Advanced Innovation in Human–Computer Interface Controlled by the Mouth Variation

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Abstract—Lip control system is an innovative human–computer interface specially designed for people with tetraplegia. This paper presents an evaluation of the lower lip potential to control an input device, according to Fitts' law (ISO/TS 9241-411:2012 standard). The results show that the lower lip throughput is comparable with the thumb throughput using the same input device under the same conditions. These results establish the baseline for future research studies about the lower lip capacity to operate a computer input device.

Index Terms—Assistive technologies (ATs), Fitts' law, human– computer interaction, pointing devices, severe disabilities.

I. INTRODUCTION

E propose a new form of interaction, a human–computer **W**interface controlled by the lower lip, for users with tetraplegia and validate it with a prototype.

While restorative treatments for spinal cord injury (SCI) [1], [2] or invasive brain–machine interfaces [3], [4] are not available outside research labs, some technologies [5], [6] can be used by people with tetraplegia to interact with the world. Interaction must be focused in the brain and muscles that users can control. The selection of an assistive human–computer interface requires maximizing the flow of information and minimizing the effort (physical and mental) to use it [6], [7].

Current alternatives include noninvasive brain–computer in-terfaces (BCI), eye tracking, electromyography (EMG)**,** sip-and-puff, voice commands, chin control, head control, mouth joystick, and tongue control.

Noninvasive BCI using electroencephalography (EEG) has two main types [6]: synchronous and asynchronous. A syn-chronous system [8], using P300 to control a power wheelchair, requires 5 s, on average, to produce a highly reliable command, too slow for a continuous control as required from a computer pointing device (more information about EEG transfer rates can be found in [9] and [10]). On the other hand, an asynchronous system using sensorimotor rhythms shows the possibility to con-trol a computer cursor [11], [12], but it will need more research to overcome the strong performance variability [6].

In general, eye tracking can be made based on image pro-cessing [13], [14] or electro-oculography [6], [15], which uses electrodes to monitor the eye movement. Any eye tracking sys-tem demands much user attention and errors can occur due to the mismatch of selecting a command and the eye already changing the position. For a pointing device, this could be acceptable, but to control a power wheelchair, maintaining the eyes position can be very tiring and false commands are not acceptable.

Another possibility is EMG, which uses electrodes to monitor facial muscles to control a computer pointing device [6], [14]. An analysis of an EMG interface according to Fitts'

law is shown in [16]; this interface provides discrete direction movements (horizontal and vertical separately) not diagonal.

Sip-and-puff is an option for people with tetraplegia mainly to control power wheelchairs [15], but this is usually difficult to operate and usually works only with four discrete directions.

Voice commands can be useful to access some computer and smartphone applications, but they are not adequate to direct control pointing devices. Some research studies use voice com-mands to control power wheelchairs [15], [17]. A way to im-prove the precision of the voice recognition system in noisy en-vironments is lip-reading (speech reading), an image processing technology to identify speech from lip images [18].

Chin control is one of the best options currently available for people with tetraplegia; this consists of a power wheelchair joy-stick adapted to be controlled by the chin [19]. Some systems provide connection with computer as a pointing device [20], [21]. A great advantage of the joystick is the possibility of soft and free movements in any direction. Chin control (also appli-cable to head control [15], [22] and mouth joystick[1] [5]) depend on neck movements; the body must be fixed and the head must be able to move freely. Power wheelchairs provide this condi-tion, but vibration during the drive and body spasms (common in spastic tetraplegia) can generate false commands. Outside the wheelchair, the user has no control, due to the dependence of the apparatus on the wheelchair structure.

The advantage of using tongue control [23]–[25] is that the tongue is not controlled by the spinal cord; instead, it is con-trolled by the hypoglossal nerve directly connected to the brain. One inconvenience of this type of interface is the hygienic is-sue, because people with tetraplegia depend on someone to put a tongue piercing; for [25], it is also necessary an intraoral system. Another restriction is that it allows only few discrete directions. The tongue drive system (TDS) [23], [24] allows four direc-tions (and two selection commands). Inductive tongue control system [25] allows eight directions (and 10 sensors for other commands).

The tongue and the mouth occupy a significant amount of motor cortex, comparable with the hands and the fingers [26], [27].

Lip muscles are controlled by the facial nerve that is directly connected to the brain. This is an important characteristic for people with SCI in the neck region. An innovative human– computer interface using the lips, such as the one proposed in this paper, indicates an excellent potential. The major contri-butions of this paper are the analysis, under the rigor of Fitts' law [28], [29], of using the lips to control a pointing device; and the comparison of the results with a common way (the thumb) to control the same device.

II. SCOPE

The proposed lip control system (LCS) is a human–computer interface with a headset and a joystick positioned in front of the lower lip. The studies to develop the prototype showed that the lip control must be head mounted in order to capture the lower lip muscles movements. The joystick, as an interaction method, was chosen because it is easy to use, provides an intuitive control, is compatible with the lips movement and is widely known and adopted in assistive technologies (ATs) [5]. Some other important characteristics of the LCS are as follows:

1) it is controlled by the lower lip (dry area), an external body part, less hygienic issues;
2) it allows soft free movement in any direction as it is based on a joystick;
3) it is a personal system that can stay with the user in the wheelchair, chair, bed, etc; and
4) it avoids false commands deriving from wheelchair vibra-tion or body spasms because it is head mounted.

An efficient human–computer interface is very important to improve the autonomy of people with tetraplegia allowing the control of power wheelchairs, computers, smartphones or other computerized appliances.

To evaluate LCS as a computer input device, it was config-ured as a Bluetooth standard mouse (compatible with computers and smartphones), but with the purpose of controlling power wheelchairs as well.

Computer input devices have been deeply studied [30]–[32] and there are effective methods to evaluate their interface ef-ficiency, such as Fitts' law [28] (standards in ISO/TS 9241-411:2012 [29] that revises ISO9241-9:2000) that is widely used.

The main measure for comparing computer input devices is the throughput *TP* in bits/s [30] from a human to a computer, and it is calculated as:

$$TP = \frac{IDe}{MT} \qquad (1)$$

where *IDe* is the task effective index of difficulty [23], [30], [32] and *MT* is the average movement time to execute it. *IDe* is based on Shannon formulation [33]:

$$IDe = \log_2 \; De + 1 \qquad (2)$$

$\overline{W e}$

where *De* is the average of effective distance between the point where the participant selects one target and the point where he selects the next target. *We* is the effective width and is defined as:

$$W e = 4.133 * SD \qquad (3)$$

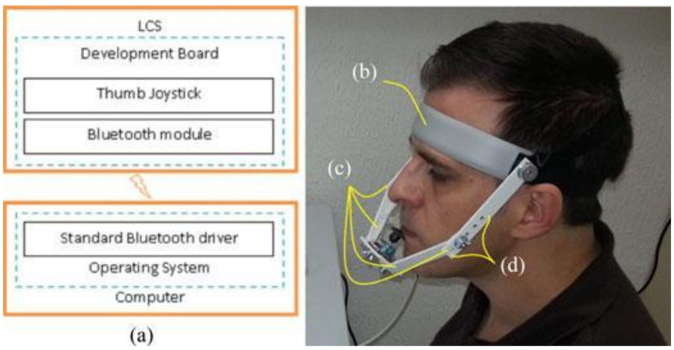

Fig. 1. (a) LCS architecture. (b) Head support. (c) Joystick support. (d) Cali-bration holes.

where *SD* is the standard deviation of the distance between the target center and the point at which the participant selects the target, 4.133 is a constant. More detailed information can be found in [30]–[32].

The LCS throughput, controlled by the lip, was measured to establish the lower lip capacity baseline to control a human– computer interface, but it is also important to understand if this throughput is limited by the device. The LCS throughput, controlled by the thumb (as a gamepad) was measured, because this can be considered one of the best use conditions, near the device limit throughput. This two-throughput comparison shows how good the lower lip could be considered if compared with the thumb to control the LCS. This is the reason why all the participants chosen to the tests are able-bodied.

III. LCS ARCHITECTURE AND IMPLEMENTATION

The LCS hardware consists of a development board Arduino Mega ADK, a Bluetooth module (Roving RN42-HID) and a thumb joystick, Fig. 1(a). The system was configured as a stan-dard Bluetooth mouse with a human interface device (HID) pro-file. All the communications occur as with a standard Bluetooth mouse.

The LCS was designed specifically to be controlled by the lower lip; the current version is the ninth. The head support, Fig. 1(b), evolved to provide the necessary stability during the operation; the joystick support, Fig. 1(c), evolved to be double and to provide calibration [see Fig. 1(d)] of length and angle in order to set the joystick in the correct operation position (just touching the skin). Fitts' law multidirectional tests were done to choose the joystick response with better throughput response. The full headset prototype has 158.8 g of mass, including the joystick and the cable used to connect the joystick. A USB cable was connected to the computer just to provide power during the tests (this prototype does not have batteries).

IV. METHODS AND MATERIALS

The tests main objectives are to obtain the LCS lip-controlled throughput and to validate the lower lip potential as a body part capable to control a human–computer interaction. An impor-tant measure is the LCS throughput controlled by the thumb compared with the lower lip throughput. To evaluate the LCS, tapping (point-and-select) tests were made according to Fitts' law (ISO/TS 9241-411:2012 [29] standard).

The tests were previously approved by the Research Ethics Committee of the University of Sao˜ Paulo, approval number 219927.

A. Participants

Twelve able-bodied volunteer participants (eight male, four female) were chosen to take the tests, and were recruited among students of undergraduate and graduate programs. Participants ranged from 20 to 37 years of age (average = 28), weighed from 43 to 145 kg (average = 78 kg) and were 1.50 to 1.89 m tall (average = 1.75 m). All of them used computers for more than 6 h a day, but had no prior experience with LCS. The joystick and the LCS headset were cleaned in front of each participant before the tests.

B. Apparatus

The test apparatus consisted of a notebook HP Pavilion Dv7 (AMD Turion II Dual-Core Mobile M600 2.40 GHz, 4 GB of RAM, LCD 17.3__, Windows 7 64 bits, Resolution 1600 $\times$ 900), standard optical USB mouse Bright (model 0106, chip PAN3511, without mouse pad) and the LCS. The software used to conduct the tests was Java (tasks) and Python (tasks launcher). During the tests, just these programs were running in the fore-ground and no network access was allowed, in order to avoid any background activity, which could interfere in the processing time and produce unexpected results in the data collected.

C. Procedure

The tests occurred in a quiet room with just the researcher and one participant at a time. Three pointing devices were used: mouse, thumb-controlled LCS, and lip-controlled LCS (see Fig. 2).
The mouse was selected to ensure that the apparatus can achieve the well-known throughput for this device, values be-tween 3.7 and 4.9 bits/s [23], [30], [34].
Twelve participants, in all sessions, followed the same test sequence: first mouse, next thumb-controlled LCS and, finally, lip-controlled LCS. This order was chosen from the most fa-miliar device and use (mouse), to an unfamiliar device (LCS), but controlled in a known way: the thumb; and in the end, the LCS controlled in an unfamiliar way, the lip. This is to explore the learning effect [31], in order to make the test more reliable, once the LCS controlled by the lip is a very different way of interaction for the participants.

D. Dwell Time

The participants were asked to click the mouse device, but for LCS (thumb or lip), instead of clicking, they were required to dwell within the target area [29]. The use of dwell time reduces the throughput [13], but isolates the cursor movement process. A 500 ms dwell time was chosen for the test to make this work comparable with other similar Fitts' law research studies: [35] used 500 ms, [13] used 500 and 750 ms, [23] used 560 ms; but to find the best dwell time for lip-controlled LCS, additional research is necessary. The use of dwell time is important to isolate the lower lip muscular behavior to control a joystick, without introducing the click interference.[2] Additional comparison was made with the LCS controlled by the thumb and by the lip, both using the same conditions, including the dwell time.

E. Movement Time

The mouse device has the movement time defined as the mouse button release period from one target and the button release on the next target.
As LCS (both thumb-controlled and lip-controlled) uses dwell time; the movement time cannot include the dwell [23], [30]. Then, movement time was defined as the period between the next target activation (dwell end) and the moment when the cursor enters the new target area (starts a new dwell), only if the cursor stays inside the target area all along the dwell time. The movement time continues if the cursor leaves the target before the end of the dwell time. The x, y position is registered to calculate the effective distance De and effective width We, in both cases, the start and the end of movement time, Fig. 4.

F. Tasks

The procedure for one-directional tapping tasks is to point and to select[3] a rectangle on the left (or top for the vertical task) indicated by a red + sign; after that, pointing and selecting the rectangle on the right (or bottom for vertical task), go back to the left (or top for the vertical task) and so on. This procedure is repeated 25 times [29] for each block.

A block is the rectangle width (W) (pixels) and the distance between targets (D) (pixels) combination, which defines the index of difficulty (bits) [32]:

$$ID = \log_2 \left(\frac{D}{W} + 1 \right) \quad (4)$$

We used four blocks for the task. Table I shows the combi-nation of D and W, as well as ID; during the tests, they appear randomly.
These values are the same as the ones for the one-directional task of [23], but four combinations of D–W that have clear distinct ID values were chosen.
The procedure for the multidirectional circular tapping task is to point and to select the circle indicated in red; after that, a circle

diagonally opposite will be indicated until all the 15 circles for each block have been gone through, Fig. 3(c). Here, the data registration considers 14 steps in 15 circles.
These values are the same as the ones for the multidirectional task of [23], which used just three *D–W* combinations. Combi-nation $D = 305$ $W = 76$ ($ID = 2.33$) was not used there. Here, we prefer to maintain this combination because it has a very distinct *ID* use one-directional horizontal tapping tasks [30]. Here, we include a one-directional vertical task to verify if a different

The participants were asked to balance cursor movement as fast and precisely as possible for all tasks.

Each of the 12 participants performed three tasks with each of the three devices (each one-directional task has 25 trials and multidirectional has 14 trials). Four blocks of *D–W* combina-tions were used for each task. All of this is one session. Each participant was assigned five sessions (two in one day and three on a different day). Table III shows the whole test design. The independent variables and levels are as follows.

1) Tasks: {one-directional horizontal, one-directional vertical, multidirectional}.
2) Trials: {25 for one-directional tasks, 14 for multidirec-tional task}.
3) Blocks: {1,2,3,4}.
4) Sessions: {1,2,3,4,5}.
5) Devices: {mouse, LCS thumb, LCS lip}.

The dependent variables were effective width *We*, effec-tive distance *De* (both based on x and y screen position) and movement time *MT* (milliseconds); all necessary to obtain the throughput *TP* (bits/s). For the mouse, additionally, there was the error rate when the participant clicked with the mouse out-side the target, which computed an error. When the participant used the LCS, there was no error [13], [35] due to dwell time.

We applied the comfort assessment defined in ISO/TS 9241-411 [29] to all the participants, just for lip-controlled LCS, with questions adapted for the body parts used to control the input device.

Before the first session, the participants had a 30-min training period with all the devices, executing all tasks without data register; during this time, they received all the instructions. This training has just 10 trials for one-directional tasks instead of the 25 trials real test; the multidirectional task had 14 trials, the same number of the real test trials. On the second day, before starting the third session, the participants trained with the LCS using the lip for about 5 min, just to remember the operation.

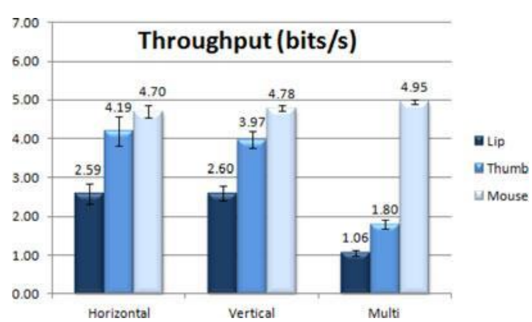

Fig. 5. Average throughput and standard deviation for all participants.

The test took about 30 min per session; on the first day, each participant spent 30 min training and 1 h in the two first sessions; on the second day, they took 1 h and 30 min in the three last sessions. This was done to avoid excessive mental or physical fatigue, reducing the fatigue effects [31]. All the tests were conducted over four week controlled LCS; the questionnaire was adapted to involve the specific body parts used during the tests.

The assessment consists of 12 questions rated from 1 to 7, where 7 means the most favorable answer.
The assessment in Fig. 8 shows the same verbal information given by the participants; some fatigue on the lips (4.17) and jaw (4.17), which affects the general comfort (3.83). The par-ticipants had no prior experience with the lip-controlled LCS, or with the force necessary to control the joystick, or the kind of movements likely to cause muscular discomfort. Its regular use could promote lip muscles strength, making the device more comfortable to use. We also observed that the participants used the jaw as a complement to the lower lip to move the joystick up and down.
There was practically no complaint about the neck and shoulder.
The participants liked the operation speed (5.25) of the lip-controlled LCS, which helped to achieve a good rate (5.25) for the overall device operation.
A participant with orthodontic brace did not succeed in using the LCS with the lips, and was replaced. During the tests, this was an important observation, showing that the lip movement over the teeth is intense.

VI. CONCLUSION AND FUTURE WORK

This paper presented an evaluation of the LCS according to Fitts' law (ISO/TS 9241-411:2012 standard). The tests showed the lower lip potential to control an input device, and the results showed viable throughputs (2.6 bits/s for one-direction tasks and 1.06 bits/s for multidirectional task) and the most important, the lower lip achieves 62.2% of the thumb throughput, showing its.
potential to control human–computer interfaces.
These results encourage us to expand the use of LCS to other applications (for instance controlling a power wheelchair), re-searching the use of other input devices that has better through-put than the joystick (to be lip-controlled) or to develop a new input device specially designed to be controlled by the lower lip.
We have two new ongoing works.
1) Development and test of a new version of LCS with a mini trackball instead of a thumb joystick.
2) Evaluating the LCS to control power wheelchairs.

REFERENCES

[1]. Y. Guo, L. Ma, M. Cristofanilli, R. P. Hart, A. Hao, and M. Schachner, "Transcription factor Sox11b is involved in spinal cord regeneration in adult zebrafish," *Neuroscience*, vol. 172, pp. 329–341, Jan. 2011.
[2]. S. Thuret, L. D. Moon, and F. H. Gage, "Therapeutic interventions after spinal cord injury," *Nat. Rev. Neurosci.*, vol. 7, no. 8, pp. 628–643, Aug. 2006.
[3]. J. E. O'Doherty, M. A. Lebedev, P. J. Ifft, K. Z. Zhuang, S. Shokur, Bleuler, and M. A. L. Nicolelis, "Active tactile exploration using a brain-machine-brain interface," *Nature*, vol. 479, no. 7372, pp. 228–231, Nov. 2011.
[4]. M. A. Nicolelis, "Actions from thoughts," *Nature*, vol. 409, no. 6818, 403–407, Jan. 2001.
[5]. H. A. Caltenco, B. Breidegard, B. Jonsson,¨ and L. N. S. Andreasen Stru-ijk, "Understanding computer users with tetraplegia: Survey of assistive technology users," *Int. J. Human-Comput. Interaction*, vol. 28, no. 4, 258–268, Apr. 2012.
[6]. C. G. Pinheiro, E. L. M. Naves, P. Pino, E. Losson, A. O. Andrade, and Bourhis, "Alternative communication systems for people with severe motor disabilities: A survey," *Biomed. Eng. Online*, vol. 10, no. 1, pp. 1– 28, Jan. 2011.
[7]. J. Abascal, "Users with disabilities: Maximum control with minimum effort," in *Articulated Motion and Deformable Objects – Lecture Notes in Computer Science Volume 5098*. Berlin, Germany: Springer, 2008, 449–456.
[8]. B. Rebsamen, C. Guan, H. Zhang, C. Wang, C. Teo, M. H. Ang, and Burdet, "A brain controlled wheelchair to navigate in familiar environ-ments," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 18, no. 6, pp. 590– 598, Dec. 2010.
[9]. J. R. Wolpaw, N. Birbaumer, W. J. Heetderks, D. J. McFarland, .