Virtual Worlds for Serious Applications (VS-GAMES'12)

"LeFCA": Learning framework for children with autism

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Abstract

Teaching children with autism requires special set of tools and methods, due to decreased level of attention towards stimuli presented and lessened capability to learn in the ways typical children do, which is manifested within this population. It has been previously shown that computer-assisted intervention is not only an effective method for developing various skills, allowing both learning with teachers and practicing on their own time without the teacher's direct attention, but it nonetheless increases the motivation and results in faster acquisition of these skills.

In this paper we present the first step in developing the LeFCA framework, that will be used for teaching children with autism basic skills and concepts. Within the pilot project, we produced four games for developing matching, pointing out (based on visual and auditory stimuli) and labeling skills, which are considered to be primary skills needed for learning. The results of our preliminary study showed that the created software in native language is completely clear and user friendly for kids with Autism and other special needs, and that is systematically and developmentally appropriately sequenced for learning. Additionally, we found that children were able to generalize learned skills, through a transfer to a new medium or environment without any needed training (i.e. computer). All four participants mastered all programs without any instructional tactic needed.

Keywords: learning; autism; learn unit; shapes; interaction

1. Introduction

Serious gaming has become an important aspect in several fields, such as education, simulation, health training, cultural heritage and many other. The advantage of using such media is that it exposes users to deeply engaging, visually dynamic, rapidly paced, and highly satisfying experiences, in comparison to conventional teaching methods [1].

Technology has proven to be an effective method of providing students with special needs with opportunities to engage in basic drill and practice, simulations or communication activities that can be matched to their individual needs, levels of functioning and abilities [2, 3, 4, 5, 6]. By reviewing 219 research studies on the effects of technology on learning and achievement, Sivin et al. concluded that the level of effectiveness of educational technology is greatly influenced by the access to technology, student population, software design, and educator's role, [7]. They found that students in technology-rich environments experienced positive effects on achievements in the major subject areas, and increased achievement in preschool through higher education for both general and

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special education populations. Bosseler and Massaro developed computer-animated program for teaching children with autism vocabulary and grammar. They conducted two experiments and found that children with autism are capable of learning new language via automated program with a computer-animated agent and active participation and can transfer and use the language in a natural, untrained environment, which is the key of learning any skill [8].

Computer-assisted interventions give children the opportunity to work on much-needed skills, practice them on their own time, or to be engaged and learning even when teachers cannot give them the direct attention. Other benefits of computer-assisted learning include increased motivation to learn with the use of a computer [9] and potentially faster acquisition of skills than with other types of learning [10]. Preschoolers who use computers have shown better school readiness [11] and increased language and improved social interactions [12] compared with children who do not have computer exposure. Therefore, Haugland recommends that children young as three years old should be introduced to computers [12]. In addition, studies have demonstrated that children with autism may learn more quickly when using a computer than with traditional teaching strategies, and are more interested and motivated to learn through computer-assisted instruction [13, 14]. Unfortunately, until today B&H elementary schools do not use computers as part of their daily instruction, and children are not systematically exposed to any technologies as part of the government curriculum. In special education particularly, computers are not available for students at all.

However, several barriers for implementation and use of the technologies in any classrooms, identified by Hasselbring and Glaser [15], are inadequate teacher training, simply not knowing how to incorporate technology in their teaching activities, and the cost of purchasing and incorporating new technologies in the schools. These barriers are problematic, and they significantly inhibit the use of technology in education, but are not insurmountable if we are aware of them and systematically introduce them to the teachers and the students.

While developing our learning framework, we based the design on the science of learning and Whalen, et al.'s [13] key components for successful computer programs for children:

- Multiple exemplars: several different examples of concepts should be taught (e.g. to teach a concept of an APPLE, you need examples of a red apple, yellow apple, green apple, small apple, large apple, apple on the tree, cut in half, etc.)
- Variety in methods used to teach concepts: different response topographies (e.g. receptive identification, matching, or sorting, selection and production responding)
- On-repetitive trials: repeating the same trial, without multiple exemplars, over and over again may result in memorised responding rather than a generalized response. Each skill needs to be developed or taught through multiple exemplar instruction to a mastery level (90% correct) in order to teach skill which the child can use in different contexts
- Customization: one should be able to adjust, tailor, and customize the program to the child's individual needs.

The plethora of research shows that the basic teaching unit upon which all learning and effective instruction is based is the three-term contingency trial (i.e. the learn unit) [16, 17]. Research suggests that to effectively teach, a teacher or a teaching device (i.e. Skinner's teaching machine [18, 19] or Emurian et al. 's computerized instruction [20]) must consist of particular teacher-student interaction (i.e. the learn unit).

Program we have created for young children in B&H is based on the Learn Unit, an interlocking three-term contingency A-B-C based on the "frames" in Skinner's programmed instruction [18, 19, 21].

Also, it follows Whalen, et al.'s components of successful computer program in education [13]. Each task within the program will have a clear:

- Antecedent: picture and/or auditory direction, requiring student's response (e.g. "Where is the ____? / Find ____ / Which one is ____?" etc.), or
- Behaviour: action from the student to complete the task, response to the antecedent (e.g. clicking on the picture, dragging the picture, etc.), and a
- Consequence / feedback: providing a student with a direct and instant feedback for each correct response and a correction for an incorrect response.

In addition, the score is provided to the student and the teacher at the bottom of the screen throughout the game, and a total score at the completion of the game. Providing a student with a score after completing an online test or a game is common in educational software. However, applications that provide more immediate feedback about the answers student is giving as he/she is completing each individual trial, is found to be better [22].

Samuels and Yi-Chen, found that children in the experimental group who were receiving reading instruction via computer acquired better reading scores then the control group getting live, regular classroom, teacher instruction [23]. We know that immediate feedback increases motivation [18] and facilitates understanding of the relationship between actions and results they produce [24].

In the context of a relatively small investment to build such a software using high spec, low cost software and Internet tools, the potential for promoting the computer based learning and creating a ripple effect far beyond the initial e-learning network is significant. Children in B&H and in the region do not have computer literacy programs as part of their education system. E-learning has been a new concept and teachers are not familiar with incorporating technology in the classroom. Simple self-instructed basic educational software could provide painless introduction of the computer-directed learning and technology as part of the educational and pedagogical process in all schools.

2. Game Development

There is a great collection of literature dealing with game design and development process, proposing various pipelines and methodologies [25, 26, 27, 28]. There are several other models that focus on motivation [29], flow [30], and requirements of an effective learning environment [31]. Based on these, Song and Zhang developed a model for educational game design, proposing the motivation increase through flow [32]. Amanatiadou and van de Weerd argue that game production process is influenced by five factors: hardware, player profile, gameplay, meaning and game world [33]. According to this categorisation, serious games are characterised by the player (i.e. learner) profile, which significantly involves pedagogy in the production process. Considering all of the above and the fact that the target audience are children with autism, a careful design was required.

2.1. LeFCA Learning Framework

Children with autism are all characterised by impaired social interaction and communication, and by repetitive, self-stimulating restricting behaviours. Autistic children show less attention to social stimuli, do not attend to human faces and respond to their name less [34]. The manifestation of all Autism Spectrum Disorders (ASD), which Autism is one of, range from mild to severe impairments. Individuals may be introverted, interested in repetitive solitary behaviours, without any communication or social skills developed to individuals who are using language to communicate, but have unusual social behaviours and understanding of environment. This, in turn, affects greatly the learning style of these children and the type of instruction that produces learning. Attending to educational stimuli or getting students attention is one of the greatest challenges when teaching students with ASD. Computers and technological tools (i.e. communicative devices), have shown great improvements in overall skill development and learning with children with autism [9, 10, 13, 14, 35].

A basic computer software sequence of skills would comprise of the following:

- Mouse use (building up eye and hand coordination skills), or utilising touch-screen technology
- Learning basic concepts: shapes, colours, numbers, transportation, farm animals, wild animals, fruits, vegetables, school items, home items, etc.

Mouse-controlled and touch-screen application should be designed using cause and effect learning. This technique uses a direct manipulation interaction style, where objects and actions of interest are directly visible on the computer screen [36].

Learning basic concepts, assuming mouse or touch-screen use ability, should be implemented through four modes of learning:

1. MATCHING (teaching a concept of sameness):

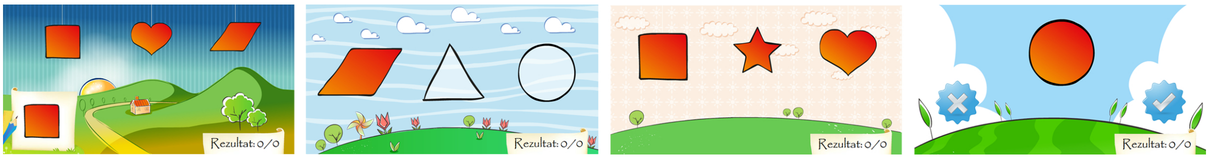

Fig. 1. A screenshot from each of the four games (left to right): *Find the same*, *Which shape does not belong*, *Select the shape heard* and *What is the shape called*.

- Matching identical pictures in the filed of 3 (e.g. red square to be matched in the filed of 1 red triangle, 1 red rectangle and 1 red square)
- Matching non-identical pictures in the filed of 3 (e.g. red square to be matched in the filed of 1 yellow triangle, 1 blue rectangle and 1 red square)
- Matching identical pictures in the field of 5-10
- Matching non-identical pictures in the field of 3 (e.g. red small apple with yellow big apple in the field of 1 apple, 1 plum and 1 pear)
- Matching non-identical pictures in the field of 5-10

2. POINTING OUT/SELECTING
   - Select one that does not belong in a field of 3 to 10 (e.g. red square to be selected in a field of 1 white triangle, 1 white rectangle and 1 red square)
   - Select one that goes together with in a field of 3 to 10 (e.g. the target shape embedded in the field of 3-10 non-target shapes)
   - Select one that matches the sound it makes (e.g. vocal antecedent “triangle” is heard, and the target shape is placed in the field of 3-10 non-targets)
3. SORTING/CATEGORISING
   - What belongs together (e.g. put in the basket all the fruits - click and drag)
   - Basic concrete categories (what we write with, what we play with, what we eat with, etc.)
   - Abstract categories (e.g. numbers, letters, sizes, gender, etc.)
4. PRODUCTION RESPONDING
   - Receptive labeling or producing vocally names of things in the environment. In this scenario a teacher-student or student-student interaction is required, because consequences need to be delivered immediately by a teacher (this type of software is widely used by speech and language pathologists).

2.2. Game Design

This paper describes the pilot project (available at: http://eseeinitiative.org/lefca), which comprises four games (see Figure 1) and the basic subset of skills, Table 1.

Table 1. The set of games and the corresponding skills to be learned, developed within the pilot project.

Game name / command	**Skill to be learned**
Find the same	Matching
Which shape does not belong	Pointing to / Selection responding (visual stimuli only)
Select the shape heard	Pointing to / Selection responding (auditory stimuli)
What is the shape called	Labeling / Production responding

Although, the main target group was children with autism, the framework can be used for other children with and without disabilities, since, the framework is based on the basic learning interaction (e.g. teacher-student or in our case computer-student), a learn unit, which produces 3-7 times faster learning for all learners and it is the only proven method of teaching for children with autism, that produces effective learning. Developmentally, the level of the skills we are trying to teach is for typically developing toddlers, but here our much older participants with major learning delays, functioning on the level of 2 to 3 year old child, were able to master this skill using this frame .

The main goal was to teach autistic children basic shapes: square, circle, triangle, rectangle, rhombus, star, heart, hexagon, and semicircle, and provide a transfer to a new environment.

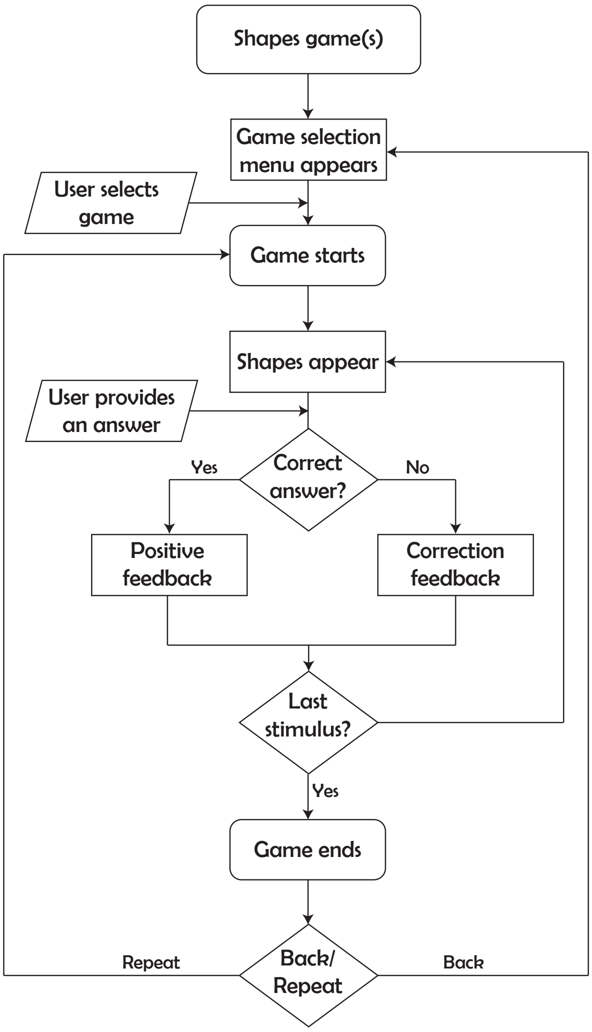

Fig. 2. The interactive logic of the games.

The flowchart, shown in Figure 2, describes the general interactive logic of the game. Firstly, once the game is started, the main game selection menu appears, providing a user with different games: *Find the same*, *Which shape does not belong*, *Select the shape heard*, and *What is the shape called*, Figure 3. After the user selects a desired game, the game starts and the initial set of shapes appears, depending on the game scenario (see Sections 2.2.1, 2.2.2, 2.2.3 and 2.2.4). The student is then prompted to provide his/her "answer". If the answer was correct, the "BRAVO!" sound is played, followed by the positive response animation. On contrary, if incorrect answer was given, the negative response animation is played, followed by the correction animation. The incorrect response is accompanied with a synthetic sound with "negative intonation". Correction animation (a visual prompt for correct answer) is being displayed after each incorrect response, until correct response is given. This animation is used to guide and teach the student, by pointing out the target stimulus. At that point, no positive response is displayed, but the next stimulus/task is displayed. Each game is designed so that the user interacts with all nine shapes. After finishing the whole cycle, the score screen is displayed with an alternative: back to the main menu or replay the game.

Fig. 3. The main menu for selecting between the four games.

After defining the game concept and choosing the initial set of skills and stimuli, we proceeded with the design phase. The first step in this phase was to create a visual interpretation of the given stimuli and environment. Therefore, a simple set of shapes were designed and created as vector graphics, Figure 4. Backgrounds needed to be appropriate to the target audience, relatively simple so that they do not distract users or affect their performance, and fit with the visual appearance of the target stimuli. Thus, a cartoon-like vector graphics were designed for the backgrounds, inspired by graphics available at [37]. Score board is designed as a papyrus in the bottom right corner. It comprises number of correct answers out of total number of trials. Positive and negative response animations were designed using a board with a “check” or “cross” sign written on it, sliding down into the screen view, freezing for a couple of seconds, and sliding up out of the screen, Figure 5a,b.

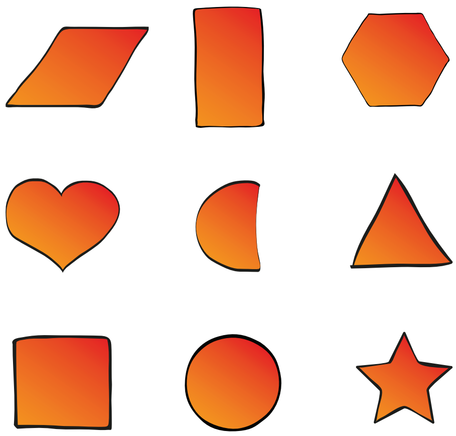

Fig. 4. Nine shapes that were used in the games.

The result screen is designed in a similar manner, using the same board with the final score and the two buttons (*Back* and *Repeat*), Figure 5c. The correction animation can be implemented by highlighting the target stimulus (e.g. size, colour, transparency, etc.) or by using an external indicator (e.g. arrow, circle or similar). In our implementation the latter was used, as illustrated in Figure 6.

For the audio, a background theme was composed and recorded using Cubase 5 software package. The theme is happy-tuned, with bright-coloured main instruments, a base and percussions. Additionally, the “BRAVO” sound and pronunciation of each shape is recorded using Shure SM58 microphone and the same software. A few more sound effects were used: one for negative response, and two for object appearance (one for target and one for test stimuli).

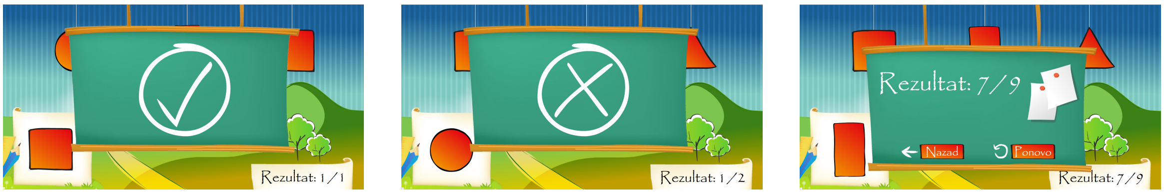

Fig. 5. A screenshot from the Matching game, displaying the (a)positive response, (b)negative response and (c) the result screen, displayed at the end of the game (after testing all nine shapes).

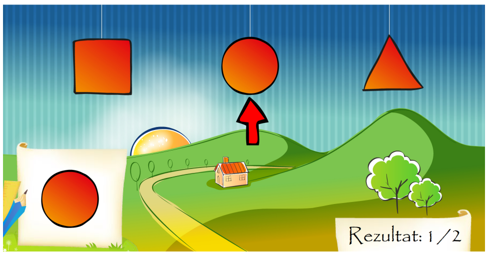

Fig. 6. The arrow bellow the circle shows the correct stimulus, after giving a negative answer.

Finally, the main menu for the game selection was designed, Figure 3. The game is selected by clicking on one of the four boxes. Each box contains the game name (in red) and a short description, e.g. for the *Find the same* game it says: "Click on/touch one of the three shapes that is identical to the one in the bottom-left corner".

2.2.1. Find the same

In this game, three test stimuli slide into the screen from the top, as if they were hanging on threads. Immediately after, the target stimulus appears in the bottom-left corner, using a fade-in animation. At the time of the target stimulus appearance, the name of the shape is pronounced. The student has to click on (if using mouse) or touch (if using touch-screen display) on one of the three test shapes that is identical to the target shape. If clicked on the correct stimulus, the positive response animation is played (see Figure 5a), the score is incremented and the next set of test/target stimuli is displayed. Otherwise, the negative response animation is played (see Figure 5b, followed by the correction animation (see Figure 6). The game ends after all nine shapes had been displayed as a target stimulus. The appearance of both the target and test stimuli is random, where test stimuli cannot be identical to each other during any trial. The position of the correct test stimulus is random (left, middle or right).

2.2.2. Which shape does not belong

All three shapes appear at the same time using the fade-in animation. The user has to click on a red shape in the field of 2 white and 1 red shape. If clicked correctly, the positive response animation is played, the score is incremented and a new set of stimuli is displayed. Otherwise, the negative response animation, followed by the correction animation is displayed. The game terminates after each shape has been used as a target stimulus. The order of shapes is random. All three shapes at each trial are different.

2.2.3. Select the shape heard

This game is similar to the *Find the same* game. The difference is that the target shape is not displayed, but its name is pronounced. Therefore, it is said to be using vocal direction, as opposed to visual direction.

2.2.4. What is the shape called

In this game, each shape is displayed alone, in the middle of the screen. The user has to produce vocally the name of the displayed shape. In this scenario, a teacher or other student is required for the response validation. Besides the shape, there are two buttons on the screen: a cross for incorrect, and check for correct answers. If the student pronounces the correct name, the teacher clicks on the check button, triggering the “BRAVO!” sound and recording a correct answer. A new shape is displayed. If wrong answer is given, the teacher clicks on the cross button. The negative sound is played, a teacher or a peer tutor is supposed to give a vocal correction to the student, and a new shape is displayed. The game terminates after all nine shapes are displayed in random order.

2.3. Game Production

Once the idea was developed and all audio-visual elements designed and generated, we proceeded with the production process. Prototyping was not performed as the previous teaching methods involved using physical shapes made of paper, which were well accepted by the children and showed positive results in learning process.

The games were implemented using ActionScript2.0 within Adobe Flash Professional CS5. Flash has been chosen as the software/multimedia platform for the application for several reasons: it does not require any additional installation, as 99% of all Internet desktop users have installed Flash Player [38]; it is cross-platform, running on a variety of systems and devices; the same implementation can be used both online or offline; developed games/appliactions are very light in terms of data size, and thus easily downloadable even for users with slow internet connection; all flash vector graphic elements are smoothly adjustable to different screen sizes. Although all audio-visual elements have been hard-coded, it is possible to dynamically display the content, allowing for easy multilingual adaptation of the framework.

Table 2. Published SWF files and their sizes.

Game / file name	**Size [KB]**
Main menu	716
Find the same	1,025
Which shape does not belong	877
Select the shape heard	1,026
What is the shape called	861

Each game has been exported separately, with the resolution 900×462 pixels, in order to reduce waiting time. During download (see Table 2 for file sizes), a dynamic loader is displayed. Individual games are selected from the main menu and loaded using the loadMovieNum() function, which allows for displaying several *SWF* files at once and switching among them without loading another *HTML* document. Most of the scripting is done using global scope, within a dedicated “Actions” layer. However, some actions have been scripted within the objects themselves.

Static elements, such as background, have been imported as vector graphics from Adobe Illustrator. Other (dynamic) elements were converted into symbols.Since symbols support nesting and instancing, movie clips were created within a top-level movie clip using the following procedure. Initially, all shapes had been imported as vector objects and converted into graphic symbol. Then, for each of these symbols a new movie clip symbol was created, with the animation of the graphic symbol. Finally, a top level movie clip symbol was created with nine keyframes, each being labeled and containing the previously created, lower level, movie clip symbols, Figure 7.

This allowed for multiple instances of the symbols (test stimuli) and playing the animation externally by using instance names of the top level movie clip symbol and the keyframe label as the argument. The target keyframe contained the command, which starts the shape animation. Button symbols were used for Back and Repeat buttons on the score board. These objects were not animated, but required interactivity.

3. A Pilot User Study

The design utilised was a single-case delayed multiple baseline, across participants and games design. Four students, one girl and three boys participated in the pilot study, ranging in age from 5.5 to 7. All students were diagnosed with Autism and/or other developmental delays with autistic elements. The participants were starting to play the game as the previous participant mastered all four games, in a delayed fashion, with the games order rotated, sequence change for better experimental control. Criterion for mastery of the game was 9 out of 9 correct responses or 100% correct (as each game had 9 trials for all 9 shapes). All the participants had been already exposed to “matching” and “pointing to” instruction, and some “shapes” instruction as part of their daily kindergarten

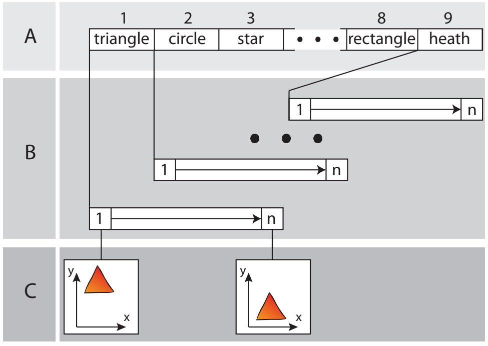

Fig. 7. An illustration of nested symbols. Top (A): An instance of the top-level movie clip symbol, with 9 frames labeled as triangle, circle, star, etc.; Middle (B): lower-level movie clip symbols, containing shape animation; Bottom (C): graphic symbols.

education through a special education kindergarten that was a part of an experimental EDUS-CABAS® project, in public special education institute “Mjedenica”, Sarajevo, BiH. EDUS-CABAS® project was based on evidence-based instruction and individualization of all educational programs for students attending. All instruction in the kindergarten (with and without the LeFCA framework) was done in 1:1 fashion, teacher delivering instruction and reinforcement and corrections while continually taking data on all students responses and behaviours.

For testing our framework, the children sat at the computer table or at the classroom desk, in front of a Sony VPCL111FX/B - VAIO L Series All-in-One 24” Touch-Screen Desktop PC, running at 2.7GHz with 4GB of RAM, and NVIDIA GeGorce G210M GPU with 512MB of dedicated video RAM. A teacher, collecting data in a data collection sheet was present at all times, Figure 8.

Fig. 8. Autistic child playing a LeFCA game.

Procedure with the shapes games was as follows:

1. First participant started instruction with the “Find the same” program until the mastery, then the “Which shape does not belong”, following with the “Select the shape heard” and “What is the shape called”.
2. As first participant mastered all the programs, second participant started the games with the “Which shape does not belong”, following with the “Select the shape heard”, then “What is the shape called”, and finished with the “Find the same”.
3. Third participant followed as soon as the second mastered all 4 games, and started with the “Select the shape heard”, then “What is the shape called”, “Find the same”, and finished with “Which shape does not belong” game.
4. Fourth participant started with the “Select the shape heard”, then “Find the same”, and finished with “Which shape does not belong”. This is the participant who had no vocal verbal behaviour and was not capable of naming, i.e. vocally identifying the stimuli.

4. Preliminary Results

The first 3 participants (DZ, TZ and BK) had 100% correct responding the first time they played the ”Find the same” and ”Which shape does not belong” games, Figure 9. This is due to the fact that since September 2011, all students in the kindergarten worked on their matching and selecting repertoires, which are the basic academic skills needed for learning. Such results during the pilot games show that they have generalised these skills and are able to use them in a different environment, on the computer, which is the main goal of all education and instruction. It is important to note that all students were highly motivated to play the games, and showed lots of interest in the computer post the pilot program. This game, in their native language, was the first software these children encountered that they could understand, therefore the value of developing such educational games for countries in transition and economically disadvantaged groups, is great.

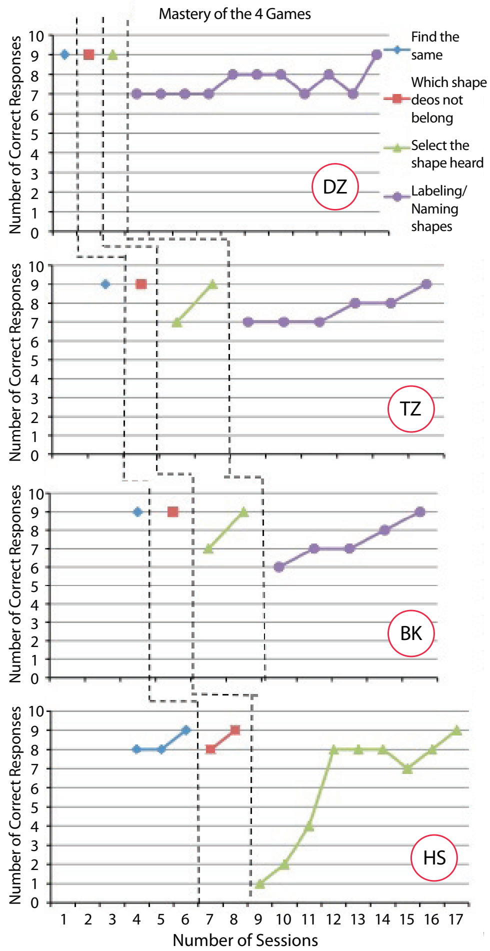

Fig. 9. Students' Mastery of the 4 Games: student DZ (top), student TZ (second from the top), student BK (second from the bottom) and student HS (bottom).

Interestingly, student HS needed many more opportunities to respond and play the game in order to master certain concepts. As he is diagnosed with the more sever case of autism, and has no language or communication developed, he had a much more difficult time mastering the program where he had to rely on the auditory plus visual stimuli as an antecedent. He had no problem mastering the matching and the selecting the one that does not belong programs in few session, since they require a student to rely only on the visual stimuli - the directions to complete the task do not require any listener behaviour, attending to the auditory command. Children with autism who do not have speaker behaviour developed, usually have not developed a listener stage of verbal development yet. That is, they do not yet attend to human voices and do not respond to/understand vocal commands, therefore teaching that skill is very time consuming and difficult, as we see on the graph in Figure 9. During the first session, out of 9 opportunities or trials given, he had only 1 correct response, which could have been by chance. Through the reinforcement of the correct responses, getting positive feedback, and through correction of incorrect responses, the student leaned what the task requires, and learned to respond to the vocal commands in order to complete the task, which we see by the final result of 9 out of 9 correct learn units.

5. Conclusions and Future Work

According to the data, all students had the concept of sameness (i.e. identical shapes) and dissimilarity (i.e. "does not belong") acquired and were able to generalise those basic developmental skills in the field of 3 on the computer (another environment). In the future, an analysis of rate of acquisition of such skills via computer with chronologically younger or developmentally younger children will be evaluated. As suspected, the acquisition of vocal labeling of the shapes took the longest for each participant. Children with autism are characterised by delayed and often severely impaired vocal verbal behaviour and all communication skills. Therefore, it was the hardest skill to master for each participant. In addition, production responding is a higher order skill then the selection responding, which is like "recognising" vs. "knowing".

This framework has been designed based on decades of research on science of learning and human behaviour, and not only on educational theories. In addition, it is based on a learning frame- learn unit, which is the best known measure and a predictor of the students learning. While non-autistic children learn these concepts early in their life through natural learning process, children with autism might not be able to do so. Therefore, this framework will help them to build up their early cognitive abilities and school readiness skills using basic interaction with a teacher. Furthermore, the framework is made in the native language, which makes it the first software of this type made in B&H. It will introduce children with disabilities to a computer and introductory software to teach basic computer literacy skills. Finally, it promotes e-Learning, knowledge transfer, expansion and deepening of users network to others, in public, private and NGO sectors, interested in and supporting the development of a participative, knowledge-based, information society.

In the future, we plan to expand the framework in several dimensions, including modes of learning, taught concepts, and languages. Once completed it should allow users from different countries to make their own language variances, without requiring high-level technical skills. A more advance study is required to better understand the differences between learning with and without the framework. Therefore, we plan to involve more participants and more advanced statistical analysis of the data.

In the time of writing this paper, four more games for learning shapes are being developed, and incorporated in the LeFCA framework. Upon the release, these games will be available at *http://eseeinitiative.org/lefca*. The future work will include testing these new application and comparing the learning outcomes with the traditional teaching techniques.

Acknowledgments

The authors would like to thank employees of the non-for-profit organisation EDUS-Education for All, that works with children with autism and other special needs, and special education institute "Mjedenica" for helping with testing the framework. We would also like to thank Namik Mesic for helping with the game development. The pilot project was funded by the United Nations Development Programme in B&H, through the Empowering Marginalised Groups in e-Governance project.

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