NEW ERGONOMIC HEADSET FOR TONGUE-DRIVE SYSTEM WITH WIRELESS SMARTPHONE INTERFACE

Hangue Park, Jeonghee Kim, Xueliang Huo, In-O Hwang, and Maysam Ghovanloo
GT-Bionics Lab, School of Electrical and Computer Engineering, Georgia Institute of Technology

ABSTRACT

Tongue Drive System (TDS) is a wireless tongue-operated assistive technology (AT), developed for people with severe physical disabilities to control their environment using their tongue motion. We have developed a new ergonomic headset for the TDS with a user-friendly smartphone interface, through which users will be able to wirelessly control various devices in their environments. This new technology is expected to act as a multi-functional communication interface for the TDS and improve its usability, accessibility, and convenience for the end users.

KEYWORDS

Tongue Drive System; Assistive technologies; Smartphones; Ergonomic design

INTRODUCTION

Tongue Drive System (TDS) is a wireless assistive technology that enabled its users to control their environments by utilizing their free volitional tongue movements inside their mouth. This system can wirelessly detect the position of a small permanent magnetic tracer, secured on the tongue via adhesives or piercing, to translate different tongue positions and gestures into a set of specific user-defined tongue commands [1]. Reports on the TDS effectiveness in controlling users' environments, accessing computers, and driving wheelchairs can be found in our previous publications, presented at RESNA'07 and RESNA'08 [2], [3].

Although we have successfully proven the TDS functionality in several able-bodied and one clinical trial [4]-[6], we observed the need for improving the TDS in terms of its appearance, comfort, ease of don and doff, and its ergonomic factors. Users were understandably not quite satisfied with the appearance of the early prototypes because they were either built on commercially available industrial safety headgears or large headphones (see Fig. 1). In fact, research shows that appearance is one of the important factors that affect the acceptability of the new ATs by their potential end users [7]. In addition, the headphones were not quite stable on the head and the headgears were not comfortable enough either because the headband constantly applied pressure to the head or the size adjustment knob on the back hindered leaning the head against the wheelchair headrest.

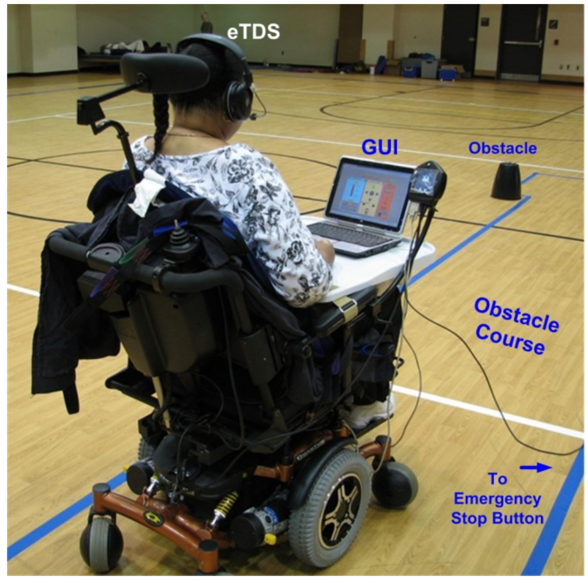

Figure 1: A subject with SCI at C4 wearing the TDS prototype to navigate a wheelchair through an obstacle course [5].

TDS users also needed a smaller, lighter, and more portable platform than laptops on their wheelchairs. Previously, users needed to place the laptop, which was responsible for receiving the magnetic signals, processing them, and showing the selected tongue commands and other items on the graphical user interface (GUI) on their lap tray. However, placing laptops with open lids in front of users while

Table 1: Headset Design Questions and Answers

Criterion	Question	Answers
Appearance	How to improve the headset appearance?	Hide all the electronics behind the ear, to look like an advanced audio headset
Comfort	How to make TDS comfortable to wear?	Adjustable headband, flexible arc, and U-shaped ear-rests
Performance	How to maximize TDS sensitivity to tongue motion?	Adjustable sensor locations and increasing their number from 2 to 4
Low power consumption	How to extend the headset operating time with a limited battery capacity?	Low-power microcontroller and wireless transceiver and sensor duty-cycling
Assembly	How to connect signals in a narrow path and enable easy assembly?	Using 10-wire flat flexible cable (FFC), crimp-style 5-wire cable for supply

driving wheelchairs (see Fig. 1), can limit their field of view and partially block the path in front of them, causing potential safety issues in uncontrolled environments. In addition, the operation time of the TDS was limited by the capacity of the laptop battery to only a few hours, unless the wheelchair battery was tapped, which could create more hassle.

DESIGN OBJECTIVES

To make the TDS more usable, we designed a fashionable outlook for the TDS headset such that the users to willingly accept it as a daily tool. Also, we improved the mechanical design of the headset by adding to its adjustability as an ergonomic headset which would enhance the user comfort while wearing it. Finally, we chose iPhone® as one of the most popular smartphone platforms and developed a user friendly interface to allow users to utilize their phones (or iPods) as an easily accessible device to control their environments. The new TDS will ease the burden of carrying a laptop and enable its users to employ the same AT (i.e. TDS) for a variety of different tasks.

HEADSET DESIGN

In order to satisfy the requirement of wearable and portable devices in the new TDS headset design, we considered these criteria: 1) performance, 2) low power consumption, and 3) ease of assembly and repair, in addition to appearance and comfort, which were discussed earlier. Table 1 shows the questions we raised and the solutions we found in response to those questions for the new headset design.

Fig. 2 shows the resulting TDS headset, fabricated using stereo-lithography (SLA) rapid

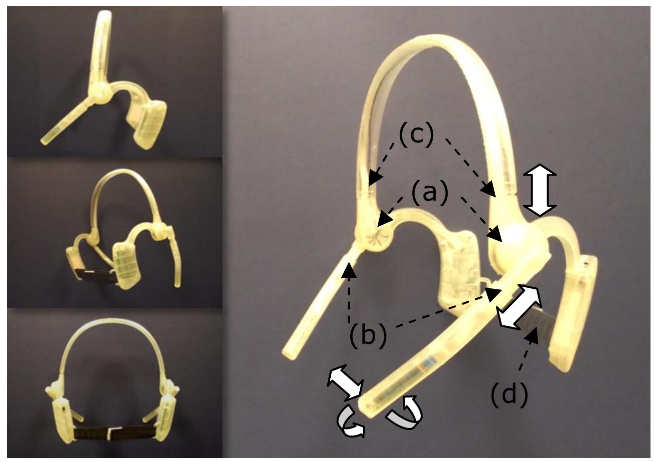

Figure 2: Custom-designed TDS headset, build by rapid prototyping.

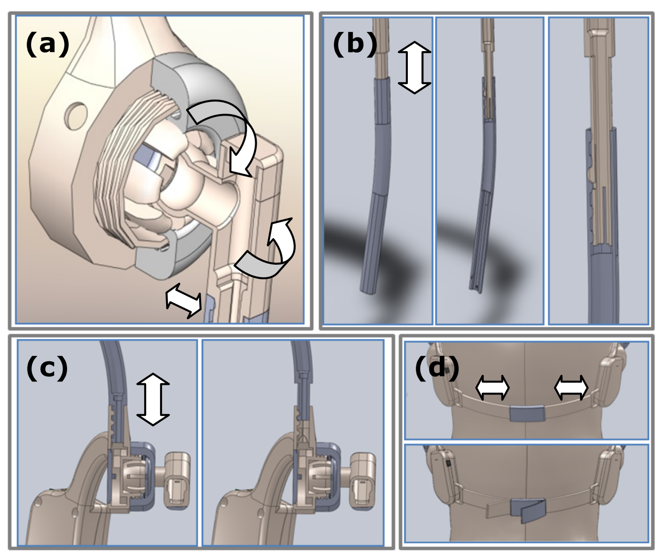

Figure 3: 3-D rendering of the headset details.

prototyping technology. Building material was resin, which gave the headset a yellowish semi-transparent color. Trapezoid shaped enclosures hidden behind the ears on both sides contained electronics and a rechargeable battery.

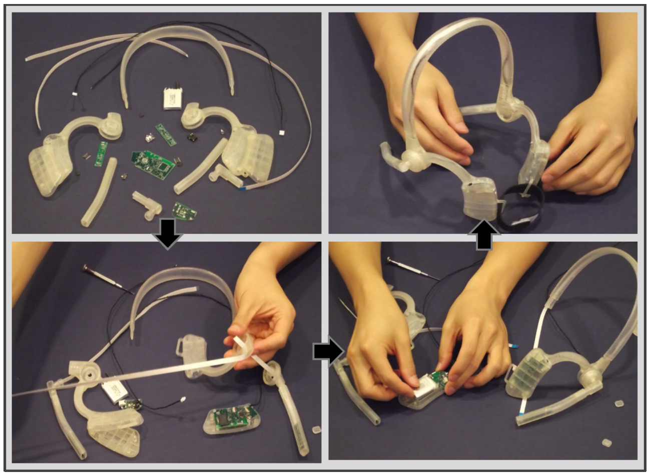

Figure 4: Assembly process of the TDS headset

Fig. 3 shows detailed views of adjustable parts of the TDS headset. Fig. 3a is a ball and socket joint on top of the sensor poles allowing up to 60° rotation in all directions. Proper positioning of the poles and consequently the sensors is key in TDS performance as it affects the quality of the measured magnetic signal. Fig. 3b shows the structure which enables the pole length adjustment. Fig. 3c shows the part that adjusts the size of the arc over the head. Fig. 3d shows the adjustable headband which holds the headset from the backside of the head. Thanks to these flexibilities, one can adjust the position of the sensors to achieve the optimal performance from the system and also stabilize the headset on the user's head.

Sensor boards, containing two small 3-axial magnetic sensors and their signal conditioning circuitry, are placed at the tip of the two sensor poles and the rest of the electronics and battery are housed in the trapezoid enclosures. The wireless control unit is included in the right enclosure, and a 500 mAh, 3.7 V, Li-ion battery with charging and power management circuitry is placed in the left side. All of the electronic circuits were carefully designed in terms of their power consumption and duty-cycling technique was employed to reduce the power consumption of the magnetic sensors. The average current consumption was about 5 mA, allowing the TDS headset to operate for 100 hours with a fully charged battery.

Fig. 4 shows the headset assembly process. We used 10-wire flat flexible cable (FFC) and crimp-style 5-wire cable to connect the sensors to the control electronic and power management boards on the two sides of the headset. These types of cables are thin enough to pass through the poles and arc on top.

TDS FUNCTIONS AND APPLICATIONS

The TDS headset function is sensing and wirelessly transmitting the magnetic signals from around the mouth, where they change based on the tongue position. The number of magnetic sensors was increased from 2 to 4 in order to increase the dimensions of the acquired data set and track the tongue position more accurately. This change can potentially enhance the TDS performance by allowing users to define more tongue commands. In addition, we intend to include Bluetooth and audio functions in the new headset to provide a bidirectional wireless voice data transmission as a wireless headphone. As a result, the new headset can be incorporated with voice recognition software such as Dragon and used as a multi-modal tongue and voice controller.

The recently developed TDS-smartphone interface processes the incoming signals from the headset through a wireless receiver dongle. This interface provides easy access to the smartphone itself as well as any application

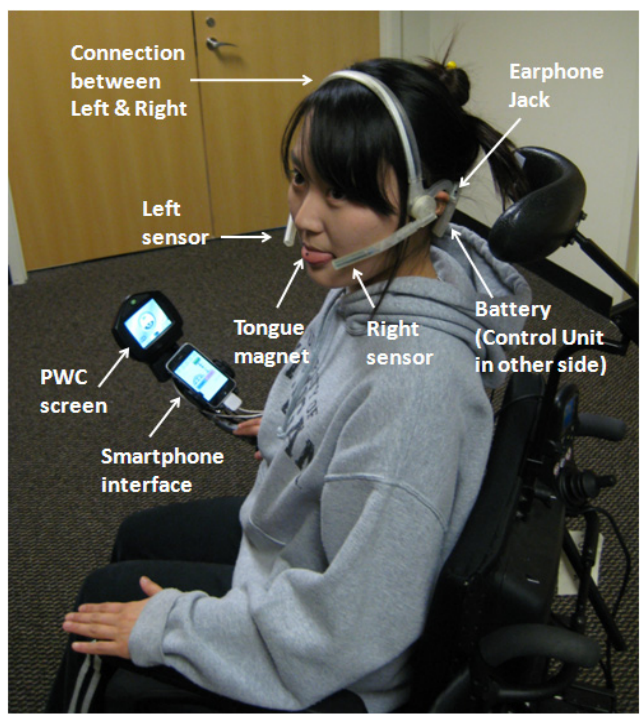

Figure 5: TDS setup with the PWC application

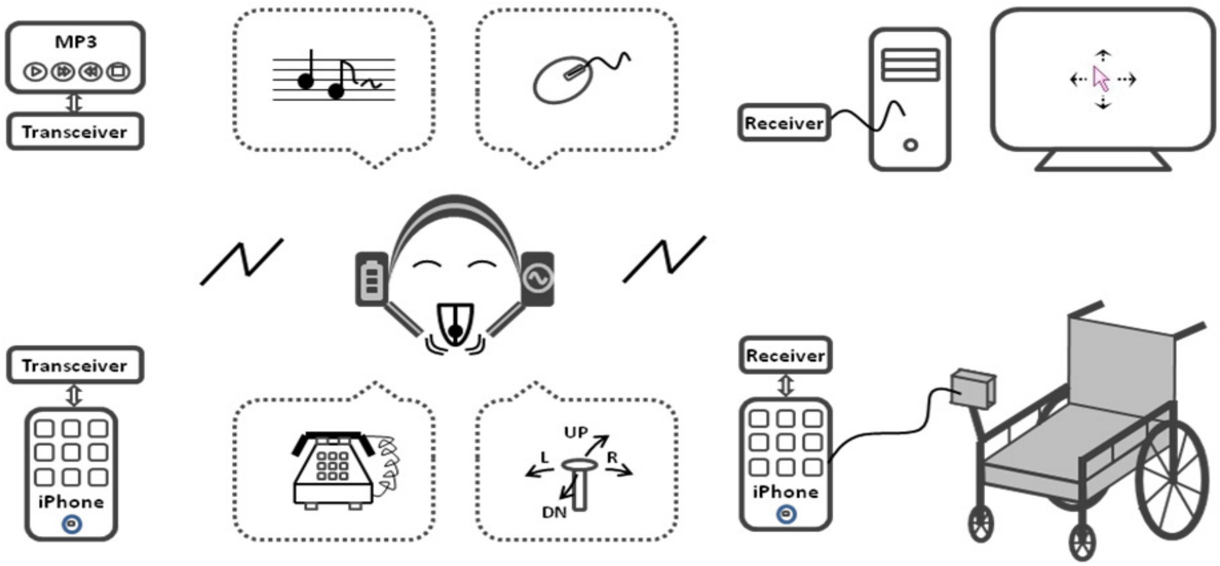

Figure 6: Various TDS applications.

running on it [6]. Fig. 5 shows the new TDS headset and its iPhone interface connected to the power wheelchair (PWC). The TDS-iPhone interface wirelessly acquires data from the magnetic sensors. In addition to processing the sensor signals, the iPhone software also provides a GUI for the user to easily perform various functions, such as making a phone call, sending a text message, playing a game, driving a PWC, and controlling home appliances.

With the new headset and iPhone GUI, TDS has become a truly wearable AT without the burden of carrying a laptop. This should make its users' lives easier because they can not only use every iPhone function, but also interact with any device that is compatible with the iPhone. Fig. 6 shows some of the possible applications of TDS from the computer mouse control to wheelchair navigation. Unlike most other existing technologies which are dedicated to one task or another, TDS users can perform several tasks without switching to different ATs.

CONCLUSION

We have improved the TDS appearance, comfort, and functionality by designing a new customized ergonomic headset. Moreover, we have developed a TDS-smartphone interface, which removes the burden of carrying a laptop and enables users to do multiple tasks without switching from one AT to another.

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