Innovative mechatronic system for testing laterality

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Abstract. The paper presents the construction and operation of a mechatronic system for determining and improving the reaction rate and the dominance of cerebral hemispheres, in order to reduce imbalances between left and right laterality and increase the selective reaction rate to visual stimuli. The mechatronic system consists of an experimental platform and tailor made software that runs on a personal computer (PC) or notebook. The mechatronic system is an innovative one, as there aren't any devices to determine laterality and improve the reaction rate on the left / right side.

1 Introduction

Testing laterality is a challenge for researchers, because there aren't devices or equipment for it. Most tests are based on observation, on the execution of current activities or on questioning subjects. It seems that being left-handed or right-handed has biological and physical causes. The human brain consists of two hemispheres, the left and right. The right hemisphere is the place where emotions, intuitions are emerging. It controls the motor functions of the left side of the body. The left hemisphere is the space of language and logic but manages the right side of the human body. The latter is prevalent in everyday life, in relation to the right hemisphere functions.

Left-handed can be educated to use the right hand, but the question is if the benefits of such action outweigh the disadvantages that may occur. All these manifestations are usually called the opposite of laterality [1].

The laterality opposite phenomena is relatively common in sports since most branches of sport necessarily require the development of sensory-motor skills for both dominant half and for the contralateral side. The laterality issue has been studied by many authors, but there wasn't a way to estimate, to explain or test it to be universally accepted. There are tests based on observation, tests based on questionnaires, exercises for laterality education like Ozeretski - Guilmmain spatial orientation test - Piaget Head, Harris laterality test, laterality battery of Galifret - Granjon [2-7].

The mathematical models designed to explain the laterality prove to be narrowed, because a lot of empirical factors and coefficients were considered [8, 9]. Predilections for left hand and its consequences have been the subject of research [10]. Some authors have attempted to discover the gene responsible for the dominance of cerebral hemispheres [11,

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12], others have tried to reveal if there is a connection between laterality and cognitive development [13], while others were concerned about the advantages and of asymmetry [14, 15].

The frequency of polymorphisms in relation to the use of the right hand or left hand was another topic of scientists [15]. Some authors have studied by different means the evolution of brain lateralization [16], or have tried to estimate the life expectancy of left-handed and right-handed [17], together with the differences in performance of some usual movements [18].

2 Description of the mechatronic system

The idea of a mechatronic system for assessing and improving the speed rate and the dominance of the cerebral hemispheres, emerged from an existing system called Batak used to improve the reaction and hand eye co-ordination [19].

A presentation of the mechatronic system was made by the first author of the paper, in his habilitation thesis [20]. So, as it is presented in the habilitation thesis, the use of this device will render the possibility to reduce imbalances between left and right laterality and to increase the selective reaction rate to visual stimuli, thus becoming an important tool for testing laterality and for the rehabilitation of disabled persons.

The mechatronic system consists of experimental platform and specially designed software that runs on a personal computer or notebook. A USB cable connects the platform and the computer.

The mechatronic system consists of the following elements:

- a) A set of 13 smart buttons. Each button contains a comeback contact (operated by touch), a light source with selectable intensity and color (red, green, blue or combinations thereof) and an electronic circuit that automatically turns off the light source when the button is pressed;
- b) A mechanical structure for positioning and support frame for the smart buttons. The support structure is in the shape of a regular octagon with 0.6m apothem. The smart buttons are placed according to a suitable schema;
- c) An electronic circuit with microprocessor that connects the smart button to the computer. The microprocessor contains a tailor-made program for this application which performs the following functions: allows multiple pre-programmed sets of exercises, some containing a fixed sequence (repeated) of buttons and colors, some with completely random order; receives the code of the test to be run from PC; allows offline exercises for demonstration purposes, or as individual training or as warming game; activates a light source for each smart button; measures the reaction time since light activation to pressing the button; disables the button and moves to the next combination of buttons and lights, if a button has not been pressed for 2.5seconds;transmits the following information to the application: code button, the hue of light used and the reaction time measured in milliseconds.

3 The operating principles of the mechatronic system

The operating principles are described by the microcontroller and computer software flow-charts. The flowchart for the microcontroller application that will run on the experimental platform is shown in figure 1.

The software is a Java application that provides a user friendly graphical interface which will help to assess the reaction time to visual stimuli of different frequencies and wavelengths.

The PC application flow-chart is shown in figure 2, while sequences marked with *A - *B are presented in detail, see figure 3. The computer software application is based on three major processes: preprocessing, serial communication and processing (Fig. 4).

Fig.1. Microcontroller flow-chart.

Fig.2. PC application flow-chart.

4 The implementation of the mechatronic system

The purpose of testing using the mechatronic system is to reduce imbalances between the cerebral hemispheres, to increase the reaction speed to visual stimuli, and to increase the selective response speed to stimuli of different colors.

Several categories of athletes, children and people with neuromotor deficiencies are targeted. As general population is right-handed, imbalances between the two hemispheres of the brain are widening and some activities controlled by nerve centers of a hemisphere can be performed more slowly or cannot be performed simultaneously with other activities [21]. The complexity of everyday life requires the softening of these imbalances and therefore such a test is appropriate only if followed by an individualized training program.

For the athletes category different meanings on laterality are developed, but all of them take into account all the sports [22].

It is possible to design programs to improve performance, especially for athletes, people with slight disabilities caused by psychomotor disorders and children. Thus, it appears that some left-handed athletes are more advantaged during direct competition (i.e. boxing, sword, floret, tennis and table tennis etc.).

There are also sports at which being left-handed is an advantage (i.e. darts, snooker, golf) [22]. A clear division of sports in which being left-handed is an advantage cannot be made. What is important is that during competitions the athlete reacts appropriately, anticipates the actions of opponents and takes decisions quickly. Therefore, it is important for athletes to develop their skills on both arms, thus being able to handle many tactical positions on the competition field, in order to adapt to specific situations during competition.

Fig.3. A*-B* sequences flow-chart.

Regarding the children, it is possible to assess laterality only after 5-6 years old, and skills can be educated and directed using games towards the efficient use of both arms and thus to the development of both cerebral hemispheres and the stimulation of all areas of the cerebral cortex. People with slight disabilities can attend training programs to increase the reaction rate.

A friendly interface was designed. See figure 5 which presents the participant’s details and the testing program that is applied. See figure 6 which presents the results of the testing procedure.

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Fig.4. Major processes of PC application.

Fig.5. Interface for participant’s details.

Fig.6. Interface with the testing results.

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5 Conclusions

The experimental mechatronic system is an innovative one, as there are not such devices to determine laterality and improve the reaction rate on the left/right side. The system can be successfully used by athletes, by physiotherapists for recovering individuals which have temporarily lost the upper limb mobility, and for stimulation the children’s brain hemispheres, from an early age.

The system implementation will open new research directions in the evaluation of laterality and study of the neuronal processes that determine the response to stimuli. It is possible to combine the mechatronic system with other devices, in order to determine brain nerve stimuli and muscle reactions controlled by brain nerve centers.

Regarding the experimental research, this will assume a series of tests that will be performed on different groups of subjects: athletes, children and individuals with slight neuromotor disabilities. For each of them, random testing programs will be generated and thus the left / right speed rate to white light stimuli will be assessed.

The software allows the randomly generation of programs with different colored lights (red, blue, white, green). Subjects will be asked to press the buttons with a certain colored light (e.g. only red buttons, or just green and blue buttons, etc.).

The software will allow the generation of reports for these cases, evaluating the left/right speed rate, analyzing in this way also the responses to colored visual stimuli. The data will be statistically analyzed for each testing protocol and initial status reports will be automatically generated. The next step will consist in the development of different training programs using the same mechatronic system.

The training will be customized and adapted to each participant in the experiment. The next step will be the final testing, aiming to track the progress of each participant in the experiment. The participants will be tested in temperature, brightness and noise level limits according to the lab conditions. Subjects will be aware of the experiment protocols and they will be asked to sign an agreement for their participation in the experiment tests. The experiment is non-invasive and does not cause trauma to participants.

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