Technology for communicational development and learning in psychomotor disability

I Trento¹, M Santucci², S Tula³ and E González¹

¹Grupo Ingeniería Clínica, Universidad Tecnológica Nacional, Facultad Regional Córdoba. Av. M. López esquina Cruz Roja, Ciudad Universitaria, 5012 Córdoba, Argentina. E-mail: ivitrento@gmx.net
²Facultad de Psicología, Universidad Nacional de Córdoba. Ciudad Universitaria, 5012 Córdoba, Argentina
³Escuela de Educación Especial y Formación Laboral Beatriz Martínez Allio. Av. M. López N° 2620 Ciudad Universitaria, 5012 Córdoba, Argentina

Abstract. The applied investigation and experimental development project described in this paper has been carried out by Grupo Ingeniería Clínica of the Universidad Tecnológica Nacional together with two Special Education Schools dependent on the Ministry of Education of Córdoba Province. Its aim is the development of computer access assistive tools for students with mobility limitations, and with or without intellectual problems that need adaptations to access to a computer in order to learn, communicate, work, etc. On the other hand, it demonstrates the benefits that the use of a computer gives to these students. The evaluation of their performance was made through Dr. Marianne Frostig’s Developmental Test of Visual Perception and reading and writing graphic tests, comparing the results of the tests made on paper with those made on computer. Thus, an interdisciplinary team was formed by Engineering, Psychology and Special Education professionals, and 40 students were evaluated. The design of the mouse and keyboard had some adaptations. At present, the rating test stage is being achieved, and the preliminary results allow us to anticipate that pupils with psychomotor disabilities may manifest their perceptual ripeness and reach education in a more efficient way through the use of informatics tools according to their needs and possibilities.

1. Introduction
The accelerated rhythm of technological innovations registered in the last years opens a new era in the teaching / learning field, and generates opportunities for disabled people, as computers significantly influence on their communication, possibilities of education and recreation, and on job opportunities. The use of the computer as an educative habilitating resource favours the psychosocial growth of the pupil with a psychomotor disability, due to the fact that when the individual is given stimuli and possibilities to express himself, he may reach the expected learning level and, may be, he can achieve a normal social development.

The rehabilitation process, or habilitation, means to optimize the individual’s potentialities. From this premise, and continuing the line of investigation on Rehabilitation Engineering developed by the
The Grupo Ingeniería Clínica of the Universidad Tecnológica Nacional, Facultad Regional Córdoba, an interdisciplinary team formed by Electronic Engineering, Psychology and Special Education professionals, had the objective to create assistive devices (hardware adaptations) to facilitate the access to a computer for students with psychomotor disabilities and associated learning problems, expecting them to reach their independence, get an education and communication, get a job and be integrated into society, helping them with their psychomotor development. In addition, the project intends to demonstrate that the use of computers is highly beneficial for the educational process of impaired students, and that they should be used by the teaching staff as an indispensable resource to improve their possibilities of integration, since they may develop communicational abilities and learning capabilities of each student.

The above goals imply a social impact as well, because the project fosters an equal-opportunity approach between common students and special-need students, specifically psychomotor-impaired individuals, therefore improving their life quality, which is a responsibility that the State and University cannot evade.

2. Materials and methods

The project begins with the development of computer access devices for students with a psychomotor disability, evaluating the student’s performance after using these devices. Forty students between 5 and 21 years old who went to the two Córdoba city’s public schools for students with motor disabilities participated in the project (Escuela de Educación Especial y Formación Laboral Beatriz Martínez Allio and Escuela de Educación Especial Blanca Feit).

At the beginning of the project, the needs of the students were analysed by the interdisciplinary team, as detected within the schools, during individual and group observations, investigating the medical diagnostics and school reports of the students. An index card was created for each student their personal data (age, gender, school, school grade, scholar brief, medical brief, familiar brief, etc.), and notes about several observations made by the team. For example, if the student could read and write or not, what kind of peripherals were used by them to use the computer, and which the best the modifications would be for those standard devices they used, or which new device they would need to access to the computer. As a result of these observations, mouse and keyboard adaptations were developed, details of which are given further in this paper.

To set an objective instrument of evaluation of the developed devices and also measure the performance of other adaptations that schools already had, the team’s Psychology area proposed the utilization of Dr. Marianne Frostig’s Developmental Test of Visual Perception, as a scientific method to compare the students’ activities performed by hand (with pencil or marker lines on paper) and their activities made within the computer using different adaptations. This Test gives information about the five perceptual areas that influence directly on the learning capability, which are: Eye-hand coordination, Figure / background discrimination, Form perseverance, Spatial orientation, and Spatial relationships. The activities of these Tests involve tasks such as vertical, horizontal and diagonal joints of several elements, the copy down of lines, identification of geometric figures, identification of identical figures, visualization of “hidden” figures behind a background, etc. Sometimes, although the student may understand the task he is being asked to execute (for example, make a line joining two figures), his mobility limitation does not let him do it on the paper, because he cannot take the pencil with his hand due to a low muscular activity, or because he has abrupt movements, etc. However, this situation may be reverted in some cases if the student uses the computer: using adequate hardware and software tools, these students are able to join the same figures without mayor problems –to continue with the same example-, so it can be verified that their perception evolves normally, and that it is not affected by their motor disability. This may be applied to other students’ activities, especially those which have to do with learning and communication. In addition to Dr. Frostig’s Test, reading and writing graphic tests were taken. They consisted in copying down letters, words and phrases -written in type capital letter- in paper format and in computer format. The tests in the computer were executed using both the standard keyboard and the adapted keyboard prototype developed by the team.
Several meetings of the interdisciplinary team were made for the execution of the project, to determine the modality of taking and using the tests, and the characteristics of the adaptations to be developed. The field work took place in the participant schools, during the years 2005 and 2006, working at the informatics classrooms of the mentioned institutions.

2.1. Developed devices

At the time tests were taken in paper, two devices were developed: a mouse with external buttons and a keyboard of big dimensions. As it was already mentioned, these adaptations were designed as a result of the observations made in the schools and their purpose is to cover common needs detected in the students. The interdisciplinary team is conscious that unique solutions do not exist when it is about disability but, having investigated the groups, it was possible to develop affordable tools that, with simple changes, may be adapted to several users.

Mouse adaptation consists of cancelling the standard mouse buttons (left and right click) when external buttons are connected to perform these functions. There are two variants of external buttons: one of them performs the same action that the internal button of the mouse, while the other plays the part of the left click retention. This adaptation benefits some students that have involuntary movements that do not allow them to use the standard mouse correctly, because they click all the time (perseverance). Sometimes, students have also intellectual problems which do not permit them understand the double function of the mouse - moving and positioning the pointer-, and after that clicking to perform an action. In other cases, students cannot make a digital pressure although they may perform a pressure with the whole hand, but with these movements they are not able to press the standard mouse buttons with their fingers. To give a solution for all these cases, an external and big clicking button was added to a standard mouse.

Some students are not capable of holding the pressure on the mouse buttons to perform an action, such as dragging an icon or drawing a continuous line. For this reason, a second button with a retention function was included in parallel with the external left click button. When this button is pressed for the first time, it performs the left clicking, but the button is held alone until the user makes a second pressure on this button, letting the user move the mouse pointer while the retention keeps on. Thanks to the interdisciplinary work, it was possible to detect these problems and to adapt a standard mouse to teach the students these two functions of moving and clicking, expecting that in the future they will dominate the concept and, with a favourable motor capability, the adaptation may act as a bridge to the standard mouse utilization. Different buttons were used, in small and big sizes, and in some prototypes the retention button was not included because it was not necessary for all the users. A photograph of a student using the mouse adaptation developed by the team is shown in figure 1.

The other device developed is a prototype of a keyboard with bigger keys than a standard keyboard, and more distance among the keys. The objective is the design of a final keyboard prototype with the minimum essential quantity of keys to operate a computer: about 55 keys. Key’s sensibility, distance among them, their dimensions, etc., were defined by the team as a result of the observations made at the informatics classrooms of the schools.
Initially, a five-key keyboard was constructed, only with the vowels, and it was tested by the pupils of both schools. For this test, simple software was designed: pictures of animals were shown on the computer screen and, under these images, the animal’s name was printed in capital letter. One letter (a vowel) of the animal’s name was missing, so the student had to press that letter on the keyboard to complete the requested word. These tests were performed with the first prototype and they were satisfactory, even some students suggested modifications to improve the device, such as designing the key rows in different levels, and the possibility of having a space between two keys added under them to rest on a part of their hand before pressing the keys.

All these suggestions were evaluated for the final prototype design, which is being constructed at present. Its total dimensions will be approximately 30 cm long by 50 cm wide, with 5 rows containing 11 keys, and the rows will be in different height levels.

To perform the reading and writing graphic tests, a second ten-key keyboard prototype was constructed, which had the necessary letters to perform the copying of the selected words, plus the space key. In addition to the final prototype, a smaller one will be constructed with the numbers from 0 to 9, meanwhile, the one with the vowels will also be used to initiate students in reading, writing and mathematics in the first school grades.

A photograph of the first keyboard prototype is shown in figure 2.

3. Results

3.1. Advantages of the created devices
A very important point concerning the adaptations introduced is that they are compatible with any software. The keyboard may be used, for example, to write on a word processor and then print the text, so that the student may have his class folder, or it may be used to surf the Internet, etc.

The advantages of the adapted mouse are that involuntary clicks are avoided, that it flexes the pressure operation of the buttons, and that it is useful to train the user to achieve the proper use of the mouse, which allows the user to try to operate a standard mouse, because thanks to the adaptation, he is able to differentiate the cause-effect result of moving the mouse and clicking.

The advantages of the new keyboard are that it minimizes the involuntary pressure of keys, allows hand or part of hand resting before pressing a key, and due to its simplicity it facilitates alphabetization and initiation in computer operations of disabled students.

3.2. Evaluation of two students using Dr. Frostig’s Test
To evaluate the performance of the students using the computer versus paper, all the components of Dr. Frostig’s Test were computerized in bmp format, and they were completed by the students using the popular graphic editor Paint.

Although the project is going through the rating test stage at the present time, and we are finishing the final prototypes which will be donated to the participant schools, the results of two children’s tests...
are presented in this paper to exemplify the impact of the applied technology in the pupils’ performance.

G A is a ten-year-old boy whose medical diagnosis is cerebral palsy; he has a good intellectual level and is literate. Figures 3 and 4 show two tests performed by this student. There it may be noticed that the student has difficulties in performing straight lines with the pencil, as well as marking out defined sectors and painting a figure to refill it. Troubleshooting these problems is possible with the use of the adapted mouse and with the help of another tool that the school already had called adaptive mouse, which consists of individual buttons to perform the horizontal and vertical movements of the mouse pointer and the functions of left click, left holding click and Escape. The results of Dr. Frostig’s Test performed by G A are shown on table 1, comparing his performance in paper and using the computer.

![Figure 3. Dr. Frostig’s Test 1a performed by G A on paper.](image)

![Figure 4. Dr. Frostig’s Test 1a performed by G A on computer.](image)

| Visual Perception Area                  | Paper test          | Computer test        |
|-----------------------------------------|---------------------|----------------------|
| Eye-hand coordination                   | 3 years and 3 months| 7 years and 9 months |
| Figure / background discrimination      | 5 years             | 5 years and 3 months |
| Form perseverance                       | 5 years and 6 months| 7 years and 6 months |
| Spatial orientation                     | 7 years             | 8 years and 9 months |
| Spatial relationships                   | 6 years             | 7 years and 6 months |

Another outstanding case due to the visible benefits achieved with the use of the adaptations and the computer, is that of V S. He is an eleven-year-old student with cerebral palsy, with involuntary abrupt movements, and an intellectual capability that tends to be superior to the standard. In the paper test that he performed, it may be observed his impossibility to make a straight line, to mark out a defined sector, serious difficulties to paint, etc. Using the computer and the adaptations, the student was able to perform straight lines joining, even marking and painting, figures; a fact which impacts directly on enhancing his perceptual ripeness score, as shown on table 2.
Table 2. Results of Dr. Frostig’s Test performed by V S, an eleven-year-old student.

| Visual Perception Area                  | Paper test           | Computer test         |
|-----------------------------------------|----------------------|-----------------------|
| Eye-hand coordination                   | 2 years and 9 months | 6 years and 3 months  |
| Figure / background discrimination      | 5 years and 3 months | 8 years and 3 months  |
| Form perseverance                       | 7 years              | 8 years and 3 months  |
| Spatial orientation                     | 8 years              | 8 years and 9 months  |
| Spatial relationships                   | 4 years              | 6 years               |

3.3. Reading and writing graphic test evaluation of a girl

Three graphic tests performed by M T are shown in figure 7. She is 7 years old and her diagnosis is cerebral palsy. Although she is not literate yet, she was asked to copy the letters and words of the test. Her score in the paper test was very poor, because she was not able to reproduce the calligraphy of the larger part of the letters; neither she was capable of respecting the quantity of letters present in the words she tried to copy. When she did the test in its computerized version using the standard keyboard, her performance improved notably, but in the final phrase the student manifested that she could not finish the task because she was too tired due to the great effort she had made. When using the keyboard prototype designed by the team, the pupil was able to properly complete the test, faster and without so much fatigue.

Figure 7. Comparison of the 3 graphic tests performed by M T. On the left, on paper. In the middle, on computer using standard keyboard. On the right, on computer using the new keyboard prototype.
4. Discussion
It is possible to use computerized Dr. Frostig’s Test and the other graphic tests together with different computer access tools to determine the right adaptation to be used by the pupil with a psychomotor disability. The results obtained in the psychological investigation about the visual perception and the use of the computer will be provided to the schools to be employed as a new set of tools for diagnosis and evolution tracking of the student.

Despite the good performance of the keyboard prototype used in the reading and writing graphic test, the team must remark that this adaptation was constructed with the only ten keys that were needed for its execution. The evaluation of the complete keyboard performance is a pending point that will be further on analysed, when the final prototype is finished. As for now, the team thinks the benefits will continue because the main goals of the new design will be the same: big size of the keys and bigger size of the letters over the keys, colourful letters, space for part of the hand to rest.

The execution of this project has been informed to authorities of Dirección de Regímenes Especiales dependent on the Ministerio de Educación, and Disability area of Ministerio de la Solidaridad, both of Córdoba Province, and both of them were very interested. The project has also been included within the Institutional Educativa Project of Beatriz Martinez Allio school.

5. Conclusions
The use of the computer as an educative habilitating resource favours the psychosocial growth of pupils with psychomotor disabilities, allowing them to reach their independence, get an education and communication, get a job and integrate into society, helping their psychomotor development.

Two computer access tools were developed during this project: a mouse adaptation with external buttons and a big sized keyboard. These devices allowed students to improve their performance, which was evaluated though Dr. Marianne Frostig’s Developmental Test of Visual Perception and a reading and writing graphic test. To carry out the project, an interdisciplinary team was formed by Electronic Engineering, Psychology and Special Education professionals.

The advantages of the computer utilization through the assistive devices designed together with the use of other adaptations that participant schools already had, are very relevant and the results have been objectively measured comparing them with students’ performance in paper and pencil tests.

6. References
[1] Bronzino D 2000 The Biomedical Engineering Handbook (USA: CRC Press).
[2] Santucci M 2002 Evolución psicosocial del niño con parálisis cerebral (Argentina: Editorial Brujas).
[3] Frostig M 1986 The Developmental Test of Visual Perception (USA).
[4] Servicio de Daño Cerebral del Hospital Aita Menni 2005 Manual de ayudas externas (España).
[5] Microchip 2001 PIC16F87X DataSheet (USA: Microchip Technology Inc.).
[6] Universidad Autónoma de Madrid 2004 Protocolo de atención a personas con discapacidad (España: UAM).
[7] Sánchez Montoya R 2002 Ordenador y discapacidad (España: CEPE).

Acknowledgments
Authors wish to acknowledge the contribution of the participant schools, their authorities, teachers and especially the students. A special mention deserves the assistance of Psychology practitioners who helped with tests performing: Mariel Nievas, Maria Laura Gianoboli and Alejandra Alanis; and the instructor of Informatics, Prof. Matias Ambühl.
A special thank is also extended to the Agencia Córdoba Ciencia and to Dr. Eng. Eduardo Destefanis, for their support to this project when participating in the Tutorial Program.
Finally, for their economical contribution in favour of the development of the adaptations, authors express their gratitude to the Rotary Club Alta Córdoba.