Virtual Instrument for Screening and Visual Function Recovery for Preschool or Primary School Children

***Abstract*—In the paper there is presented a stage of research in order to improve screening and casuistic procedures, applied in the pediatric field, specific especially for visual function. During the current research phase, a software interface was designed, programmed and tested, aiming both visual screening and its use for recovery procedures, in the case of detected preschool children with visual problems. The procedure by which the answers of preschool children to different tests on visual function can be evaluated is "serious games" type, which should be an attractive one for the child (with different chromatic effects on computer, tablet, smart-phone). etc.). On the other hand, it is intended both to gradually develop the skills related to visual function and to support the doctor or pediatric optometrist in assessing quickly and objectively whether the answers to tests recommend a normal situation or a pathological case that requires treatment. From the point of view of evaluation procedure via virtual instrumentation, two main aspects have been considered: testing and/or training of visual memory, as well as testing and/or training of visual acuity in preschool children, for which visual sense is still developing.**

Keywords—children, screening, virtual instrument, visual

I. INTRODUCTION

Although visual function is the last of the 5 senses that develop in children, it is one of the most important both in terms of assimilation of knowledge and in terms of perception of reality in the external environment [1], [3]. Due to the fact that until the age of 14, the dynamics of visual system development is fast and continuous, the identification and treatment of possible pathologies up to this age is crucial for a normal life both in adolescence and later as an adult [2], [3]. Thus, it can be noticed that, in most cases, without any intervention in time for the visual function recovery, after a certain age, even if this is tried, it will be too late [3], [4], [5].

Until recently, pediatric eye and vision health concerns were not taken very seriously. However, due to the fact that more and more ophthalmologists have signaled the importance of the opportunity to intervene from a very early age in detecting and treating problems with visual or auditory function, the field of pediatric medicine and optometry has gained more and more importance in recent years. Related to the classical means refering to visual function investigation, as modern methods used in both visual screening and pediatric visual training, it have experienced an unprecedented diversification. Also a continuous increasingly effective interdependence between the means and conventional and innovative methods have been achieved. Among the latter, in the case of children, very attractive and effective methods of investigation and training by using the concept of serious games. This involves practicing physical or virtual games that are meant to develop the mind, but also to be able to develop or train more or less any of the 5 fundamental senses [6], [7].

Starting from these aspects, this paper presents a research stage on the development of a methodology with a dual role: to use virtual game tests for visual screening investigations, but also to use them for visual training procedures, as the case. Bots issues refer first of all to preschool and primary school children. In this order, for the development of the testing methodology in screening procedure but also of visual training, the main issue was to concept, to program and to test a software interface. It represents the basis for the development of an assisted complex test (as serious games) dedicated to preschool and primary school children, and can be used both for visual screening investigations and for training and recovery of visual function [9], [10], [11].

II. PROPOSED METHOD

From the point of view of the conception of the interface, it have been considered the following hypotheses: The interface must be easy to use by the medical staff from the pediatric offices, by the school or preschool educators or even by the parents. On the other hand, the test interface must be seen and understood as an interesting and stimulating game for the child, so that he is attracted to solving the tests. For this reason, the interface was designed so that it could be easily implemented on a laptop or tablet, knowing that nowadays the attraction of children to computer and tablet games is very high. In order to present a greater interest for children, in the test-games, as graphic elements it have been considered some items familiar to them (e.g. houses (having different colors and sizes, with different features), which, during the test, the child can observe and remember them) [12], [13], [14].

Reelated to one test example (described in the paper), related to the interface design, the main issue was focused on two aspects, directly associated with the development of the brain and visual function: the first direction refers to testing the child's visual memory, being able to answer a series of questions related to image details displayed in different steps during the test running. The second direction aims to test visual acuity, by checking the convergence and fixation on some details of the images presented in the interface. Related to this aspect, testing is also done by asking questions to which the subject must give an answer [14], [15]. For the testing to be done in a pleasant and fast way from the examiner's point of view (optometrist, pediatrician, educator or parent), the wording of the questions was designed to be a multiple choice type, with 4 answer options, with one or two correct variants. Because assisted testing must be addressed to both primary and preschool children, for the latter category, it was envisaged the following premise: The examiner reads aloud the question and all the answers, the tested child chooses the answer that he considers correct and the examiner is the one who selects in the interface the answer chosen by the child [13], [15].

From the point of view of the test, it must include 2 steps, the first being for testing visual memory, the second for testing visual acuity. At the end of each of the 2 stages, a grade from 1 to 10 must be given, depending on the correctness of the answers, and at the end of the test, the final grade obtained must be displayed. At the same time, depending on the degree of complexity, at the end of the test, its duration must be displayed [14], [15].

Due to the fact that the procedure is aimed for children aged between 5 and 7 years (preschool children) but also those in the primary cycle (aged between 7 and 10 years), it was proposed that assisted testing can be done after 3 levels of difficulty: low difficulty (with a long time allowed to answer questions (3 seconds)), medium difficulty (with a given time of 2 seconds to answer questions) and high difficulty (with a short time allowed to answer questions) (1 second)).

Regarding the programming of this interface for assisted testing, we started with the definition of 5 groups of Boolean LED input variables (two states: turned off / turned on), each group defining the image of a house, each image being different. For each image, more precisely for each group of variables, 4 sub-groups of such variables were defined (the first being related to the house facade, the second to the windows, the third to the doors and the last to the roof). In figure 1 there is presented an example related to the 1st image.

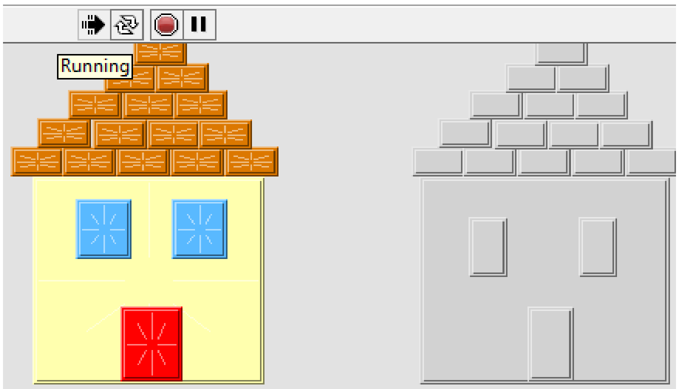

Fig. 1 Example by which, at the beginning of the test run, the activation of the first image takes place, the second one remaining still unactivated

In this context, by activating an image is meant that all Boolean LED entities must light up, thus changing their color, as appropriate. In order for this event to occur successively for all 5 images (in the first stage of the test), a While-Loop conditional structure was programmed, through which, one by one, if one condition is achieved, the activating of the current image must to be done. For example, considering that the While - Loop structure runs continuously until the number of iterations reaches 52, if the current number of iteration *i* is between 0 and 2, then the activation of the first image must take place, if the current number of iteration *i* it is between 3 and 5 then the activation of the second image and the deactivation of the first image and so on must take place. An exameple of this programming sequence is shown in figure 2.

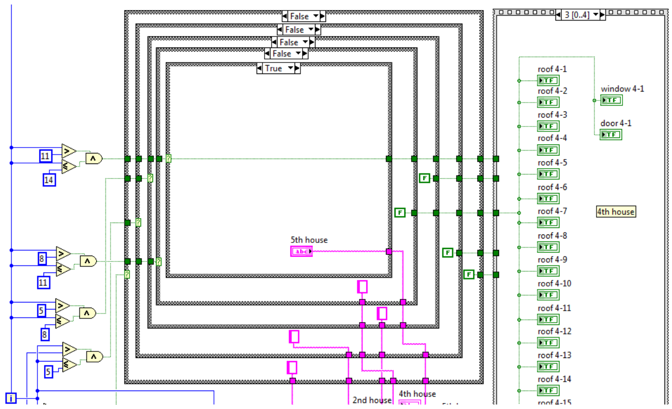

Fig. 2. Example of sequence for programming the order succession for each image activating in the 1st running step

The duration of an iteration is imposed by the degree of difficulty of the test (3 seconds, 2 seconds or 1 second, as appropriate).

The next step for programming was to define an input variable text selective type, through which the used could to select the degree of difficulty of the test. This was related to a *Switch Case* structure, having 3 cases, each one for each degree of difficulty. Another input variables, same type were defined to select the answer for each question for the 1st and for the 2nd step of the test (figure 3).

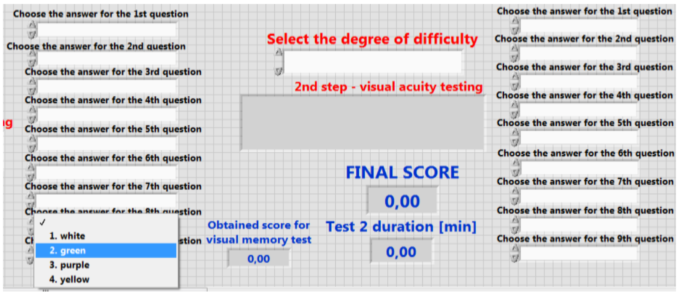

Fig. 3. Displaying the input selective text variables to choose the answer for each question (the left group – for the 1st step (visual memory), the right group – for the 2nd step (visual acuity)

Each type of *Switch-Case* variable programming structure has been assigned, including four cases, one for each response variable.

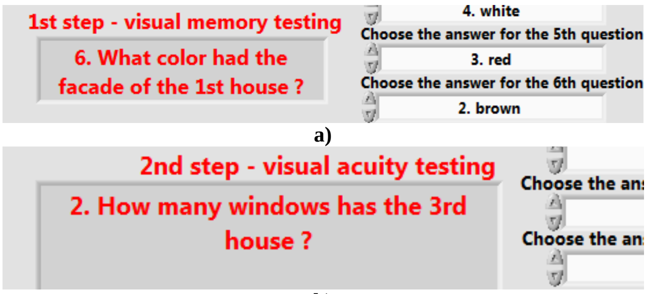

Fig. 4 Text output variables that address the current questions in the two stages of testing; a) the 6th question for the 1st step; b) the 2nd question for the 2nd step

Two output text string variables were programmed, each one to address the current question in the test, which must be answered at that time (figure 4).

Other six numeric output variables were defined to show the intermediary and final results related to the test. Two of them refers to the intermediary times for each stage of testing, other two refers to the obtained scores for each testing stage, one refer to the final obtained score and the laset refer to the total test duration. An overview of theese output numeric variables in the interface context is presented in figure 5.

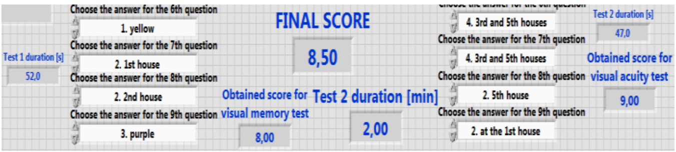

Fig. 5. The six numeric output variables to show all results after test running and solving

Another particularly important aspect in the programming referred to the algorithm for calculating the intermediate scores and the final score, depending on the answers given. For this, in each of the 2 sequences specific to the 2 stages of testing, a multiplexing function of the partial scores awarded for each given answer was programmed, separately (figure 6).

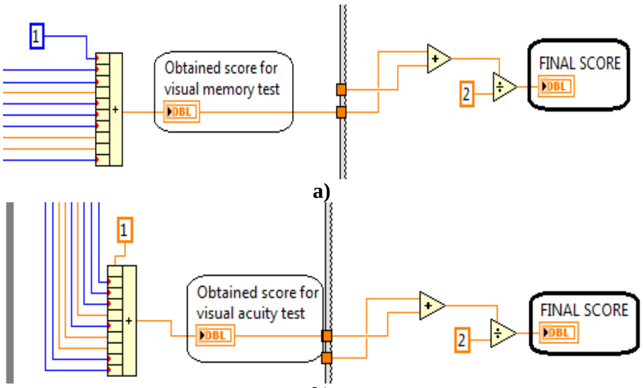

Fig. 6. Example of a sequence specific to the programming of the algorithm for calculating the partial scores and the final score; a) for the 1st step; b) for the 2nd testing step

Depending on the correctness of the answer, the value of the score can be 1 (for a correct answer to a question with only one correct variant, 0.5 (for a correct answer to a question with two correct variants) or 0 (for a wrong answer).

Using the graphical interface, for a test running, the following steps must be completed: selecting the degree of difficulty of the test (depending on the situation (visual screening for preschool children – low difficulty level; visual screening for primary cycle – medium or high difficulty level; visual recovery by training procedure (casuistic situation) – low difficulty in the 1st stage, medium and high difficulty in the next procedure stages)).

In the second stage, the test run is started (using the Run button), after which for the visual memory test the five images that follow one after the other must be followed with maximum attention. After that, each question in the first group, specific to the visual memory test, must be answered in turn. After completing the first test stage, the interface will continue to run, displaying the score and duration specific to the visual memory test. Next, the subject will answer each of the specific questions of the second part (specifically for visual acuity testing). At the end, all the necessary information will be displayed, namely the specific score and duration of the visual acuity test, the total score and the total duration of the test (figure 5). Depending on the result obtained and the context in which the test was performed, it is up to the examiner to determine whether the score obtained after solving the test is satisfactory or not.

III. Obtained Results

In order to test the effectiveness of the proposed method of screening and/or assisted pediatric visual training, it was intended to test 2 samples of children (5 preschool children and 5 children in primary school), at least one of whom had certain vision problems.

However, due to the Coronavirus pandemic, so far the feedback of the proposed method could be observed being tested on a single subject, aged 10 years, who is emetropic, male and has no vision function or visual memory problems.

The testing of the method could be done by applying some simulations on the subject in question, this being tested after the 3 degrees of difficulty, in 4 different hypostases as follows: test under normal conditions, test by induction of a + 3DS myopia in the right eye, test by induction of a myopia of + 3DS in the left eye, test by induction of a myopia of + 3DS in both eyes. For each degree of difficulty, three tests were performed. In Table 1 there are presented the results for the testing in normal conditions (without inducing any refractive error).

TABLE I. Testing results for normal situation

Obtained scores for:	Degree of difficulty		
	Easy	***Medium***	***Difficult***
visual memory testing	9.33	8.83	6.33
visual acuity testing	10	9.5	10
final obtained score	9.67	9.17	8.17

In this situation it was found that due to the high degree of difficulty, the tested subject encountered the biggest problems when testing visual memory, being difficult to fix the successive images with a much higher frequency.

For the stage, in which, on the subject in question, a myopia of + 3DS was simulated in the right eye, after testing on all 3 degrees of difficulty, the following results were obtained, summarized in table 2.

TABLE II. Testing results for simmulated myopia of +3DS, right eye

Obtained scores for:	Degree of difficulty		
	Easy	***Medium***	***Difficult***
visual memory testing	7.33	6.33	5.5
visual acuity testing	7.83	8.5	7.5
final obtained score	7.58	7.42	6.5

The tests were performed similarly with the first situation. In this case it was found that decrease in the averaged obtained score was 20.37% and for the highest degree of difficulty it was 20.44%. Also in this case it was found that the subject encountered the biggest problems in the visual memory test, due to the high degree of difficulty.

For the simulated myopia of +3DS on the left eye, after the similar testing conditions, the results were synthesized into table 3.

TABLE III. TESTING RESULTS FOR SIMMULATED MYOPIA OF +3DS, LEFT EYE

Obtained scores for:	Degree of difficulty		
	Easy	***Medium***	***Difficult***
visual memory testing	6.83	6.83	5.67
visual acuity testing	8.17	7.83	7
final obtained score	7.5	7.33	6.33

It was found in this situation an averaged obtained score decreasing of 21.63%, while the score decreasing for the highest degree of difficulty was 22.51%.

Finally, for the simulated myopia of +3DS, both eyes, after testing, the results were disposed in table 4.

TABLE IV. TESTING RESULTS FOR SIMMULATED MYOPIA OF +3DS, BOTH EYES

Obtained scores for:	Degree of difficulty		
	Easy	***Medium***	***Difficult***
visual memory testing	4.33	2.83	2.67
visual acuity testing	4.5	4.67	2.67
final obtained score	4.42	3.75	2.67

In this case, the score decreasing was of 59.85 % relatively to the normal situation and, for the highest degree of difficulty, it was 67.32 %. It could be noticed, therefore, that, in the case of inducing a refractive error of +3DS in both eyes, the decrease of the obtained score was approximately 3 times higher than in the case of inducing the same myopia in one eye.

IV. CONCLUSIONS

Following this study, so far it has been demonstrated that the proposed method can be very effective in terms of detecting visually impaired children (such as myopia or visual memory disorders), in strategies such as screening through assisted, rapid testing in kindergartens or schools.

Moreover, such an assisted testing method in the context of online education (for example due to pandemics) could be a viable solution, provided that this online visual screening procedure is properly and effectively supervised by to an optometrist or pediatrician.

In terms of feedback related to the application of the procedure in the case (for recovery sessions through assisted visual training), unfortunately, so far it has not been possible to prove to what extent this would be really effective. This was due to the fact that, in the current epidemiological context, it was not possible to identify preschool or primary children having any visual impairments. However, in the case of the subject under test, it could be seen that he was attracted and motivated by this procedure, being considered by him as a dynamic game on a laptop.

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