Tangible interface for a rehabilitation of comprehension in aphasic patients

Yves RYBARCZYK[a,1] and José FONSECA[b]
[a] *Electrical Engineering Department, New University of Lisbon, Portugal*
[b] *Language Research Laboratory, Medical Faculty of Lisbon, Portugal*

Abstract. This paper describes a tangible user interface (TUI) built to be used for written and spoken comprehension therapy in aphasic patients. The tool works with the Trackmate system [1] and an application especially designed from clinical tools developed by speech and language therapists. The software implements a series of tasks that ask the disabled person to identify, from a set, tagged objects and put them on the sensing table to be recognized by the TUI system. At the end of each exercise, the percentage of identification is saved into a database, which records patients' performances according to the time and the task types. This information technology (IT) was chosen and adapted to the aphasia rehabilitation to take the advantage of the manipulation of physical objects, in order to ensure an effective transfer of training exercises into everyday life activities.

Keywords. Tangible user interface, stroke rehabilitation technology, aphasia.

[1] Yves Rybarczyk
DEE, FCT, Universidade Nova de Lisboa, 2829-516 Monte de Caparica, Portugal
y.rybarczyk@fct.unl.pt
http://www.uninova.pt/~yr

Introduction

Characteristics of aphasia

Aphasia is the loss or impairment of language functions, such as oral expression, auditory comprehension, reading and writing. It is caused by brain damage. Aphasia disorders that impair motor programming (involved in expression and writing) are localized in anterior brain areas. On the other hand, posterior lesions generate auditive and reading comprehension impairments [2, for a review]. An aphasic syndrome can be more or less debilitating. In an initial stage some patients can only complete simple tasks of object identification, whereas other ones just need to exercise the comprehension of complex sentences. Although the tool described here is useful in both situations, it is particularly relevant for the most severe cases.

Rehabilitation techniques

Traditional approach. Multiple studies show speech therapy efficacy on aphasia recovery [3]. In this kind of treatment, the speech-language therapist stimulates the patient with questions, which the patient must answer. Indeed, an important factor in aphasia rehabilitation is the repetition of task completion [4]. Pencil and paper tests and bidimensional pictures (which illustrate objects and actions) are the most common materials used in recovery process. However, these rudimentary and relative representations of the physical world limit the evaluation of the patient's real speaking and comprehension skills. For instance, it is known that the visual discrimination of objects is more difficult when it is based on a two dimensional than on a normal three dimensions view, especially in persons with a low educational level [5].

IT approach. Since the 80's, the implementation of software as a form of aphasia treatment has been tried, using programs with a single as well as global language purpose [6]. Several studies show how efficient IT is on aphasia treatment [7]. However, their diffusion has not been an easy process. Indeed, the IT developed until now has the disadvantages of being too expensive and using equipments too specialized to be used on a large scale and outside the clinical structure. Moreover, they are still based on a virtual representation of objects [8]. On the contrary, the TUI is a more recent IT, which takes advantage of both: the computational processing of the information and an interface based on everyday physical objects. These two properties make the TUI an excellent paradigm to be used in therapy.

TUI approach. A TUI is a different type of Human Computer Interface (HCI) that allows users to interact with a digital device through the manipulation of a commonplace object which the computer recognizes [9]. In the context of rehabilitation this kind of technology has numerous advantages over the other ITs.

At first, the interface can be built with cheaper materials than in the majority of other advanced IT (e.g., Virtual Reality, Augmented Reality…), as demonstrated in this study. This is an important feature because an affordable system will permit an injured person to be able to practice at home, with limited human assistance. As mentioned previously, a regular and intense training is crucial for recovery.

Second, the physical interaction with real objects can improve the learning progress of the patient. Indeed, there might be a close link between physical activity and cognition that can facilitate some forms of cognition, like the language. Research in cognitive science focusing on embodiment argues for a close link between physical activity and cognition [10]. Moreover, the tangible interfaces can be more intuitive and accessible for the older patients who did not have much computing experience prior to their stroke. Studies stressed the affordance properties of the tangible objects [11].

Finally, a therapeutic TUI is particularly adapted for the disabled children. A body of literature in education emphasizes the role of physical manipulative materials in supporting learning. According to Beaty's studies, children learn best while actively manipulating real materials [12]. Also, interacting with various physical artefacts can increase the playfulness of learning. Tangibles have been reported as having the potential for providing innovative ways for children to play and learn, through novel forms of discovering, and the capacity to bring the playfulness back into learning [13].

1. System design

1.1. Hardware structure

The tangible interface was built from an adaptation of the Trackmate system described in [1]. Our configuration is a wooden box with an acrylic glass on the top side (figure 1). A webcam is placed on the bottom side, pointing to the glass. It is carefully centered in the middle of the box, in order to capture the entire transparent table. The acrylic transparent glass is used as a sensing surface. To ensure a correct illumination of the space, two bright LED lights, which plug into the USB ports of the computer, are screwed on the lateral opposite sides of the box.

The object identification is carried out through a tag stuck on the bottom side of the object. The tag is a small square of paper (1"x1") on which a circular barcode containing a unique identifiable ID is printed. To be discriminated by the system, each object has a different tag.

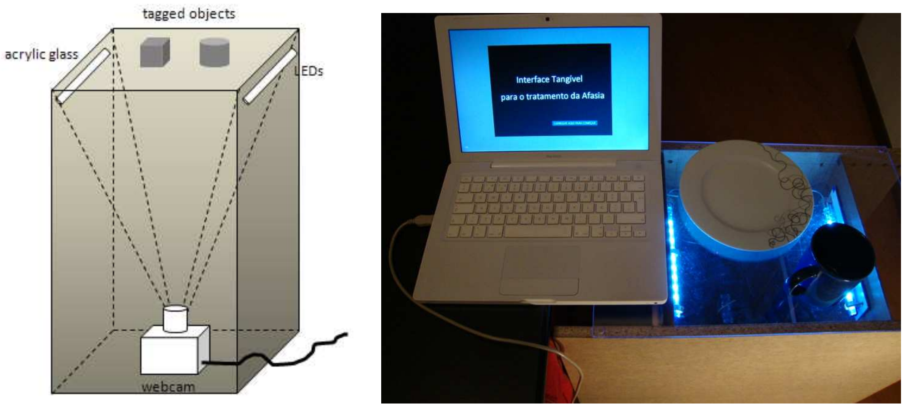


Figure 1. The TUI box: schematic drawing of the main components (left side) and image of the real prototype (right side).

1.2. Software structure

The open source software Trackmate Tracker [1] was used to allow the computer to recognize the tagged objects put on the sensing table. The software processes images acquired from a webcam. When a tag is identified, its information (ID, position, rotation and color) is sent to the desired application via LusidOSC, a protocol developed to work with a large range of tracking devices. In practice, three steps of setup are necessary before using the software with an application:

- Adjust the webcam's image for perspective warping.
- Specify the dimensions of the sensing surface.
- Calibrate the gradient of illumination on the transparent glass.

After these manual manipulations, and if the device is correctly configured, the system can identify automatically all the tags sensed on the table. In our application, only the data related to the ID and the position of the tagged object are used.

1.3. Clinical material

The therapeutic material is designed according to different levels of language complexity. Ordered by crescent difficulties, the three types of exercises are:

1 - Object identification: The patient just needs to discriminate a specific object between the other ones (e.g., "Pick a cube").

2 - Simple order comprehension: The instruction is only based on a "name - verb - direct complement" construction sentence (e.g., "Put the glass next to the plate").

3 - Complex order comprehension: The order is composed by a coordinate or a subordinate sentence (e.g., "Put the glass next to the plate and the knife behind the glass").

2. Application implementation

2.1. System architecture

As represented in figure 2, the system architecture is composed of two main devices: a webcam to capture the image of the sensing surface and a computer to process the information and display the application. The image from the camera is sent to the computer and, thanks to the Trackmate Tracker system, the tags are recognized. The LusidOSC library allows information contained in each tag to be used in a Java/Processing program. The library listens for events that are triggered when an object data is received. Then the events can be mapped to desired functionalities.

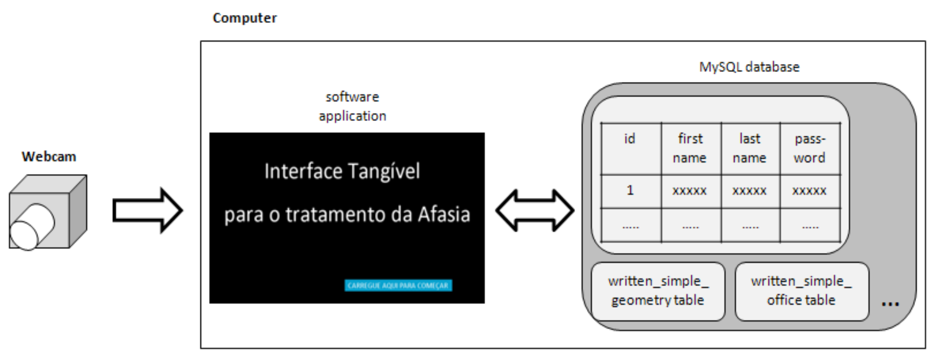


Figure 2. Global architecture of the TUI for the aphasia treatment.

Since this application is used in a clinical context, the patient performances must be recorded in a database. To do this, the program is connected to a MySQL database management system that ensures a data exchange (reading and writing) through PHP/SQL requests. The database architecture is divided into twenty-five tables: one table to register the patients and twenty-four tables for the different categories of test. The patients' table contains four fields: an automatic generated "id", the "first name", the "last name" and the "password" entered by the individual. The patient performances are registered in the other twenty-four tables. All of the tables have four fields: an "id" of the row, a "date" of the record, a "personal id" (the same as the "id" in the patients' table) used to match the performance with the right patient and a "score" on the test. A number of twenty-four test categories is imposed by the organization of the rehabilitation exercises, which is a combination of 2 modalities (written and spoken) x 3 task levels (identification, simple and complex orders) x 4 kinds of objects (geometric, cutlery, office supplies / toys and varied). This database architecture was chosen to ensure a global as well as a specific analysis of the patient results and her/his progression across the training sessions.

2.2. Computer interface

The program was written in Java/Processing because it offers a simple way to use the LusidOSC protocol and facilitates the creation of sophisticated visual applications. Because aphasia is a language problem and this work takes place in Portugal, all the written and spoken instructions are in Portuguese (to be understood by the international community, the application interface in the figure 3 was translated into English). In the first window, the user is invited to initiate a session of the "Interface Tangível para o tratamento da Afasia" (Tangible Interface for the treatment of Aphasia), through a click on the bottom-right button. Next, there are two choices. The patient can be a new user or someone who is already registered. If s/he is new, the individual needs to create an account by filling the first name, last name and password textboxes. If s/he is already registered, s/he just needs to introduce her/his personal identifications (last name and password) and, if the data matches with someone registered in the patients' table of the TUI database (DB), a new session opens (figure 3b). This tool is programmed with a multi-user access to facilitate the using and recording of the data in a clinical context that deals with numerous patients. After the login operation, the user can make a choice between executing an exercise and consulting the results of former exercises.

Before carrying out an exercise, the individual chooses a category from a list of twenty-four possibilities (figure 3c). As mentioned in the precedent paragraph, the list is subdivided in reading and oral tasks. It means that the orders are written on the computer screen, in the first case, vs. are listened through the phones, in the second case. Thanks to these two options, the patient can train the modalities where s/he needs more stimulation and practice. Then, there is a choice between executing the comprehension exercises for object identification, simple order or complex order (see section 2.3 for more details). The three tasks represent three crescent levels of comprehension difficulty. They are been designed for the user begins by the lowest level and finishes by the highest at the end of the therapy. The transition from a level to the next one occurs when the patient obtains at least 80% of correct answer. At last, the objects are grouped in 4 classes: geometrics, office supplies (or toys, for children), cutlery and a variety of commons objects. These classes are selected to represent the most standard and commonplace objects in the actions of everyday life. In each kind of test, when the individual has chosen the modality, level and object category, a series of ten different orders and answer feedbacks is displayed before the patient receives her/his final percentage of success. The score is recorded in the database. After that, two buttons permit the user to go back to the main menu or exit and shut down the program.

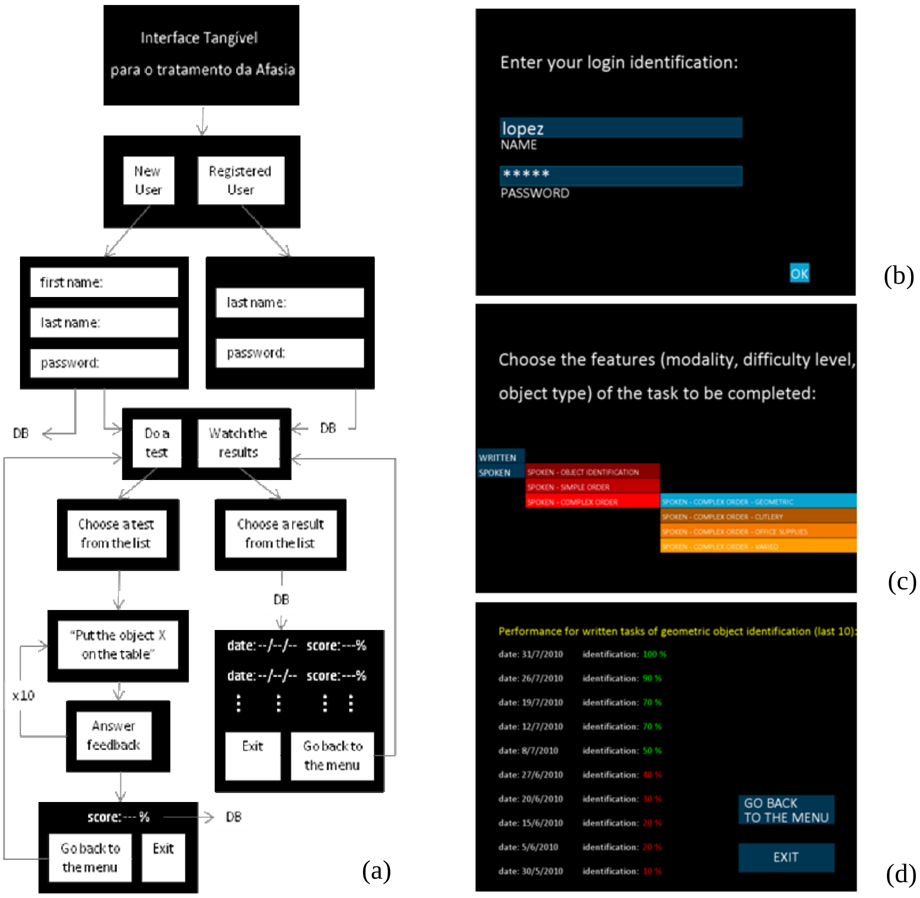


Figure 3. The software application interface: overview of the tool interface (a), snapshots of the login screen (b), menu list of possible tasks (c) and results of the last ten sessions for a determinate task (d).

In the main menu window, the user can decide to do an exercise again or to watch a history of her/his past results. In the last situation, s/he must select the desired results from a list identical to the one used in the test execution mode. The hierarchical organization of the list ensures different reading levels of the data, from a global to a detailed point of view. For example, if the user selects the root “Writing” item s/he has access to the last session of each category of the written exercises. At this reading level, the user (therapist or aphasic patient her/himself) has a global perception of the written comprehension capacities of the patient. If the individual is only interested in watching the results for the simple tasks or, on the contrary, the complex tasks, s/he must select the second level on the list. This option provides access to the last two results for each category of objects. Finally, the third hierarchical level shows the most detailed representation of the scores for a determinate task (figure 3d). It permits the therapist to analyze the evolution of the patient's performance across the last ten practice sessions. Whatever the reading level, the results always specify the type of task, the date of the exercise and the score in percentage of objects identified, through a reading of the DB. The "Oral" results are organized following the same multi-layer hierarchical architecture. At last, two buttons on the bottom side of the window ensure the user to go back to the main menu or exit the program.

It is important to notice that we do not expect the patient to be able to navigate through the tool in an entire autonomous way. The assistance of an able person, like a parent, might be necessary, at least at the beginning. The level of autonomous use of the system will depend on the degree of aphasia impairment of the patient. Nevertheless, once the task is loaded, the interface is designed to ensure the aphasic individual to complete whole exercises without any help from another person. Also, all instructions of navigation are always displayed following two modalities: written and spoken. So, a reading aphasic person will be able to understand the writing instructions and an auditive aphasic person will understand the speaking ones. In the conclusion section, some techniques are discussed to increase the autonomous utilization of the tool in the future.

2.3. Therapeutic tasks

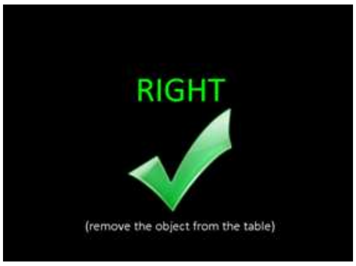
2.3.1. Repetition possibilities

Once the task is chosen, a screen asks the user the number of trials s/he wants in case of a wrong answer. According to the comprehension level of the patient, this field can be filled by the aphasic her/himself or by a close person. The repetition number is a critical variable in aphasia therapy. A general principle in rehabilitation shows that the more the patient executes successive trains, the higher will the chance of recovering be. However, the quantity of trials for a wrong answer must be correctly adjusted, in order to take into account the level of comprehension (more repetitions for a low level) and the personality (more possibilities of repetitions for an obstinate person) of each individual. Whatever the case, the number should be defined according to the therapist's opinion and altered following the patient's progresses.

2.3.2. Orders

In the "object identification" task, the user is asked to put a determinate object on the sensing surface (figure 4a). For the "simple and complex order" tasks, more than one object must be placed on the table. In this case, the patient does not only identify a unique object but must perform an action related to different objects at the same time. For example, the patient can be asked to put an object in a specific position relative to another, to touch a determinate object with another determinate object, to make a choice to perform an action with one or another object. These second types of exercises are more realistic from a day-to-day activity point of view and the complex sentence constructions that an individual deal with.

(a)



(b)

Figure 4. The sequences of an exercise: window of the asked order (a) and window of the feed-back message for a right answer (b).

2.3.3. Feed-backs

After the user completes the order, s/he receives a feed-back message (written and spoken) as a result of her/his action: “right”, if the order is correctly executed or “wrong” if the order is not understood (figure 4b). If it is wrong and the repetition number is superior to one, the same order is asked again, until the repetition possibilities finish or the patient executes the order in the right way. To improve the information comprehension, the feed-back message is always complemented by another feed-back presentation. Various kinds of complementary feed-backs are implemented: congratulating (applauses) sound vs. strident sound and symbolic designs, such as green tick (√) vs. red cross (X). In order for the patient to enjoy using the system and to make the exercises less boring, a different complementary feed-back is displayed from one trial to the next.

Conclusions and future works

This work has consisted of applying the concepts of the TUI for aphasia therapy. This paradigm was preferred to other ITs because i) it implements a cheaper technology that facilitates regular training at home and ii) it ensures a manipulation of physical objects to put the user in a higher ecological situation. A true haptic experience should promote an easy use of the IT and a better learning transfer to day-to-day activities, especially for older patients [14]. Also, the playfulness characteristic of the tangible interfaces and results from testing the technique in educational settings suggest that the approach could be particularly useful for children with language development disorders [15].

The main features of the proposed system are:

- Manufacturing and implementation of a TUI for therapeutic use.

- Programming of written and phonic instructions for the training and evaluation of the user’s reading and spoken comprehension.

- Division of the tasks into object identification, simple and complex order.

- Performance recording in a multi-user database that can be consulted through the program interface and according to different reading levels.

Future implementations of this technology include:

- Using the tool in the hospital or at home, to test its usefulness and adaptability in a real clinical context.

- To increase the autonomous level of the system utilization by the patient, in a way to facilitate the patient’s registration (for instance, through a wearable RFID tag for each user) and an automatic calculation of the needs of repetition for a user, based on her/his last performance statistics.

References

[1] A. Kumpf, *Large-Scale Accessibility of Tangible User Interfaces*, Massachusetts Institute of Technology, M.S. Thesis, Cambridge MA, 2009.

[2] H. Damasio, Neuroanatomical correlates of the aphasias, *M.T. Sarno (Ed.) Acquired Aphasia*, Academic Press, San Diego CA (1991), 45-71.

[3] A. Basso, *Aphasia and its Therapy*, Oxford University Press, New York NY, 2003.

[4] S.K. Bhogal, R. Teasell, M. Speechley, Intensity of aphasia therapy, impact on recovery, *Stroke* **34** (2003), 987-993.

[5] A. Reis, K.M. Petersson, A. Castro-Caldas, M. Ingvar, Formal schooling influences two-but not three-dimensional naming skills. *Brain and Cognition* **47** (2001), 397-411.

[6] J. Fonseca, G. Leal, L. Farrajota, J. Carneiro, A. Castro-Caldas, Lisling – Multimedia program for aphasics training, *G. Anogianaki, C. Bühler and M. Soede (Ed.), AAATE,* Chalkidike Greece, 1997.

[7] I. Robertson, Does computerized cognitive rehabilitation work? *Aphasiology* **4** (1990), 381-405.

[8] C. Sik Lányi, Z. Geiszt, V. Magyar, Using IT to inform and rehabilitate aphasic patients. *Informing Science Journal* **9** (2006), 163-179.

[9] H. Ishii, B. Ullmer, Tangible bits: towards seamless interface between people, bits and atoms. *ACM SIGCHI Conference on Human Factors in Computing Systems,* Atlanta GA, 1997.

[10] F. Varela, E. Thompson, E. Rosch, *The Embodied Mind,* MIT Press, Boston MA, 1991.

[11] D.A. Norman, Affordances, conventions and design, *Interaction* **6** (1999), 38-43.

[12] J.J. Beaty, *Skills for preschool teachers,* C. E. Merrill Publishing Company, Columbus OH, 1984.

[13] S. Price, Y. Rogers, M. Scaife, D. Stanton, H. Neale, Using 'tangibles' to promote novel forms of playful learning. *Interacting with Computers* **15**(2003), 169-185.

[14] S.V. Cobb, T. Starmer, R.C. Cobb, S. Tymms, T. Pridmore, D. Webster, Interfacing tactile input devices to a 3D virtual environment for users with special needs, *M.J. Smith, G. Salvendy, D. Harris and R.J. Koubek (Ed.), HCI International* (2001), 36-40.

[15] C. O'Malley, D.S. Fraser, Literature review in learning with tangible technologies, *Report 12, NESTA Futurelab Series*, 2004.