphincter for communication.

The patients with ALS can contract the anal sphincter voluntarily, control contraction intensity, and the contraction duration. We designed a sensor which works by changing intensity of the contraction and is enable severely paralyzed patients to communicate by means of self-regulation of the anal sphincter contraction. Patient scan the Korean alphabet board on screen and select a letter by contracting the anal sphincter. The Communication Device using the Anal Sphincter (CDAS) makes sentences through combination of selected Korean letters derived from sphincter contractions.

II. Methodology

The CDAS system is composed of the anal sensor (the apparatus that is inserted into the anus), the processing device (or module locating where the data gathered from the anal sensor is collected, sorted, then transmitted to the CDAS program) and the CDAS program (location where data is converted into a signal and displayed) as a Korean letter.



(a)

(b) (c)

Fig. 1. (a) Real image of the anal sensor. (b), (c) Detail images of a hall-electrode and magnet.

1) *Anus Sensor*: The sensor is inserted into the anus. The main parts of the anus sensor are made up of the hall-sensor, which converts the distance between the magnet (more than 1,300 Gauss) and the hall-sensor to the electric potential. The space between the two electrodes is empty

The anchoring spot is approximately 1.8cm in width and the head is approximately 2.5cm in width. The external sphincter holds the anchoring spot. The head part of the sensor, which is regulated by the external and internal sphincters, is located in the rectum. We use condoms or rubber thimbles that are disinfected, to wrap the sensor when it is operate in the anus of the subjects.

This sensor can also be operated by a person’s finger or lips, as long as the person is no completely affected by motor paralysis. It is uncomfortable to insert into one’s anus, but this kind of discomfort is not a problem to the patients experiencing general paralysis, like ALS.

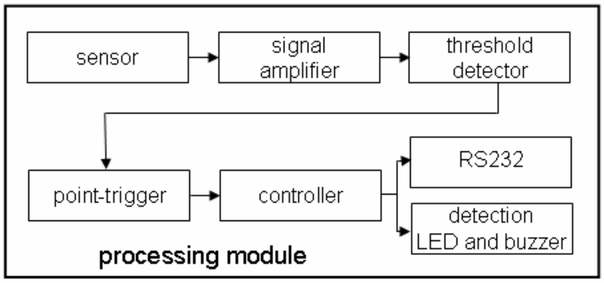


Fig. 2. Block diagram of the processing module

2) *Processing Module*:

The processing module of the CDAS system consists of three analog parts: the signal amplifier, the threshold detector, and the point-trigger.

The raw signal from the sensor has low dynamic range of voltage which is within the range of 0.2 to 0.5 volts. In the signal amplifier part, the level of raw signal voltage has to be boosted up to recognize difference between the state of the sensor's click and non-click.

Then in the threshold detector, the signal is required to be set up on a baseline voltage equal to threshold, due to the patient's initial sphincter contraction intensity having an individual characteristic.

The point-trigger prevents the pseudo-trigger signal from being recognized as a detection of the patient's contraction.

Finally, the detected signal (contracted or non-contracted) is transferred to the controller. The controller then sends information to the PC by using the RS232 protocol. If a patient contracts (clicks) the sensor, one can see a LED light and hear a beep sound.

For later mobility and portability, the CDAS system will utilize the MSP430 (Texas Instruments' ultra low power controller) to handle the hardware except for the software.

3) *CDAS Program*

We have two kinds of modes in the CDAS program because it provides more effective communication skills with the caregivers under various environments. The two modes are called the Icon Mode and the User-Writing Mode.

In the Icon Mode, patients can ask to their caregivers routine questions such as "Open the door", "Change my position", "I'm hungry", etc. We could get the ALS's routine questions from their doctor. They categorize the daily routines of the ALS patients [3]. Figure 5 shows the categories and expressions. In the CDAS program, the Icon Mode is similar to a tree structure. It has seven categories with three to five specific expressions in each branch. The patients, by

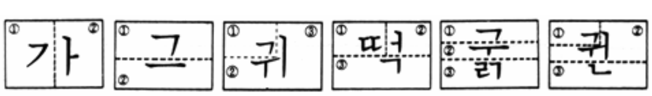


Fig. 3. The structure of the Korean character

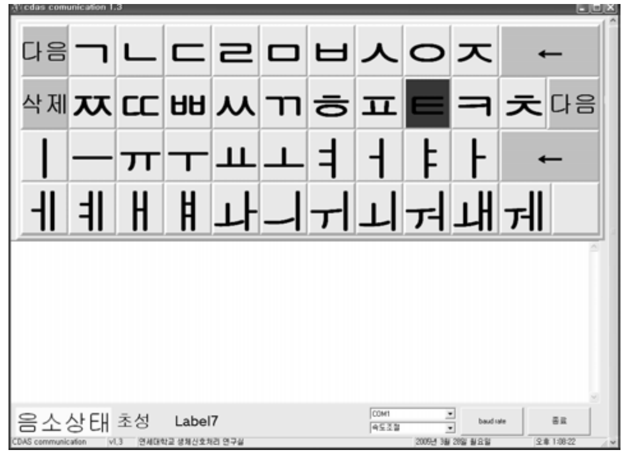


Fig. 4. Example of the selection method when using the User-Writing Mode

clicking the apparatus, would be able to choose the category and command he or she wishes. Additional expressions and categories are capable of being added to the CDAS program.

In the User-Writing Mode, you can write words freely. The User-Writing Mode is specialized for the Korean alphabet, Hangul, consists of 14 consonants and 21 vowels. In the Hangul system [2], several characters are combined to form a complete syllable. Usually, when you write a word in Hangul, each syllable consists of a syllable-initial, a syllable-peak character, and an optionally syllable-final character. Figure 3 shows the building process of a Korean character. The User-Writing Mode provides the same writing environments like handwriting to the ALS. The selection prompt scans the whole letter board as shown in Figure 4. You can choose syllable elements using the sensor in the order of the Korean character building process. The first and second rows are a set of consonants. However, the third and fourth rows are a set of vowels. Five kinds of function keys are located on the edge of the first, second, and third row.

III. Results

A. The results of the processing module

In the CDAS system, there isn't a static threshold but a dynamic threshold as shown in figure 6. Each patient has different voltages in his or her stable-state. The rest period voltage changes in patients. In figure 6, the contractions in t_1 and t_3 have different thresholds. It is also a problem when a trigger (contraction) event occurs after one second, because it takes some time (one second) to re-select the next character. Figure 6 shows us that the events which occur in less then one second (in t_4 and t_5) are not triggered. The output is then delayed. This process gives sufficient time for patients to select the next character. To decide this time interval, we use the equation shown below.

$$\text{Duration time of the triggered signal} = R_{var} \times C_x \text{ (seconds)}$$

where, R_{var} = the resistance of the variable resistor.
C_x = the capacity of the related point-trriger.

B. Researcher's notes

There is no reference to test or to compare the CDAS system. This system is unique.

The CDAS system was tested by two subjects (men, 23 and 24 years old) who are good health. It operates properly, however, but there is a problem in which it takes quite long time to write a sentence. Table I shows us the several repeat experiments that write a same sentence. Two subjects are well trained to write a sentence using the CDAS system. During experiments, subjects lie on their back with easy.

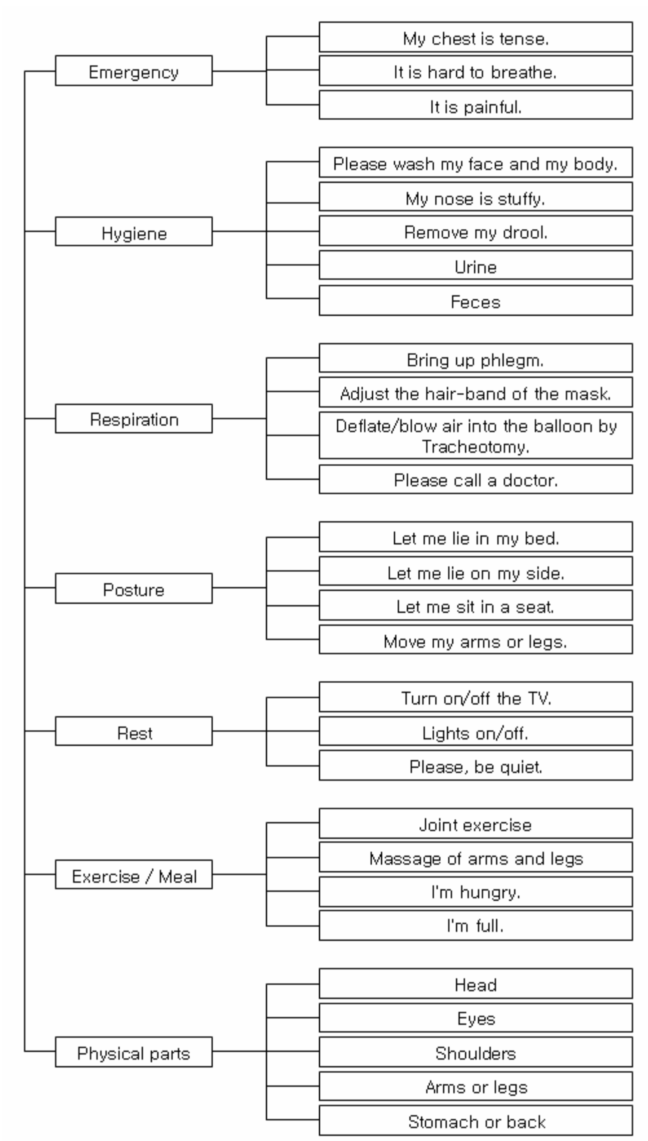


Fig. 5. Categories and icons of Icon mode

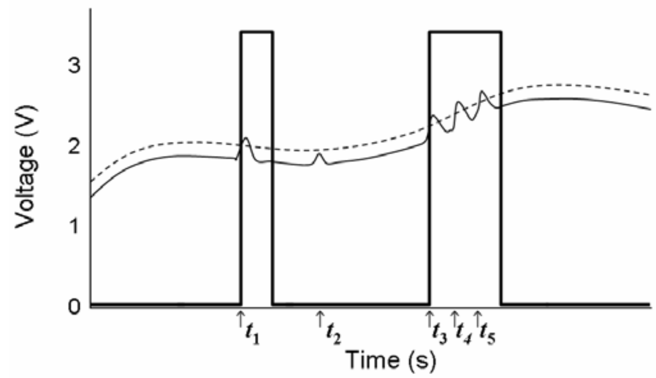


Fig. 6. The original sensor signal (solid line) is compared with the threshold voltage (dashed line) following the original signal. The output signal triggered on time while the original signal exceeds the threshold.

TABLE I
ELAPSED TIME OF 10 TRIALS

Length of a sentence includes spaces	Results of 10 trials	
	number of clicks	elapsed time (min)
8	22 (7 characters, 1 space) [a]	3.74
12	32 (10 characters, 2 spaces)	5.12
18	46 (14 characters, 4 spaces)	8.05

[a] successful contractions = n characters × 3 times/characters + m spaces × 1 time/spaces

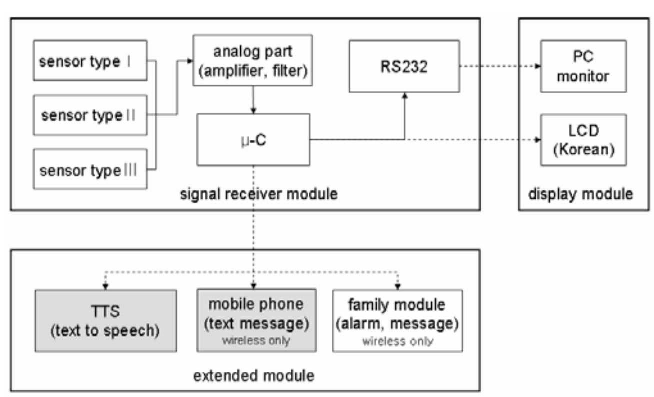


Fig. 7. The ultimate goal of the CDAS system

IV. DISCUSSION

This sensor can be activated by any part of the patient's body that retains adequate movement. A cost of the CDAS system is more inexpensive than other similar devices, for example the eye-blinking detection system. The accuracy of the system is approximately 99 per cent.

Figure 7 shows the ultimate goal of the CDAS system. To implement whole details, related topics are researched at Yonsei University and Youngdong Severance Hospital. The CDAS system can substitute TTS (text to speech) for the patient's words. Patients can send text massages via a mobile phone to their family or caregivers [4].

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