Memori: A Serious Game for Diagnosing and Treating Visual Sequential Memory Deficit

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Abstract—Visual Sequential Memory (VSM) allows a person to perform tasks such as remembering letters, numbers, objects or shapes in the correct order. Its deficit can lead to challenges in one's personal life, including dyslexia and dyscalculia. Detecting Visual Sequential Memory Deficit (VSMD) is essential for those who suffer from its related consequences. But current clinical methods don’t have a high rate of diagnosis, and also for treatment are limited to the few hours the person spends in the clinic. In this paper, we propose an Origami based Serious Game, called Memori, for the diagnosis and treatment of children with VSMD. We illustrate the rationale behind using Origami, the design process of our game, and its implementation.

Keywords—Serious Games; Game Design; Visual Sequential Memory; Origami; Play Therapy.

I. Introduction

VSM indicates a person’s competency of remembering letters, numbers, objects or shapes in the correct order [1]. VSM is crucial as it affects various aspects of life since we use this ability in our daily lives while remembering names, phone numbers, directions, recipes, etc. A person with VSMD; i.e., a person whose VSM is not working as well as a healthy person, could experience problems in various aspects of life and be affected by different disorders such as dyslexia [2] and dyscalculia [3]. Findings of the USA National Institutes of Health suggest that dyslexia affects 7% of the population [5]. Their definition of dyslexia is broader than Kooij who enounced 3% to 4% of people have dyslexia [6]. In Turkey, where our proposed system is designed and will be tested, approximate prevalence of dyslexia is 5%-7% of people [7]. Moreover, worldwide dyscalculia rates reach 6% of the population [8] [9]. Additionally, a quarter of children with dyslexia and dyscalculia exhibit Attention Deficit Hyperactivity Disorder (ADHD) [10].

Children who experience difficulty in VSM often show it when having difficulty remembering numbers in sequence, sequencing letters in similar words such as was/saw or reverse/reserve, copying from a book to a notebook, or recalling events and tasks in series. In the absence of such abilities, possible problems arise: dyslexia [2], reading difficulties [4], and dyscalculia [3].

Even though VSMD is important and can negatively affect various aspects of life, it is not diagnosed very accurately [30]. If it is found early, treatment methods could significantly improve the condition [28] [29]. To help with the early diagnosis and treatment, in this work we propose Memori: a serious game to diagnose and treat children with VSM difficulties. This serious game has been developed in the context of our European project “Intelligent Serious Games for Social and Cognitive Competence” [31], the target group questionnaire of which can be seen here [32]. Memori works by making the children use their sequential memory by following instructions and trying to copy the folds of an origami game in the correct order. As a byproduct, children with ADHD can be determined as well. Origami is the Japanese paper folding art that makes shapes of paper. Figures 1 show some examples of Origami shapes. We chose Origami because it is a game that has been shown to heavily involve VSM, as will be discussed in Section II. For diagnosis, Memori can tell the parents or the therapist if this child could possibly be affected by VSMD. Because it is a game, children will be tempted to play it, making diagnosis easier. For treatment, Memori can also serve as an assistive technology in addition to clinical treatments. Since children receive limited hours of clinical treatment, our game will allow them to receive treatment at home and as much as needed under the supervision of a parent. Because Memori runs in WebGL [33], it can be played in any WebGL-compliant web browser (Mozilla Firefox, Google Chrome, Apple Safari, MS Internet Explorer, MS Edge) on any platform, including PC, tablets, and smartphones running Android and iOS. This makes Memori very accessible for home usage.

In Memori, after the first tutorial games, the system, depending on the performance of the child in the tutorial, will bring up other Origami games, and show to the child, fold by fold, what the child must do. The child uses an actual paper and follows the instructions of the system. The parents or the therapists will monitor the number of sequentially correct folds, without stopping the child if the child makes a mistake. The performance of the child can be assessed using our proposed method in Section V. This process can be repeated as needed.

To the best of our knowledge, while there are some games
available for visual memory, dyslexia and dyscalculia treatment, as will be shown in Section II, there is no serious game directly targeting VSM. In this paper, we will show the design of our game, and the rationale behind it. The rest of this paper is organized as follows: in Section II we cover related work, in Section III we present and discuss the game design, while in Section IV we show our implementation. We then elaborate on our future work, and conclusions.

II. RELATED WORK

We discuss the related work in the following subsections: Current Clinical Methods, Serious Games for Visual Memory, Serious Games for Dyslexia, Serious Games for Dyscalculia, and Origami in Therapy and Education.

A. Current Clinical Methods

VSMD can be diagnosed by Visual Sequential Memory subtest of the Illinois Test of Psycholinguistic Abilities (ITPA) [11] or Knox Cube Imitation Test (KCIT) [12]. KCIT is a very efficient way that serves as diagnosing and treating. The problem with these methods is that they are confined to a clinical setting, and cannot be used at home. So their effectiveness is limited to the clinical exposure the child has.

B. Serious Games for Visual Memory

Nagle et al. [34] designed a memory training game for measuring the effects of different task difficulty levels and user control choices in a serious game. The memory training game takes place in virtual environment, a room, and players receive a list of some objects they need to locate in the room. Objects are numbered and then placed in the room. The challenge was to memorize the list items and their location numbers, to place them in corresponding locations.

Illanas, et al. [37] developed a mini-game, MemOwl, for memory stimulation. In this game, participants are shown some pictures for a specific time. Pictures consist of owls of different colors. When the time is over, users need to pick the correct picture. The number of owls increases and the time duration of picture display decreases by level difficulty. MemOwl targets to improve attention, visual memory and short-term memory skills.

C. Serious Games for Dyslexia

Rello, et al. [35] developed a browser-based game, Detective, to detect risk of dyslexia. The game is designed to have linguistic tasks that are shaped according to the typical mistakes done by dyslexic people. It can diagnose English and Spanish speaking school age children with dyslexia.

Rello, et al. [36] created a game, DysEggxia, to improve the spelling of children with dyslexia. Its exercises have misspelt words for players to correct them. The words are gathered from texts written by dyslexic children. The experiment was held for 8 weeks. During the first 4 weeks, 48 children played the game DysEggxia. Then they are switched to another word game, Word Search and played it for 4 weeks. At the end of the experiment, the results were compared and children who played DysEggxia had less mistakes in word spelling.

D. Serious Games for Dyscalculia

Kuhn and the research team at the University of Münster developed Meister Cody - Talasia for diagnosing and treating children with dyscalculia. It is an educational game consisting of 20 therapeutic exercises [38]. The game and difficulty levels are shaped according to the user profile on daily basis. Meister Cody is designed in a way to improve working memory, number processing and calculation skills.

E. Origami for VSM in Therapy and Education

While playing Origami, a child will invoke his/her VSM quite heavily. Gross suggests that while doing Origami, one needs use the following skills: following a sequence of directions, listening skills, reading skills, language skills, writing skills, social skills, mathematics, spatial relationships, memory and concentration [13]. According to Kaplan, performing a folding act requires following instructions, solving problems, learning the steps in the proper order, thinking skills, self-image, and success experience [14]. Other studies have come to similar conclusions, that Origami requires skills that are directly related to VSM [15] [16] [19] [20] [26] [27].

Origami has been used for therapeutic and educational purposes by many researchers in the past. Origami has also been shown to benefit learning disabled, dyslexic, physically or emotionally handicapped students [17]. Origami also helps with fine motor control and hand writing, attentiveness, sequential memory, and specifically helps children with learning disorders to develop fine motor skills, observation skills, and visual sequential memory [18]. A child suffering from dyscalculia who cannot comprehend or manipulate numbers, forms or anything related to those can also benefit from Origami by learning to follow the sequence and order of things [3]. For diagnosis, Origami can evaluate which basic difficulties a child might have in the acquisition of topological concepts and spatial orientation [21] [18]. Origami is also utilized in pediatrics for mental health, clinical fine/visual motor skills, memory, and sequencing [22].

The above work all show very promising effects that Origami applications can have on VSM, for both diagnosis and treatment. In this paper, we are revisiting such applications of
Origami, in the context of today’s technology and gaming environments. We design a platform-independent mobile serious game called Memori that shows to a child the step-by-step order of making various Origami shapes. Using the child’s performance, one can then diagnose the child for VSMD, as well as treat children with VSMD at clinics and homes.

III. PROPOSED GAME DESIGN

The design of the game is shown in Figure 2. As demonstrated, the game will start by inquiring whether it is the first time the child is playing or not. If it is the first time, then the player will start with the tutorial under the supervision of an instructor. Tutorial is designed to make the user become comfortable with the game environment and the game flow. It also helps eliminating the training effect. At the end of the tutorial, if the performance of the child is not satisfactory, then the instructor will repeat the same or another tutorial. As soon as the child achieves a sufficient performance, the child will start playing independently. Diagnosis will be based on the first time playing with each origami tutorial. On the other hand, treatment will be based on the progress of the child playing the game independently. In tutorial, T-shirt origami is set along with the instructions of how to play and navigate through the game. For diagnosis, we decided to have Basic House, Sailboat and Duck origami shapes. On the other hand, for treatment we selected Heart, Windmill and Plane origami shapes.

![Fig. 2. The flow chart illustrating the game design.](image)

Since the game must be played by children at home, we decided to make it very portable; i.e., accessible on laptops, smartphones and tablets, running on any operating system. We also decided to use 3D graphics in order to give the game a realistic feeling. To meet these requirements, we need a platform that supports 3D on various operating systems. For that, we chose WebGL which supports 3D and runs on any web browser [33]. This makes our game very accessible.

To generate the required 3D scenes and animations, we chose Blender [23]. There are three reasons we preferred Blender and found it a perfect platform for our game; not only for modeling the paper objects, but also for the whole game structure:

- For modelling, Blender is easier and simpler than most of the other engines, like Maya or 3D-Max, yet quite powerful. The simplicity of Blender is to the extent that we do not need to write any code for the game logic, as we will see in Section IV.
- Using the Blend4Web [24] plugin allowed us to take the game online by simply compiling the game in an HTML file and uploading it in a web server so that it can be accessible through any device such as PC, tablet or even smart phones. This is for the fact that Blend4Web has a built-in webplayer utility that is automatically added to the HTML file of the game when compiled. Although Blend4Web is still new and has a lot of limitations, the two most important challenges we faced were as follows:
  - No switching between scenes. We overcame this by simply making a separate HTML file for each level or scene and by having a button that can re-direct the user to other scenes through URL redirection. Our game is stable in the sense that changing a level or adding more levels is just appending the new level's HTML file to the webserver and link it to the game. This gives an opportunity for any modeler to expand the game with ease.
  - Selecting just one animation type. We were limited to choose only one animation type to export to HTML, either “Shape Keys” or “Vertex Animation”. If we pick one of those then we cannot use “Modifiers” with the object animation of which we are to export. Mainly we used Vertex Animation with armatures and bones, yet for one shape we used Lattice modifiers which were significantly better in look but not applicable for most of the origami shapes and require much more space.

- Although using other game engines such as Unity [25] might be a first choice for many developers due to the power and speed of codes over logic trees and node editors of Blender, designing paper-like objects and animating them are relatively harder. Designing the objects on Blender and exporting them to Unity, though will allow us to utilize Blender more efficiently without the limitations of Blend4Web, proved to create many problems in having animations and “rigids” working properly.

To make the shapes for the Origami, we came up with two approaches, described next:

A. 1st Approach: Rigid Folding Using Armatures and Bones

1) Pre-modelling Phase: First, we do the origami on a normal plain paper. We determine and highlight each folded edge in the paper (See Figure 3). Later, we identify the vertices in the highlighted scheme of the folded paper.

2) Modelling Phase: In editor mode, we design our plane object just as the scheme drawn on the paper (edges-vertices). That also includes calculating the angles between the folded
parts and the lengths of the edges in order to draw the scheme accurately in the Blender grid space. To turn the plane into a paper-like object, we carried out the following procedure:

- Add bones at specified edges.
- Add weights to the vertices that are to be moved by the attached bones; see Figure 4.
- Overlapping weights of vertices distort the animation, so we separate them by simply separating the armature of each group of bones.

Blend4Web introduced some problems with changing the textures dynamically throughout the animation, so we use Blender Cycles to change the textures how we desire and save them as new textures in image format, just like original ones. We duplicate the planes and map each of them with the textures we want to be shown with. Now once the plane is folded, we merely show the plane that has a line on the edge the plane was folded across, which is the texture we already prepared, and hide all other duplications of that plane.

B. 2nd Approach: Lattice and Subdivision Surface Modifiers

In order to make folding animation more realistic, we used a 2-dimentional lattice modifier. Although Blend4Web does not allow exporting “Modifiers” and “Vertex Animations” together for the same object, we animated (i.e. translated the position of) the lattice itself towards the plane with such angles that it would “fold” the paper as desired. While bones are joints to which certain vertices are attached (see Figure 5), we used Subdivision Surface modifier with the Lattice modifier and hence the paper is folded in a more realistic way (see Figure 6). By animating the size parameters of the lattice, we could make the folding animation yet more realistic. Although, compared to the first approach using Bones, this approach looks better, it has two limitations:

i) It requires more space since on average we need a lattice object for each two folds. The final HTML file of one shape is about 20 Mega Bytes which is not small.

ii) More importantly, most of the shapes are not applicable with this approach as they have overlapping folds that cannot be modeled using lattice modifiers (see Figure 7).

IV. IMPLEMENTATION

To implement the necessary animations for the Origami, we use Blend4Web logic node-editor. For that, we make two variables; current state and previous state. By only adding forward (green) arrow and back (red) arrow and bending the event of clicking at them to switching between the states and update the state variables. Updating the state variables, the user can fully control the scene timeline and play the origami animation step by step, forward or backward. With Blend4Web webplayer utility, the user can rotate and move the object in 3D space to get the perfect visuals of each step from any angle wanted.

Switching between states is done via playing the timeline from current state to a new or next state and then updating the current state and previous state. The state variables are integers referring to instances in the timeline. Lastly, the “PLAY” Button is for playing the whole timeline, which is used in the test (See Figure 11).

a) Solenoid Algorithm and Right Hand Rule: Since we are using Blend4Web, we cannot work with Blender Game Engine (BGE) Logic editor; however Blend4Web B4WLogicNodeTree has sufficient tools to build up the logic tree of the game. Influenced by the right-hand rule in deciding
the direction of the flow of electric current, the logic tree also looks exactly the same: the thumb points in the direction of the animation flow as shown in Figures 9 and 10. When Next (green arrow) button is clicked, the animation flows according to the logic tree grouped in NEXT frame, which uses current as state determiner, and the same procedure is applied for BACK (red arrow) button. The red arrows in the figures do not refer to the flow of the code execution, they are just for understanding how state variables (current, previous) change dynamically with each click on Next or Back buttons. The thumb up/down cannot be understood correctly without considering the other logic blocks.

b) “Reset Camera” Button: In case the user has difficulties navigating through the scene or getting away from the origami object, instead of adding constraints to the navigation within the scene, we added a “reset camera” button which whenever clicked shall reset the camera to the default position and thus allowing the user to navigate as desired, following the animation from any view angle and distance while having a default position to which the user can be returned with a single click (see Figure 11).

Figure 8 is an illustration of an example game and its various stages. It shows a sequence of Origami folds in the game.

V. FUTURE WORK

For the next step of our research, we intend to perform experiments to measure the effectiveness of our game in diagnosing and in improving VSM skills. To test our game, we intend to have two different groups. One group will play Memor and the other will be using Know Cube for a certain time period. After that, the groups will exchange the games. Throughout the procedure, we will continue measuring the performance of the child and observe the progress. Based on the feedback acquired from the tests on different study groups, if needed, we can modify the games. Moreover, we plan to personalize the game by including user profiles and improve the engagement by adding gamification elements.

Currently, the game comprises five origamis, one of them is the tutorial and the rest are ordered in an increasing difficulty level. Child will perform the tutorial origami on the electronic platform with the help of the instructor so that the child can get used to the game flow and does not face complications.
After that, the child will start playing independently. The instructor will note down the following data for each origami: the number of consecutive folds that the child successfully reaches; how many times the child hits the re-play, back and next button, time durations for each interaction with the game, demographic information about the child (age, gender, physical impairments, siblings, siblings with disabilities, etc). Based on the data gathered, we will measure the performance of the child. On the other hand, with the same data features, we will collect another dataset by applying ITPA and KCIT which actually diagnose the children with VSMD. Based on this data, which we consider to be the Gold standard, we will create our classification model which will then be used to diagnose the players of Memori. For treatment, we intend to have two different groups. One group will play Memori and the other will be using Knox Cube for a certain time period. After that, the groups will exchange the games. Throughout the procedure, we will continue measuring the performance of the child and observe the progress.

VI. CONCLUSION

In this paper, we proposed the serious game called Memori to identify children with VSMD. The game can serve patients for diagnosis and treatment, in addition to their clinical treatment. Furthermore, because the game is developed on WebGL, its accessibility and simplicity is quite high.

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REFERENCES


Fig. 10. Logic Block for button “Next”: the state determiner is $crnt$.

Fig. 11. User controls: Top left button plays the whole animation, top right button is the camera reset, bottom left is Back, and bottom right is Next.


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[28] singleton1988-early diagnosis of dyslexia


