Tongue-computer interface for disabled people

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ABSTRACT

This work describes a new inductive tongue-computer interface to be used by disabled people for environmental control. The new method demands little effort from the user, provides a basis for an invisible man machine interface, and has potential to allow a large number of commands to be facilitated. The inductive tongue–computer interface implemented with 9 sensors was tested in three healthy subjects and the results shows typing rates up to 30 to 57 characters pr. minute after 3 hours of training.

1. INTRODUCTION

Tongue-computer interfaces are favorable since they are practically invisible and they are often manageable for people with even severe motor disabilities. A comparative study, comparing a tongue control method to a head control system and a rather simple mouth stick, resulted in all four severely disabled test persons preferring the tongue based control system, even though, it was not the fastest system (Lau and O´Leary, 1993), emphasizing the importance of aesthetics – the last thing many disabled persons want, is to be even more different. There have been different attempts to interface the tongue, including electrical contacts (Clayton et al, 1992), hall element techniques (Buchhold, 1995) and pressure sensors. Further, a current commercially available tongue control systems is based on pressure sensitive buttons placed in the mouth cavity over the tongue (New Abilities Systems, 1993). The use of electrical contacts may not function during eating and talking. The technique with the Hall element has similar limitations. Further, the use of pressure sensitive sensors does not seem optimal, since normal speech and swallowing generates tongue-palatal pressures in the range of 20-60% of maximal achievable pressure (Müller et al, 1984, Hayashi et al, 2002), which poses demands on the detection threshold and therefore may increase the risk of fatigue. The use of pressure-based sensors may limit the maximal number of sensors that can be placed in the oral cavity, since the requirement of pressure increases the tongue-palatal contact area. In addition, having only 9 control buttons the commercially available tongue control system (New Abilities Systems, 1993) far from utilizes the high selectivity in the movement of the tongue, which readily can pick out every single of our 32 teeth. Utilization of this selectivity would make, a variety of electric aids, including wheelchairs and neural prostheses, controllable with a wide range of commands from the same interface, making the tongue-computer interface suitable for environmental control systems and virtual reality systems.

Therefore this work describes a new inductive tongue-computer interface (ITCI) to facilitate tongue-activated commands.

2. METHODS

2.1   Theory

The detection method used in this work is based on Faraday´s law of induction for a coil, and uses variable inductance techniques.

From Faradays law the voltage drop across an inductance can be found as:

$$\varepsilon = -L\frac{di}{dt} = -\mu_0\mu_r N^2 \frac{A}{l}\frac{di}{dt}$$

where

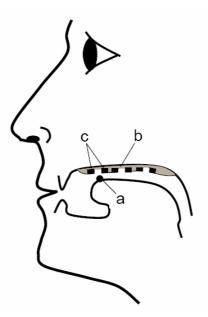 L = inductance

  μ_0 = vacuum permeability

  μ_r = relative magnetic permeability of the core material

  N = number of turns

  A = the area, and

  l = is the average length of the magnetic flux path

When only air is present as the core of the inductance, $\mu_r=1$. As a ferromagnetic material is placed in the coil, the core becomes a combination of air and ferromagnetic material, and μ_r changes according to the magnetic permeability of the ferromagnetic material.
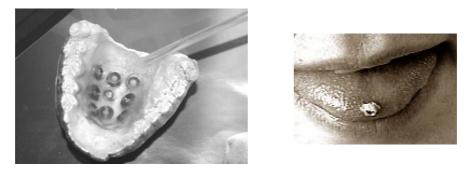

Figure 1. *The Inductive tongue control system. a: The activation unit, b: the palatal plate, c: the inductors. The tongue activates the sensors by placing the tongue-mounted activation unit at or inside a coil.*

Applying a sine wave current, i, of constant peak-peak amplitude, a constant amplitude voltage drop, ε, is obtained across the coil L. Introduction of the ferromagnetic material into the air gap of the coil, results in an increase of ε, which stays increased, a until the material is removed. This will be utilized for activation of a command in the inductive tongue control system (Fig. 1). The method resembles the known techniques used for displacement sensors (Göpel et al, 1989).

2.2   Mounting of Sensors at the Palatal Plate, and fabrication of the activation unit

Using dental acrylic, nine air cored inductors were placed on a palatal plate resembling the ones used as dental retainers, see Fig.2. The inner diameter of the inductor coils was 4mm, and the coils had 90-150 turns. A silicone tube was fixed to the palatal plate and carried the wires out of the mouth, see Fig. 2.

A small ferromagnetic metal cylinder was fabricated from stainless steel of the type SUS447J1. The diameter of the cylinder was 3.2 mm and the height was 2 mm. The steel had a maximum magnetic permeability, μr, of 2000-6500.

Figure 2. *Left: The palatal plate (placed on a mould of the upper part of the mouth) with inductive coils and a silicone tube leading the wires out of the mouth. Right: The activation unit glued to the tongue.*
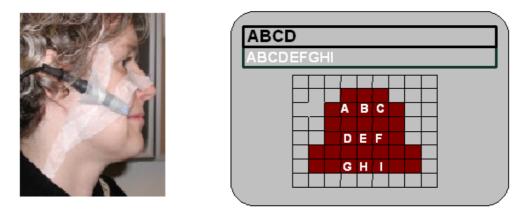
2.3. Experimental Setup

The ITCS was tested in 3 healthy male subjects, age 22 -29 years.

The palatal plate with the inductors was placed at the hard palate. The activation unit was glued to the tongue using tissue glue, Fig. 2. A 50 kHz sine wave current with a 0.03 mA amplitude was applied to the inductors from a galvanically isolated current source. The signals form the 9 inductors were amplified and rectified. Then the signals from 4 of the inductors were inverted before the inductor outputs were connected to obtain 4 channels with 2-3 coils in series.

The subject activated the inductive sensors by positioning the tongue in a manner that placed the activating unit in the centre of the different inductor coils. hour on three consecutive days.

Figure 3. *Experimental set-up. The inductor leads comes out of the subjects mouth. The subject is provided with a visual feedback showing the position of the coils/characters on the dental palate, what to type in white and what have been typed by the subject in black.*
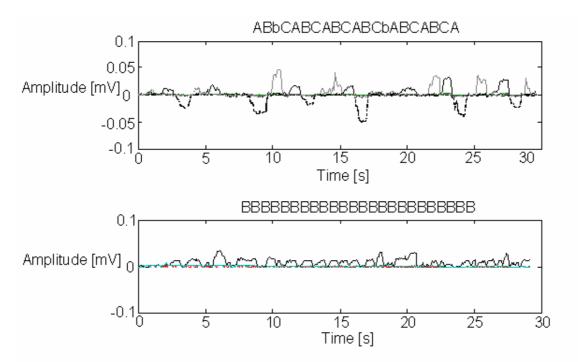
2.4   Signal Processing

The measured signals were amplified and rectified to obtain envelopes of the signals. Measurements were performed for intervals of 30 seconds

Then the signals were sampled and processed using the Matlab DAQ toolbox. The baselines of the sensor signals corresponding to no activation of the inductive sensors were subtracted. Using online thresholding of the inductor signals, one of the characters: "ABCDEFGHI" was related to the activation of each inductor, and typed on the visual display of a computer (Fig. 3) when the corresponding inductor was activated. From the visual display, the subject could see which sensor had been activated, see Fig. 3

In this way the subject was typing given sequences of the characters "ABCDEFGHI".

3. RESULTS

The subjects could activate desired sensors as shown in Fig. 4.

Figure 4. *Example of the signals from the ITCS during typing. The typed characters are shown above each of the two graphs. Capital characters are correctly typed characters, lower case characters are incorrectly typed characters. On the top graph, ABC is typed repeatedly:* ***Grey:*** *signal from the inductor related to the character "A",* ***black:*** *signal from the inductor related to the character "B",* ***dotted:*** *signal from the inductor related to the character "C". On the bottom graphs the signal from the ITCS is shown during repetitive typing of B. On both graphs signals from all 9 inductors are included, but only the activated inductors show amplitudes deviating from zero. The baseline potential corresponding to no activation of the coils has been subtracted. The data are from the third and final day of measurement.*

Typing sequences, including all nine characters, that had been repeated approximately 40 times during the 3 days of measurements, without having a visual display of the position of the characters resulted in a typing speed of 32-42 characters per minute with an error rate of 14-25%. Typing a random sequence of characters, that has not previously been typed, again without visual display, resulted in a typing speed of 30-57 characters per minute with an error rate of 15-29%. Repetitive typing of the same character was performed with maximal typing speeds of 48-114 characters per minute, and an error rate of 0-0.1%.

Table 1. *Typing rate of correct characters on day 3.*

Subject	correct characters pr. minute		
	max	mean	minimum
1	48	18.6	10.4
2	114	41	29.6
3	100	13.8	0

When asked on a scale from 1 to 10, about the perception of usage of the visual display (1= no use, 10=constant use) the subjects rated the use of the display to 1-3, the tongue palatal pressure needed for activation of the units (1=no pressure at all, 10=maximum obtainable pressure) to 2-3 and the difficulty in using the system to 3-5 (1=very easy 10 = impossible).

The typing rate of correct characters is shown in table 1. In average the mean typing rate of correct characters of all measurements from one day, improved with 117% from day one to day 2 and 22% from day 2 to day 3.

The total size of the designed inductors, given as the outer diameter was 5-6mm, indicating the possibility of having more than 25 sensors in the palatal plate of future ITCSs.

4. DISCUSSION

For a future control system to be truly successful it has, in reality to be a help for the user. This may imply that the system:

- Can be used/worn all day and night
- Is easy to use and induces a low degree of fatigue
- Is cosmetically acceptable in and outside the home of the user – preferably invisible
- Can be used to control a wide range of equipment, e.g. computers, wheelchairs, toys and prosthesis.
- Provides an efficient and quick activation of the desired function

These requirements may be met by future applications of this new inductive tongue-computer interface.

The small size of the sensor-coils opens up for the possibility of having the whole alphabet as separate "buttons" on the palatal plate, which may lead to substantial increase in e.g. the rate of writing for quadriplegics.

The typing rate of 30 to 57 characters per minute with 15-30% error rate suggests that the system may be quite efficient after sufficient training. The increase in the typing rate between consecutive measurement days indicate that learning may still taking place after the 3rd day, which may mean that longer training will reduce the error rate and further increase the typing rate. Therefore longer training is needed to get a more acceptable error rate.

The high typing rate of up to 114 activations pr. minute related to repetitive typing suggest the implementation of an interface having multiple functions for each inductive sensor, which can be activated by repetitive inductor activation.

The subjective experience of the subjects using the system suggests that the system may be used without visual display, potentially making it quite mobile. In addition the subjective experience was, that the activation of the inductive sensors only demands a low degree of tongue-palatal pressure, thereby reducing the risk of fatigue.

Future work will focus on implementing inductive tongue control interfaces with more than 9 inductive sensors and explore the possibility of implementation of a mouse or joystick function. Further, the Inductive tongue computer interface will be tested by people with motor disabilities. Finally, incorporation of wireless control and development of command strategies to control a wide range of devices will be considered.

5. REFERENCES

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