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How does the dedicated software PLEIA provide computer access assessment for people with physical disabilities?

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ABSTRACT

Computer tools allow to ease the daily life of everyone, especially for people with disabilities. The optimal choice of pointing interfaces or types of settings can be difficult to achieve. Although there exist a few tests to compare and evaluate the performance of computer access technology (CAT), most of them only provide results as qualitative terms. Besides, the current choice is based mainly on clinical observations or non-standardized tests. To objectify the recommendations in CAT, support funding for people with disabilities and measure the functional repercussions of a therapeutic action, it is necessary to carry out comparative tests with measurable criteria. This paper presents the development of a personalized, free, and dedicated evaluation platform of pointing interfaces and assistances. The quantitative evaluation process is described in detail, such as the configuration of different exercises with settable parameters that permits to build a customized evaluation process with increased difficulties, the definition of performance indicators and the statistical analysis methods for quantified comparative tests. Finally, we present the assessment results of four people with different disabilities using multiple pointing interfaces, which verify the effectivity of this evaluation platform with the help of occupational therapists.

KEYWORDS

Computer access assessment, pointing devices, performance evaluation, disabilities, software tool.

1. Introduction

The use of computer tools has become widespread in recent years. Now they accompany everyone in their work, their hobbies, social relationships and so on. Through the use of the Internet, computer tools also allow for the constitution of a common background knowledge and the sharing of knowledge. In particular, for people with disabilities, computer tools promote access to work and certain leisure activities such as culture, games, social networks, etc. Especially for students with a disability, the ability to access a computer may be their only way to learn new skills, participate in

classroom activities, and demonstrate their knowledge (Drescher et al. 2009). Therefore, computer tools contribute to the users' social and professional integration, which is helpful in developing their autonomy and openness to the outside world.

1.1. *Current computer access technologies*

People who are unable to control a computer due to their disabilities need assistive technology for computer access, *i.e.* Computer Access Technology (CAT) (Simpson et al. 2010). Currently, there are a number of pointing interfaces such as mouse, joystick, trackpad, touch screen, eyepiece control and so on. In order to help people with disabilities to use these interfaces well, the CAT can be developed as a software application, device or equipment (hardware) based on analysis of individuals' impairments or preferences. In the developed software applications, for example, (Trewin et al. 2006) presented a click-assist technology, Steady Clicks, to address some of the clicking problems of elderly people and people with Parkinson's disease. Similarly, (Salvia and Hourcade 2013) proposed PointAssist, a personalized software that detects difficulties by analyzing a set of movement of people with motor impairments during pointing tasks. The cursor speed can be modified to adapt users in a flexible way to the needs and comfort. There are also some studies that focused on the CAT used for online learning activities. For example, (Laabidi et al. 2014) presented an accessible online learning environment for people with disabilities. Every learner can specify his type of disability and preferences in this software, and then a relevant accessibility model will be generated in Moodle¹. In (Cinquin et al. 2019), the accessibility of e-learning for people with cognitive impairments was studied. Several categories of accessibility solutions were proposed for different learning activities. Moreover, the authors discussed both the design and the assessment recommendations of this kind of CAT.

Besides the software applications proposed above, there are also a few studies about the development of assistive hardware. For example, (Chen et al. 2006) presented a universal integrated pointing device apparatus (IPDA) for people with cervical spinal cord injury (SCI) who are unable to operate common pointing devices. The highlight is that IPDA can integrate many current pointing devices and can be controlled by various combinations of movements of users. In addition, there are also some innovations beyond traditional inputting devices. In (Ramos et al. 2016), the authors introduced Keyboard Surface Interaction (KSI), which can turn the keyboard surface into an interactive surface and thus the user can keep their hands on the keyboard to reduce fatigue. A proof-of-concept implementation, Fingers, was developed and evaluated against the mouse and trackpad. Results showed that their KSI device could reduce discomfort compared to the trackpad and mouse. However, these technologies do not appear to be sufficient to provide comprehensive support for people with different disabilities.

1.2. *Existing assessment tools*

As presented above, many pointing interfaces or the corresponding CAT were proposed for different types of users. However, the choice of this kind of tool, such as its positioning or its setting, is not easy for therapists. Similarly, the functional impact of a therapeutic action on the use of the computer tool can also be difficult to evaluate. It is a true challenge when a specialist or a multidisciplinary team of experts

¹<https://moodle.org/?lang=en>

has to assess and select the appropriate CAT that would enable the user to control a computer as efficiently as possible with as little as possible fatigue (Jenko and Zupan 2010). (Simpson et al. 2010) has presented the importance of CAT, and it also presented that the optimal choice of CAT requires collaboration of consumers, clinicians, and third-party payers. In order to improve the support for these people, now it is essential to assess the impact of disability on the use of computing tools, which is also our main objective in this study.

(Hakkinen 2015) provided a reasonable overview of new developments in assistive technologies for computer-based assessments. The author pointed to a number of accessibility issues including trends in technology use in education of students with disabilities, technical accessibility standards, and needs for additional research. The existing research about assessment of CAT can be divided into three groups:

- The first group focus on the design of hardware or interface. For example, (Vincent et al. 2003) presented an instrument to measure the performance of students with low vision on computer tasks. A group of students were asked to realize several standardized tasks such as pointing, drawing and writing in different computer applications. In (Shintani et al. 2010), a pointing interface used for large touch screens was presented. The interface was developed based on learning users' pointing actions using multiple linear regression analysis.
- The second group of studies focus on the design of experiment or selection of measurement based on the analysis of users' disabilities or their movement during the use of assistance tools. For example, (MacKenzie et al. 2001) proposed new accuracy measures to verify differences among four devices (mouse, trackball, joystick, touchpad) in precision pointing tasks. (Hwang et al. 2003) presented a study on mouse movements of people with motor impairments. In order to better understand the impaired movement, the cursor trajectories of two user groups, with and without motor impairments respectively, were compared. The results showed that there were significant differences between the two groups in several measures such as the frequency and duration of pauses between submovements. (Dumont and Mazer 2013) studied the standardization of the assessment of computer task performance for children. The authors found several factors that could influence the performance of children in keyboard tasks, *e.g.* age, level of education and internet use. (Borgestig et al. 2016) verified the effectiveness of gaze-based assistive technology in eye gaze performance of children with severe physical impairments. The children were asked to perform the same task after different periods. The results showed that their eye gaze performance could be improved after a long-term practice. In order to help people with motor impairments for small target acquisition, (Payne et al. 2017) measured and compared participants' performance under three conditions. One is using an assistive tool, and the other two are used to verify if the additional movements could improve the interaction efficacy. In (Rybanov and Tretyakova 2015), the performances of 12 students were compared and classified using Fitts's law (Fitts 1954). The participants performed pointing and dragging tasks with three common types of interaction respectively. The results confirmed the effectiveness of Fitts' law to model the two tasks. Similarly, (Zhou and Shen 2016) also used Fitts' law to evaluate the performances of pointing tasks with three input devices respectively, but for two user groups, *i.e.* elderly people and young people. The authors found that the best input device for the elderly is touchscreen compared with mouse and stylus. In addition, based on Fitts' law (Bachmann et al. 2015) compared

the user’s performance with a mouse and a leap motion controller, which is a contact-free input system. Obviously, Fitts’ law is a classical analysis method for the assessment of compute access tools (MacKenzie et al. 1991), (Rao et al. 2000), (Gump et al. 2002), (Wobbrock and Gajos 2007), (Felzer et al. 2016), (Pérez et al. 2016), (Payne et al. 2017), (Pérez et al. 2019).

- In the third group of studies, the selection of devices or interfaces to be assessed, the design of experiment, the measurement of users’ performance, and/or the analysis method, might be integrated to a platform or a software. For example, in (Foucher et al. 2007), the authors developed an assessment tool called Efficasouris for occupational therapists to improve the use of input pointing devices by people with motor disabilities. (Evans and Wobbrock 2012) presented the input observer to measure users’ performance in writing (text input) and pointing tasks. Unlike the lab studies in which participants were asked to perform prescribed tasks, this tool can measure users’ errors in writing and pointing from their daily use because it runs in the background of the computer. (Kim and Yook 2012) presented Korea-Computer Access Assessment (K-CAAS) to help people with disabilities access and use computers. It is a personalized tool and also a training program for users because they can choose skill levels of test in the tool according to their impairments or preferences. The software was also improved to assess future mobile computer access (Yook and Kim 2015). In addition, (Koester and Mankowski 2015) presented AutoIDA, which is also a personalized software tool for the configuration of Windows keyboard settings according to users’ needs. The same research team also developed another software tool, *i.e.* COMPASS, for the configuration of mouse and other pointing devices. Using the two softwares, the users’ performance during typing or pointing task with different configuration of keyboard and mouse settings can be evaluated. Thus, the results can help to recommend certain setting to improve individuals’ efficiency and comfort while meeting their specific requirements (Koester and Mankowski 2014). (Valencia et al. 2015) and (Arrue et al. 2019) presented RemoTest used for web accessibility evaluation of users with disabilities. The platform provides guidance on how to set up experiments and is therefore suitable for experiments targeted in both remote and on-site environments. Personalized touchscreen settings can improve computer accessibility for users with physical or motor disabilities. In a recent research (Peng et al. 2019), the authors presented a software called PersonalTouch, which could recommend an optimal touchscreen accessibility setting to reduce individuals’ typing or input errors by gathering and analyzing their gestures during the tasks.

1.3. *Our evaluation software PLEIA*

This paper integrated the existing three groups of research. Our objective is to present a free evaluation platform for pointing interfaces and assistances, *i.e.* the software PLEIA² (Platform for the Evaluation of Interfaces and Assistances). It has three principal advantages. Firstly, PLEIA can objectively measure the skills observed in different environments using multiple pointing interfaces. The current version of PLEIA can provide 19 performance indicators to characterize the test and describe the handling of the pointing interface by each user. Therefore, when using a pointing interface (mouse, touch screen, trackball, joystick, mind control, ocular, etc.), the functional impact of

²<http://www.pleia.uvsq.fr/>

motor and/or cognitive impairment can be quantitatively assessed. Secondly, the development of PLEIA is a continuous and open process. Everyone can download and test it. Therapists have been invited to share their practices and results during the early stages of the development process. In addition, a collaborative website is being developed to facilitate the exchange and sharing of assessments of PLEIA. Thirdly, users can create their exercises and analyze the results using PLEIA. Therefore, it offers the possibility of personalizing the use of the microcomputer according to the patients' capacities, needs, interests, personal evolution and therapeutic objectives. It has been tested by occupational therapists that PLEIA can be adapted to their needs and uses and it can help them to build a specific evaluation process with graduated difficulty for their patients.

The rest of the paper is organized as follows: Firstly, Section 2 presents recommendations for computer tools selection. Next, the software PLEIA and its contributions are introduced in Section 3. It also explains the quantitative evaluation process using PLEIA. Section 4 presents how to perform the quantified comparative tests. Then, the experiments and analysis results of four participants with different disabilities are given in Section 5. Finally, Section 6 presents some conclusions and suggestions for future work.

2. Recommendations for computer tools selection

The recommendation and configuration of computer tools requires a multidisciplinary evaluation in collaboration with the users' family, the education and rehabilitation team. Patients' requests and contexts related to the use of these tools should be taken into account. In addition, the long-term risks of possible orthopedic deformities and pain caused by the use should also be estimated. Moreover, the implementation of occupational therapy rehabilitation to learn to use a computer tool or rehabilitate a function is not easy. It mobilizes energy and time of patients and brings financial costs to society. Therefore, it is necessary to assess the benefits/risks, as shown in Fig.1.

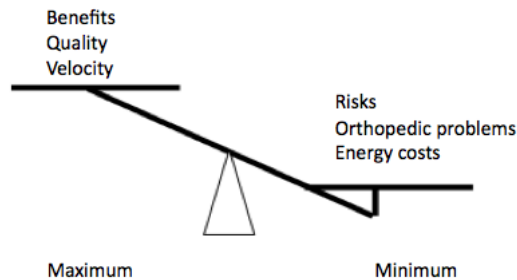


Figure 1.: The benefits/risks of compromise assessments.

At present, the classical clinical and standardized assessments of motor, cognitive and perceptual skills aim at optimizing the handling of the microcomputer in terms of effectiveness and user comfort. For example, on the motor level some studies focused on posture, anti-gravity capacities of the whole body, motility of limbs and neck, and oculomotricity (House et al. 1981; Thétio et al. 2012). On the cognitive level, the assessment of language, attention, memory, executive functions and praxis were performed (McCormick et al. 2007; Aupiais and Bera 2013). More commonly, on the

perceptual level such as visual acuity, hearing, superficial and deep sensitivity could be evaluated in specialized medical centres. In precedent studies, functional scales and dexterity tests were always used to objectify the therapeutic effect (rehabilitation, oral treatment, etc.), *e.g.* Classification of House (House et al. 1981), Box and block Test (Mathiowetz et al. 1985), MACS (Eliasson et al. 2006), etc .

According to the use of pointing interfaces, one can observe an energy expenditure associated with a patient's action which can be variable and cause fatigue on biomechanical and physiological indicators. Currently, we do not have reliable energy measures, which should also be non-invasive and easy to implement in an ecological situation. Based on the assessment results of the oculomotor and perceptual skills, it is possible to customize the visual environment of a computer desk and the sensitivity of the interface. The Windows graphic elements (folder, menu bar, bottom of the screen, etc.) can be modified (size, contrast, number of icons or change of font, etc.). But presently, the benefits of these adjustments on the patient's behaviour cannot be quantified.

All of these expertises leads occupational therapists to propose a positioning of patients and an arrangement of their environment. A pre-selection of pointing interfaces, their locations and settings is then carried out. Currently occupational therapists are improving their choice with the help of clinical assessment during comparative tests in "ecological situation". These are qualitative tests of the use of peripherals. In addition, uncalibrated tests are most often performed with a drawing software. Moreover, occupational therapists take into account patients' satisfaction index during the tests. Obviously, this complex process involves technical and human factors. Even though the motor skills and the required posture were considered during the assessment process, it was very pragmatic. In addition, it does not include an integrated storage of activity measurements (such as speed, distance travelled, cursor accuracy, or quality of movement). Therefore, the current recommendation and evaluation of the use of computer tools without indicator measurements depends solely on the professional level of therapists. Moreover, the final selection is usually based on clinical observations and uncalibrated tests.

3. The software PLEIA

In France, people with disabilities can be received by computer consulting sectors to obtain advices on the choice of hardware, software and/or pointing interfaces adapted to their abilities. For example, the Therapeutic Informatics Unit (TIU) of the Hospital of Saint-Maurice³, one partner of this project, receives children and adults with disabilities and their carers to advise them on the most suitable computer equipment considering their situation and needs. Generally, a specialist of physical medicine and rehabilitation will propose assessments of motor and cognitive skills at first. Then comparative tests of the use of computer tools will be performed. It is worth mentioning that a project about the implementation of these computer equipments has been developed with the educational and rehabilitation team. In addition, occupational therapists and computer technicians at the TIU also helped this team for the implementation. If necessary, a mobile team consisting of an occupational therapist, a speech therapist, a physical medicine and a rehabilitation doctor as well as a social worker, can accompany the person with disabilities to use these computer equipments

³<http://www.hopitaux-saint-maurice.fr/Centre-referenc-informatique-therapeutique/5/138/13/>

in an ecological situation. Since 2006, we collaborated with the TIU on the development of PLEIA. The dialogue and interaction between the field of medicine and that of CAT have been very rewarding although they required many adjustments to understand each other. Besides, regular collaboration between technologists and therapists improved the ergonomics and functionality of the software PLEIA because different partners contributed to its validation in different fields.

PLEIA assists occupational therapists or others in recommending computer tools and in monitoring the patient's evolution on objective and quantifiable criteria, which makes it possible to quantify and qualify the functional performance of the disabled people. Since patients' computer tools may be taken over by the social security systems, the therapist should demonstrate the value of his recommendations based on these criteria. The corresponding optimal choice considering the most efficient installation, configuration and type of equipment should be proposed. It can be imagined that this highlighted functional gain will presage the daily use of the prescribed computer tools.

3.1. *Development of PLEIA*

The PLEIA software is developed by designers as a free software. According to their practice, health professionals can download it for free from the website of University of Versailles Saint-Quentin-Yvelines (UVSQ)⁴. Users can create exercises and analyze the results (see Section 3.2 and Section 4.2 respectively). Besides that, a collaborative website that can support a multi-center assessment network (in different institutions) is being developed, which could increase the number of observations. Thus, it can be continuously developed. The goal is to create a user community to develop this software tool. From now on, various educational institutions have participated in the community.

PLEIA has been tested by occupational therapists and technologists. It has been validated on a Windows system. The measurements carried out are reproducible for the same computer configuration. Using the software with patients has allowed it to evolve as closely as possible to their needs.

3.2. *Quantitative evaluation process using PLEIA*

PLEIA offers the possibility to perform tests from a quantitative assessment process, so that the efficacy of one person with multiple interfaces in different environments can be compared. In addition, therapists can set options to create an appropriate test with PLEIA for people with different disabilities, as shown in Fig.2 and Fig.3. During the test, certain exercises with settable parameters will be finished by users. As an example, for the exercises shown in Fig.4, the parameters that can be set include:

- size, shape and location of the target to be reached;
- speed and acceleration of the pointer;
- size and shape of the pointer;
- screen background, trajectory, obstacles, presence of distractors on the screen;
- addition of obstacles on the specific screen zones.

At the end of each test, many results shown in figures and tables can be obtained to help therapists to make recommendations. Based on the therapists' practices using the traditional assessment methods, 19 performance indicators were chosen to characterize

⁴<http://www.pleia.uvsq.fr/>

Users edit

User

Recorded Users

PAR_00

User

Code * :

Name * :

Comments :

Pathologies : Muscular Spinal
 Peripheral Neuro Cognitive
 Orthopaedic Sensorial
 Cerebral

Date of creation * :

décembre 2020

lun.	mar.	mer.	jeu.	ven.	sam.	dim.
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

Aujourd'hui : 08/12/2020

(*) Required field

Modify Create

History

	Exercices	Date of Execution
*		

Delete

Close

Figure 2.: Selection of patient's profile (screenshot).

Run a test

Users

PAR_00

Exercices

- AO_DiagonaleDBs
- AO_DiagonaleDHT
- AO_DiagonaleGBs
- AO_DiagonaleGHs
- CO_DiaDBs Vt 5 Diam30 TêteBle
- CO_DiaDBs Vt 5 Diam30 TêteJau
- CO_DiaDBs Vt 5 Diam30 TêteRos
- CO_DiaDBs Vt 5 Diam30 TêteVer
- CO_DiaDBs Vt10 Diam20 TêteBle
- CO_DiaDBs Vt10 Diam20 TêteJau
- CO_DiaDBs Vt10 Diam20 TêteRos
- CO_DiaDBs Vt10 Diam20 TêteVer
- CO_DiaDBs Vt15 Diam20 TêteBle
- CO_DiaDBs Vt15 Diam20 TêteJau
- CO_DiaDBs Vt15 Diam20 TêteRos
- CO_DiaDBs Vt15 Diam20 TêteVer

Hide exercises already done

Comment

Test/Exercices to do

Options

Hide (background) Random

Draw mouse position

Repetitions : 1

Interface : Mouse type

Cancel Start

Add >>

<< Remove

Figure 3.: Selection of an exercise to start a test (screenshot). The definition of exercise names considered the parameters of the exercises, *i.e.* click/touch + trajectory/direction/position + speed + target size + target image.

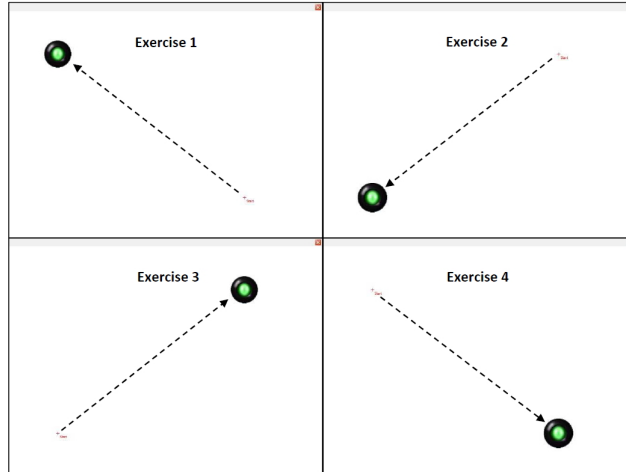


Figure 4.: A description of four minimalist exercises.

the test and describe the handling of the pointing interface in the current version of PLEIA (see Table 1 and Step 3 in Fig.6). The indicators can be divided into three classes as follows:

- temporal indicators, *e.g.* reaction time (*i.e.* the delay from the start of the exercise to the first movement of the cursor), duration of the approach path, duration of the adjustment on the target, duration of the implementation of the click, etc;
- trajectory of the pointer, *e.g.* its distance, shape and orientation;
- operations on the device such as type of command, order of operations, number of pauses, regularity of the cursor movement, etc.

These measurements can be carried out on more or less complex tasks according to the predefined scenario. For example, the exercise may only require reaching the target to select it or, on the contrary, require "clicking" on a certain number of ordered targets while avoiding obstacles. In particular, they allow us:

- to accurately qualify motor, cognitive and perceptual skills of patients when they use a pointing interface to designate a target,
- to analyze the impact of neuro-visual and attentional disorders by adding distractors in the Windows environment during patients' reaction time,
- to evaluate the evolution of the use of a pointing interface in the short, medium and long term,
- to quantify the functional impact of a therapeutic action (*e.g.* installation, displacement or adaptation of the interface, use of medicines or injection of botulinum toxin) on the use of the interface.

4. Performing quantified comparative tests using PLEIA

By performing quantified comparative tests, the interest is twofold. Firstly, it brings a direct aid for choosing the most suitable interface during the assessment of the pointing task (see the case 1 in Section 5). This is because comparative tests can help us to objectify the recommendation of a pointing interface and the settings of the computer and its environment by analysis and comparison of performance indicators. Secondly,

N	Indicator	Definition	Unit
1	Total Time	Total test time from start (press start button) to end (reached or clicked last target)	ms
2	Reaction Time	Time between test start and user's first action on his pointing device to move the cursor	ms
3	Action Time	Time during which the user is using his pointing device = (Total Time - Reaction Time - Pause Time)	ms
4	Pause Time	Total time during which the pointing device's cursor does not move after starting the action. The pause time excludes the last pause, which is the last stop before final click	ms
5	Pause Ratio	Pause time divided by action time	%
6	Pause Number	Number of stops during test time	
7	Adjustment Time	Time between arrival to target (first time) and stopping the windows cursor	ms
8	Click Time	Time between stopping windows cursor on the target and clicking validation button on the pointing device	ms
9	Total Click Time	Time from entering the final target and clicking on it. It is equal to (Adjustment Time + Click Time)	ms
10	Fixed Speed Ratio	Ratio between time cursor is moving with fixed speed (no change of action to pointing device) to total test time	%
11	Discontinuity Ratio	Ratio between the pause time and the total test time. With more stops, the discontinuity goes up	%
12	One Way Motion Ratio	Ratio between movement time in one direction only (x or y axis) and total time	%
13	Efficient Motion Ratio	Ratio between effective movements approaching target and total movements	%
14	Efficient Action Ratio	Ratio between effective actions approaching target and total actions	%
15	Efficient Fixed Speed Ratio	Ratio between effective time cursor is moving with fixed speed (approaching target) to total time where cursor is moving with fixed speed	%
16	Total Distance	Total distance cursor moved during a test	Pixel
17	Adjustment Distance	Distance between arrival to target and stopping the windows cursor. It is the distance traveled by the cursor during Adjustment Time	Pixel
18	Mean Approach Distance	Average amplitudes of cursor movement (constant or variable speed) during the approach path. That is to say before the first entry into the target	Pixel
19	Total Approach Distance	Total approach distance during a test	Pixel

Table 1.: 19 performance indicators in the current version of PLEIA.

it also brings an indirect aid for objectifying the effects of therapeutic actions (see the cases 2 and 3 in Section 5). Following a therapeutic action (rehabilitation, equipment, modification of posture, medication, etc.), the functional impact on computer use can be measured. Thus, the comparative tests, before and after the therapeutic action, can help to validate the continuation, discontinuation or establishment of a therapeutic window with respect to a treatment.

There is a strong interaction between these two types of aid (see the case 4 in Section 5). The use of a pointing interface and/or computer settings influence the motor skills and posture of patients in the more or less long term. An improper use can cause pain and fatigue. As a result, orthopedic deformities can be caused and gradually disable their functions in the long run, thereby reducing their autonomy.

In summary, rehabilitation treatment, use of equipment or proper medication can induce variations in the ability to use computer tools. It is therefore necessary to measure these changes and to propose adjustments according to the different activities and contexts where patients use computer tools, *e.g.* place of leisure, school and so on. The next section will show that the behaviours analysis obtained under PLEIA allows us to predict the patients' efficiency and motor skills with the proposed interfaces.

4.1. Protocol developed for tests

We have voluntarily restricted the use of PLEIA for performance evaluation or objective selection of pointing interfaces, their installation and configuration. It can undoubtedly be used to measure other skills, such as attentional or neuro-visual abilities. We created two types of scenarios for our tests:

- Scenario 1: it is a fun scenario for children.
It is presented in the form of a mission that they have to accomplish on the computer. During the handover, we make the child forget the evaluation situation in the game, so the test is carried out in a more ecological way (see Fig.5).
- Scenario 2: it is intended for adults.
It includes a series of classic exercises (see Fig.4).

The two types of scenarios are designed with the functions available in the PLEIA software. They have the same test structure: firstly, a starting point should be linked to a diagonal target. Next, the two diagonals will be made in both directions. In total, there are 16 diagonal cursor movements to be performed to validate the target with a click. The exercise begins when the starting point appears on the screen, then the participant should connect it to the target by moving the cursor and "clicking" on it. Finally, the exercise is finished when the target was clicked. All of the scenarios (form of exercises and procedures) can be directly configured by an occupational therapist.



Figure 5.: Test carried out with a play scenario (Scenario 1) at the Hospital of Saint-Maurice: "The aliens stole the light from the stars. Today, your mission with your friends is to give them light. Do you accept this mission?"

4.2. *Statistical analysis*

To compare the results of any two tests, the statistical analysis process using PLEIA is described in Fig.6. There are 4 steps in all. In Step 1 and Step 2 we can determine two groups of data to be compared by choosing the name of user, the type of exercise, and the test number that denotes the time of test. As presented in Section 3.2, the current version of PLEIA can offer 19 performance indicators for every test. However, considering the users may have different disabilities or their exercise types are different, not all the same indicators might be chosen in Step 3.

Next, to determine whether there is a significant difference between one configuration and another, the arithmetical mean of performance indicators is not sufficient. It is necessary to carry out a statistical study, without which it is impossible to exploit the results. We can export the PLEIA test results to certain analysis tools directly, *e.g.* EXCEL. However, for a layperson, it is difficult to choose and use adequate sta-

tistical tests. The knowledge of the variance (Fisher’s Test)⁵ allows us to select a parametric or non-parametric statistical test⁶. The latter can check whether there is a significant difference in the means. In order to do that, we chose a significance level of 5% ($p < 0.05$). According to the demand of our occupational therapy team, PLEIA has been added with installable statistical data analysis tools, such as Fisher’s Test, Student’s Test and Wilcoxon Signed-Rank Test. Occupational therapists will thus be able to choose what they want to study from indicators and exercises, as shown in the Step 4 of Fig.6.

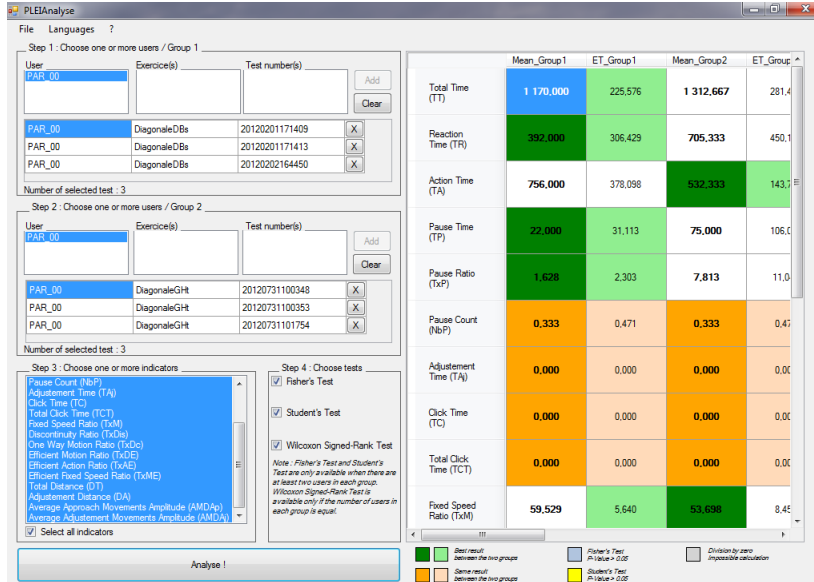


Figure 6.: Statistical analysis of the data in PLEIA (screenshot)

5. Experiments and discussions

In order to verify whether PLEIA can help to objectify the recommendation of a pointing interface or objectify the effects of therapeutic actions on computer use, the test results of four different clinical cases using PLEIA will be analyzed in this section. These cases are representative of the needs and practices of therapists. By using the statistical analysis interface shown in Fig.6, we will verify if there exist significant differences in several performance indicators to help therapists to make a conclusion for every clinical case. The corresponding research activities are as follows:

- compare the use of a mouse and then a trackpad of the laptop to choose a more suitable interface (case 1 in Section 5.1),
- compare the use of the joystick before and after 10 days of the botulinum toxin injection to determine its functional impact on the movements of the user (case 2 in Section 5.2),

⁵Fisher’s Test is a statistical test which makes it possible to test the equality of two variances (*e.g.* comparison of the dispersion of two groups or two sets of tests of the same person). Variance is a measure of the degree of dispersion of a set of data.

⁶Parametric statistical test is selected when the data comes from a parametrized distribution (equal variances), and non-parametric statistical test makes no assumption about the underlying distribution of the data.

- compare the use of the joystick before and after an oral treatment of Artane to determine its functional impact on the movements of the user (case 3 in Section 5.3),
- compare the use the joystick with the left and right hand to determine the more effective hand for the use of joystick (case 4 in Section 5.4).

Details are given in the following sections.

5.1. *Clinical case 1: Direct aid for choosing a more suitable interface*

Participant: L, 7 years old.

Type of disability: Cerebral palsy, *i.e.* alternating hemiplegia and motor regulation disorders.

Test scores using different classification systems:

MACS ((Eliasson et al. 2006)): 2,

House ((House et al. 1981)) : 7,

GMCS ((Palisano et al. 1997)): 2.

Context: Until now L uses regularly the trackpad of his laptop.

Objective: Accurately determine a more efficient pointing interface. This is a direct help in choosing the interface in the place of play and school.

Test⁷: 16 diagonals, target diameter is 20 mm and speed of cursor movement is set to 10.

Comparison: Use of a mouse and then a trackpad of the laptop in 12 exercises under the same conditions.

Analysis:

1) Fig.7 compared 7 temporal indicators (TI) of Case 1 using mouse and trackpad, it shows that there were statistically significant differences in certain indicators summarized as follows:

- Total time: 3.36 times faster to perform the exercise with the mouse than with the trackpad,
- Pause time: 6.83 times fewer pauses (time of pauses greater than 100ms) were recorded during the cursor movement with the mouse than with the trackpad,
- Adjustment time: 6.56 times faster to adjust the posture from the time L reaches the target until L clicks on it with the mouse than with the trackpad,
- Click time: 5.29 times faster to press the click of the mouse than to press that of the trackpad.

2) Fig.8 compared 4 indicators of the cursor's displacement (DI) using mouse and trackpad. It shows that there were statistically significant differences in certain indicators such as:

- Total distance: 1.89 times less distance travelled with the mouse than with the trackpad,

⁷A Hewlett Packard 8540p Laptop Computer with a 15.6inch display was used in the tests. Its resolution was chosen as 1024x768. A target size of 20 mm in diameter means a width of about 59 pixels and a height of about 78 pixels. The cursor speed can be configured in Windows from Slow to Fast. We set it in a middle position and its value is 10.

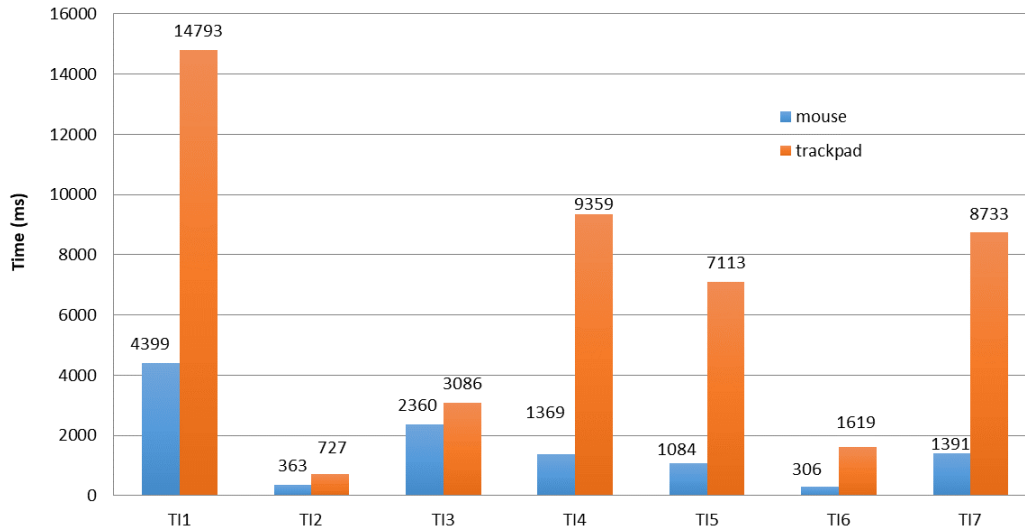


Figure 7.: Comparison of temporal indicators (TI) of Case 1 using mouse and trackpad, where TI1: Total time, TI2: Reaction time, TI3: Action time, TI4: Pause time, TI5: Adjustment time, TI6: Click time, TI7: Total click time.

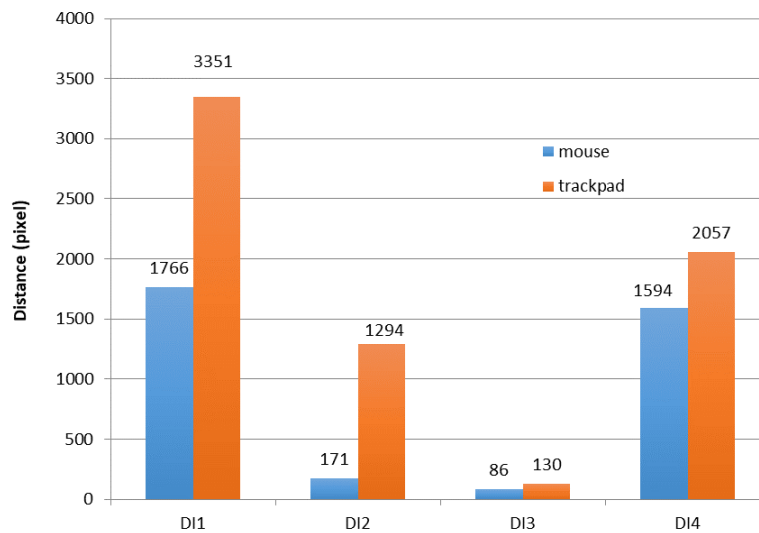


Figure 8.: Comparison of indicators of the cursor's displacement of Case 1 using mouse and trackpad, where DI1: Total distance, DI2: Adjustment distance, DI3: Mean approach distance, DI4: Total approach distance. The default unit of measurement is pixel.

- Adjustment distance: 7.56 times less distance travelled from the time **L** reaches the target until **L** clicks on it with a mouse than with a trackpad.

3) Fig.9 compared the pause number of all the 12 exercises using mouse and trackpad respectively. Overall, the results show that the participant **L** has fewer pauses (time of pauses greater than 100ms) with the mouse than with the trackpad. It also means that the participant has smaller discontinuity rate, *i.e.* less variations in speed with

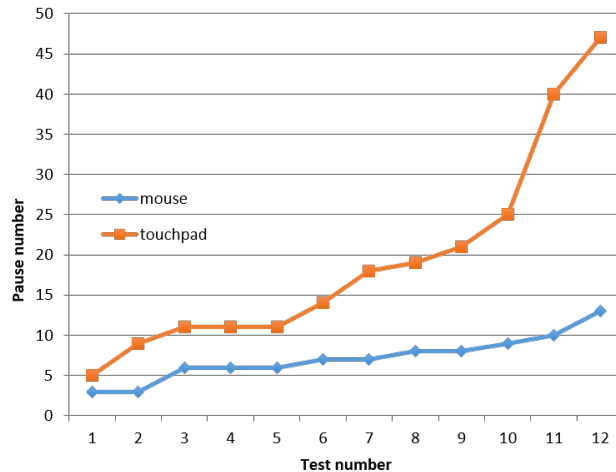


Figure 9.: Comparison of pause numbers of Case 1 during the 12 exercises using mouse and trackpad, where the data of the two groups are rearranged in ascending order respectively, so the test numbers noted in X-axis is not the real order of the exercises.

the mouse than with the trackpad.

Conclusion for clinical case 1: When the speed of the pointer movement is set to a median speed, **L** is more effective with the mouse than with the trackpad adapted to the size of his hand. This result confirms the occupational therapist’s clinical observation and also follows the advice of **L**’s teachers and parents.

5.2. *Clinical case 2: Indirect aid for objectifying a therapeutic action*

Participant: **M**, 5 years old.

Type of disability: Cerebral palsy and quadriplegia.

Test scores using different classification systems:

MACS ((Eliasson et al. 2006)): 4,

GMCS ((Palisano et al. 1997)): 4.

Context: **M** uses regularly a joystick (Penny and Giles roller plus) for study and leisure activities with the right hand in a bending position, thus the wrist is moved in ulnar deviation which leads to orthopedic risk.

Objective: Accurately determine the functional impact on the use of the joystick before and after injections of botulinum toxin in the muscles such as pronator teres, flexor carpi radialis muscles, and adductor muscles of the thumb.

Test: 16 diagonals, target diameter is 20 mm and speed of cursor movement is set to 10.

Comparison: Use of the joystick before and after 10 days of the botulinum toxin injection before specific rehabilitation.

Analysis:

1) For the temporal indicators, the participant **M** browses no significant difference before and after 10 days of the botulinum toxin injection, as shown in Fig.10.

2) For the indicators of the cursor’s displacement, Fig.11 shows that there were

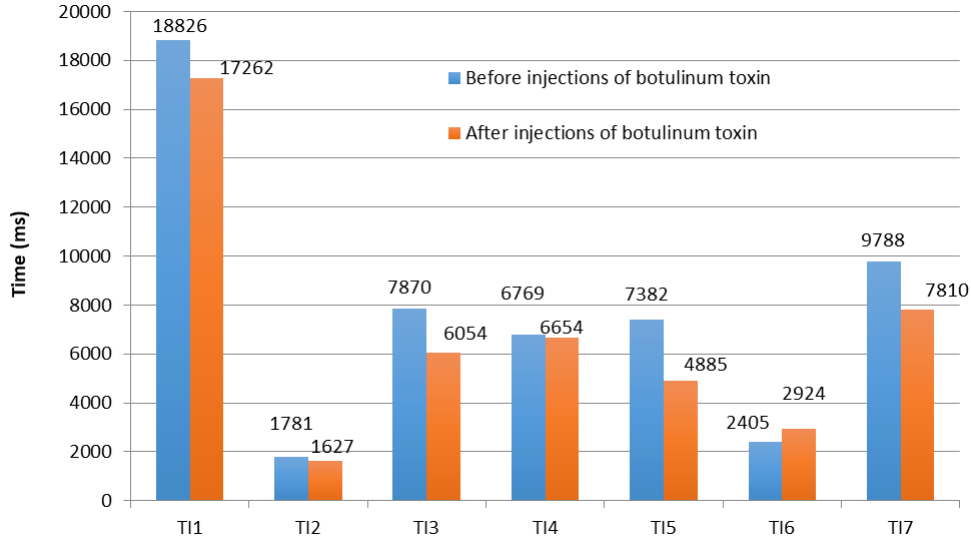


Figure 10.: Comparison of temporal indicators (TI) of Case 2 before and after the injections of botulinum toxin, where TI1: Total time, TI2: Reaction time, TI3: Action time, TI4: Pause time, TI5: Adjustment time, TI6: Click time, TI7: Total click time.

statistically significant differences in certain indicators summarized as follows:

- Total distance: 1.46 times less distance travelled after the botulinum toxin injection than before,
- Adjustment distance: 4.08 times less distance travelled from the time **M** reaches the target until **M** clicks on it after the botulinum toxin injection than before.

3) Overall, the participant **M** has fewer pauses after the botulinum toxin injection than before, as shown in Fig.12.

Conclusion for clinical case 2: Ten days after the botulinum toxin injection, **M** can better regulate the movements than before. In particular, the movements are more fluid and more efficient than before. In addition, the trajectory of the cursor is more direct so the orthopedic risks can be minimized. A video-based evaluations of his occupational therapist corroborated the measures of PLEIA. The clinical observation about the improvement of the hand's orientation has a positive functional impact, which was objectified by the statistical results.

5.3. *Clinical case 3: Indirect aid for objectifying a medical treatment*

Participant: **B**, 11 years old.

Type of disability: Cerebral palsy and quadriplegia.

Test scores using different classification systems:

MACS ((Eliasson et al. 2006)): 4,

GMCS ((Palisano et al. 1997)): 4.

Context: **B** uses regularly a joystick (N'abler) for study and leisure activities with the right hand.

Objective: Accurately determine the functional impact on the use of the joystick before and after an oral treatment of Artane.

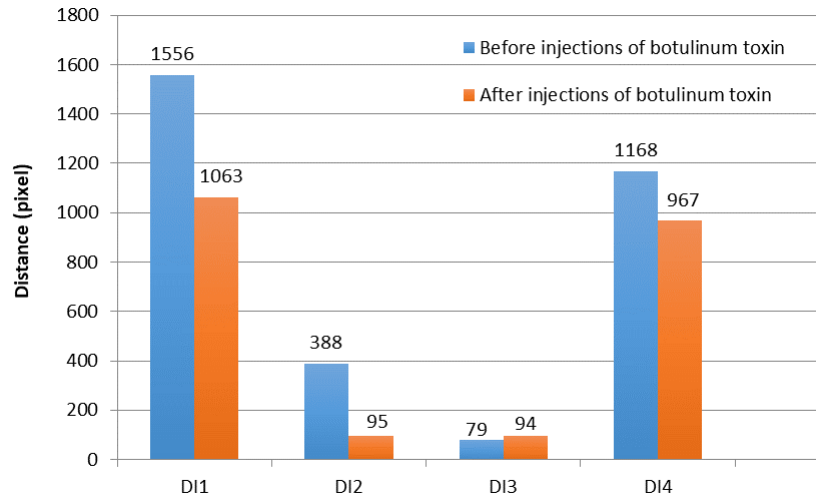


Figure 11.: Comparison of indicators of the cursor's displacement of Case 2 before and after the injections of botulinum toxin, where DI1: Total distance, DI2: Adjustment distance, DI3: Mean approach distance, DI4: Total approach distance. The default unit of measurement is pixel.

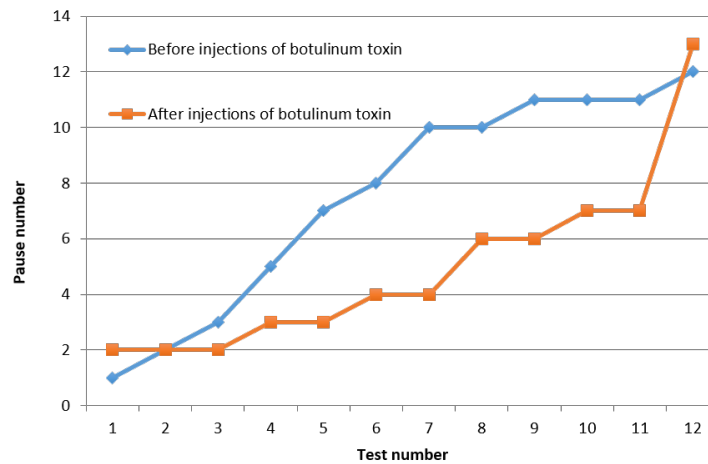


Figure 12.: Comparison of pause numbers of Case 2 during the 12 exercises before and after the injections of botulinum toxin, where the data of the two groups are rearranged in ascending order respectively, so the test numbers noted in X-axis is not the real order of the exercises.

Test: 16 diagonals, target diameter is 20 mm and speed of cursor movement is set to 10.

Comparison: Use of the joystick before and after an oral treatment of Artane under the same conditions.

Analysis:

1) For the temporal indicators, Fig.13 shows that there were statistically significant differences in certain indicators such as:

- Total time: 2.09 times slower after the oral treatment than before,
- Action time: 2.01 times slower during the cursor movement after the oral treatment than before,
- Click time: 2.88 times slower to activate the click after the oral treatment than before.

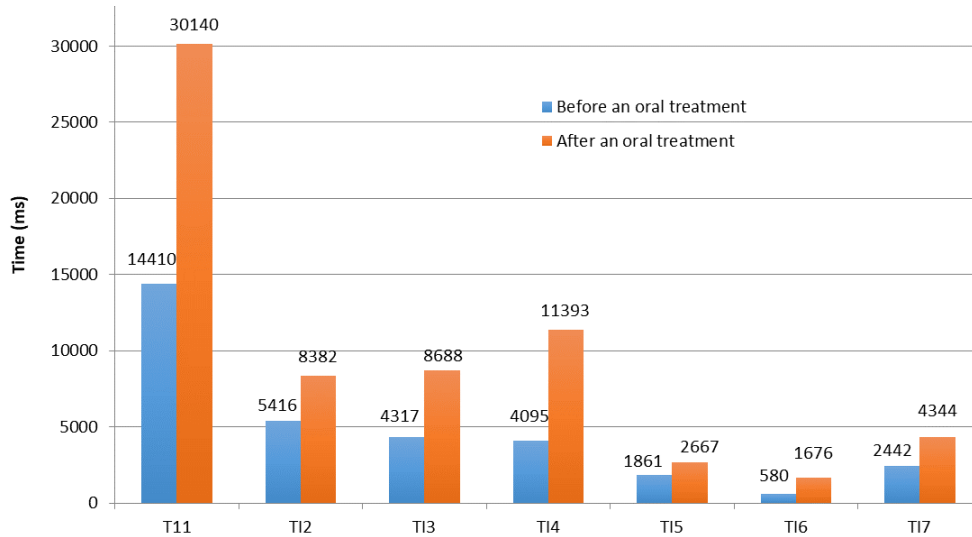


Figure 13.: Comparison of temporal indicators (TI) of Case 3 before and after the oral treatment of Artane, where TI1: Total time, TI2: Reaction time, TI3: Action time, TI4: Pause time, TI5: Adjustment time, TI6: Click time, TI7: Total click time.

2) For the indicators of the cursor's displacement, Fig.14 shows that there were statistically significant differences in certain indicators such as:

- Total distance: 1.62 times more distance travelled after the oral treatment than before,
- Total approach distance: 1.67 times more distance needed to approach the target after the oral treatment than before.

3) The participant **B** has more pauses after the oral treatment than before, as shown in Fig.15.

Conclusion for clinical case 3: Under the same conditions, the comparison of the use of the joystick in PLEIA before and after the oral treatment shows negative functional repercussions. With an oral treatment of Artane, the movement of **B** is much slower and the trajectories are of poorer quality than without that. This confirms the impression of **B**'s mother, who expressed **B**'s state of fatigue since the implementation of the oral treatment of Artane.

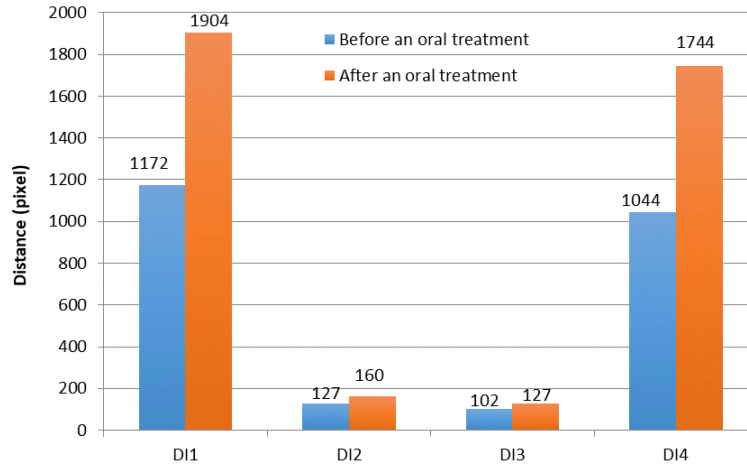


Figure 14.: Comparison of indicators of the cursor's displacement of Case 3 before and after the oral treatment of Artane, where DI1: Total distance, DI2: Adjustment distance, DI3: Mean approach distance, DI4: Total approach distance. The default unit of measurement is pixel.

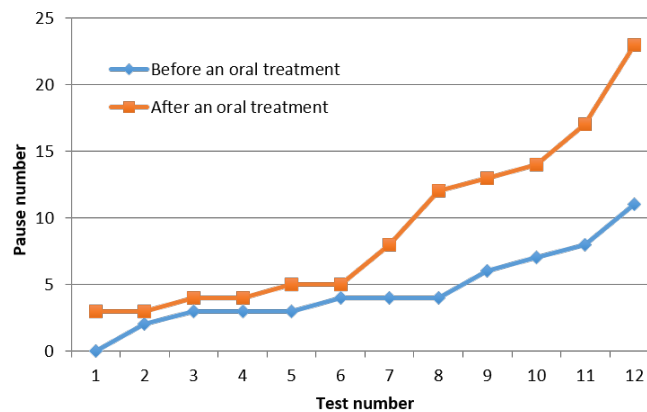


Figure 15.: Comparison of pause numbers of Case 3 during the 12 exercises before and after the oral treatment of Artane, where the data of the two groups are rearranged in ascending order respectively, so the test numbers noted in X-axis is not the real order of the exercises.

5.4. *Clinical case 4: Direct and indirect aid for objectifying the more effective hand to use a joystick*

Participant: A, 7 years old.

Type of disability: Genetic anomaly with extra pyramidal syndrome.

Test scores using different classification systems:

MACS ((Eliasson et al. 2006)): 2,

GMCS ((Palisano et al. 1997)): 4.

Context: A uses a joystick (Penny and Giles roller plus) with the two hands alternately for study and leisure activities.

Objective: Determine the more effective hand for the use of joystick.

Test: 16 diagonals, target diameter is 20 mm and speed of cursor movement is set to

10 on the joystick.

Comparison: Use the joystick with the left and right hand respectively while it is being placed in the extension of the hand used.

Analysis:

1) For the temporal indicators, Fig.16 shows that there were statistically significant differences in certain indicators such as:

- Action time: 2.08 times faster to move the cursor to the target with the left hand than with the right hand (it is the measurement of the delay between the first action of the user and the last immobilization for the click action by subtracting the breaks),
- Click time: 1.40 times faster to press the click button with the left hand than with the right hand (it is a period from the moment, at which the user immobilizes the cursor and stops the cursor for the last time, to the moment of his click action).

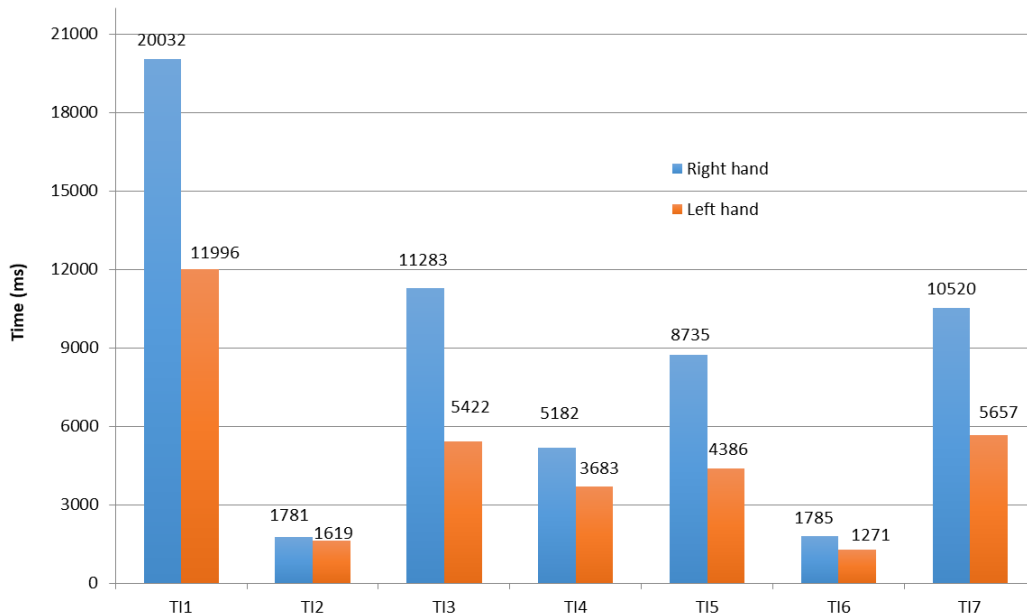


Figure 16.: Comparison of temporal indicators (TI) of Case 4 using the joystick with the left and right hand, where TI1: Total time, TI2: Reaction time, TI3: Action time, TI4: Pause time, TI5: Adjustment time, TI6: Click time, TI7: Total click time.

2) For the indicators of the cursor's displacement, the participant **A** browses no significant difference with the two hands, as shown in Fig.17.

3) The participant **A** has fewer pauses with the left hand than with the right hand, as shown in Fig.18.

Conclusion for clinical case 4: The movement of the participant **A** is faster with the left hand than with the right hand when the Penny and Giles roller plus joystick is used. This joystick was selected by **A**'s therapist previously. Since the abnormal

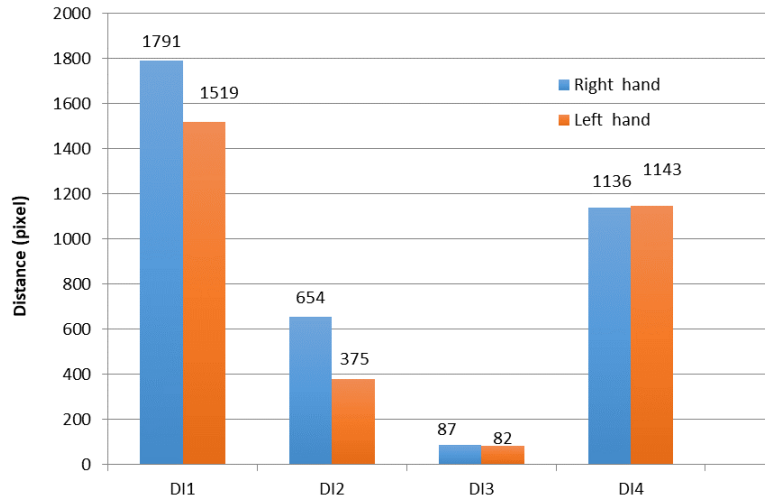


Figure 17.: Comparison of indicators of the cursor’s displacement of Case 4 using the joystick with the left and right hand, where DI1: Total distance, DI2: Adjustment distance, DI3: Mean approach distance, DI4: Total approach distance. The default unit of measurement is pixel.

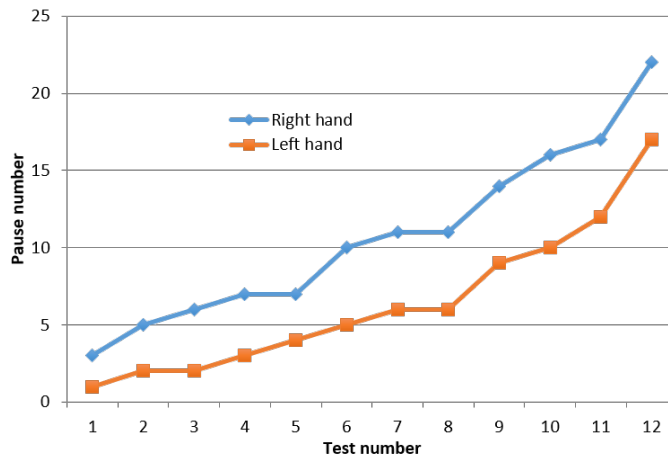


Figure 18.: Comparison of pause numbers of Case 4 during the 12 exercises using the joystick with the left and right hand, where the data of the two groups are rearranged in ascending order respectively, so the test numbers noted in X-axis is not the real order of the exercises.

movements of the upper limbs of the child are very random, the clinical analysis did not allow occupational therapists to favour an upper limb in this type of activity. However, using PLEIA helped them choose the more effective hand to use the pointing interface.

6. Conclusions and future work

In this paper, we present a free and open measurement software PLEIA. It provides occupational therapists with a set of functionalities and tools allowing them to build a specific evaluation process with graduated difficulties, and for different patients. It can be of great help to therapists in their recommendations. The evolution of supply and rehabilitation techniques leads us to think that occupational therapists now should complete their clinical views with quantifiable analysis tools and objectify the functional repercussions of their therapeutic actions. Training for the purpose of learning to use computer tools and/or rehabilitation of movement can now be registered and graduated in difficulties. The results obtained by a treatment and/or a rehabilitation can be maintained by regular use in daily life. Thus, the quantitative objectification of maintaining performance can be an argument whether or not to renew a treatment.

This software still has some limitations. First, the recordings of performance measurements are carried out through a recreational test situation but not yet possible in a continuous ecological situation. Second, as in many studies, current statistical analysis allows data to be analyzed only when there are significant differences among their means. It is therefore necessary to study and compare further the data to make a choice. In addition, PLEIA allows us to carry out a longitudinal study to quantify the learning of pointing interfaces use, but it does not allow us to prejudge in advance the possible learning of the use of one interface compared to another, since it is a question of performance measurements at a given moment. However, it allows us to compare the tests that are carried out on different dates or under different conditions.

In some cases, the PLEIA software tool expresses the inconsistency of the patient's results. For example, the movement of a patient will be faster with one interface but more precise than with another. It will be up to the therapist to choose the most appropriate tool as a whole or to equip the patient with several interfaces, which depends on the task to be performed. In order to better understand patients' problems and thus guide the therapeutic actions of the occupational therapist, PLEIA should allow us to classify the behaviours of people with different levels and forms of their disabilities. This may give rise to new studies. The subject thus modelled could lead to the development of new pointing interfaces and adapted environments.

This software PLEIA has been referenced by the Agency for the Protection of Programs. It has been available to health establishments for free of charge. Thus, the collaborative network created will allow the evolution of the software and the enrichment of its database and common knowledge. The development of PLEIA follows an open approach in collaboration with partner users. It will also follow the evolution of technological advances. For example, a version of the tablet software has been developed. In order to do all of this, the partnership between health professionals and technologists needs to be continued and further diversified. This collaboration is essential for the adaptation of new technologies for people with disabilities.

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8. Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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