ABSTRACT

This study aims to investigate to what extent a game that trains spatial skills, can affect mathematical performance of young children. The game was developed as a combination between the classic version of *Tetris* and *Dominos*, which spawned the name Trinos. The main goal of the game was to earn points, by positioning falling shapes on the table, in order to match blocks with the same number of spots on it, or to complete a line.

The testing procedure took place at the *Esbjerg International School* with a 4^{th} grade class of 20 children with the age between eight and nine year old. The children played the game fifteen minutes a day, for a period of four days, and their scores were saved for further analysis. As measurement tools for assessing their mathematics and mental rotation level, tests were given both before and after the entire training period.

The gathered data was analyzed using Wilcoxon signed-rank test, for observing if there was a significant difference between the repeated measurements. Also, the Spearman's Rank Correlation coefficient was used in order to assess the level of correlation between the game score and the results from math exercises and mental rotation test.

The obtained results showed no significant effect on players' math abilities, but revealed a positive improvement in the mental rotation tasks. Moreover, the game score appeared to have high level of correlation with children's spatial skills, and a moderate one with the math results.

CONTENTS

1 INTRODUCTION

Educators and behavioral scientists have long recognized the value of play in children's development process (Smith, 1995). In particular, games have been identified as facilitators of children's cognitive, social and moral development (Kamii and DeVries, 1980). Over the years, the most well-known and desired variety of games were *Video Games* (Okagaki and Frensch, 1994).

In the last decades, computer and video games experienced a fast growing popularity. Game industry provides engaging and enjoyable activities that promote active learning, strategic thinking, knowledge construction and collaboration (Kirriemuir and McFarlane, 2004). The potential of computer games to support learning could be found in a variety of subjects, such as science, math, medicine, engineering, language learning and problem solving (Mitchell and Savill-Smith, 2004).

Apart from educational field, video games have been linked to another important area - *Cognition*. The relation between them occurred, and has been picked up considerably since the pioneering work of Green and Bavelier in 2003. Their findings, that playing action video games could modify spatial attentional processing, had a great impact on the upcoming studies. Moreover, it was proposed that spatial skills are the cognitive skills that benefit the most from video game practice (Greenfield, 2014).

The diversity and range of games seems almost limitless but genre classification make the distinction easier. Action, adventure, role playing, sport, driving and puzzle games are some of the most popular genres. Each type of game requires different skills and strategies for performing the best game play. Some games involve problem solving and planning, whereas others inquire fast reflexes and superior visuomotor coordination to succeed (Spence and Feng, 2010).

Puzzle and maze games are the genres that usually involve perceptual and cognitive skills which seems to affect mostly the spatial cognition (Spence and Feng, 2010). As one of the most notably and popular puzzle game from late 1970s and early 1980s is *Tetris* (Sabadello, 2006), it was investigated in numerous researches, whether this game's multiple play sessions could affect players' spatial cognition (De Lisi and Wolford, 2002; Sims and Mayer, 2002).

In addition, as previous researches have established, spatial skills are also connected with mathematical abilities (Delgado and Prieto, 2004; Holmes, Adams and Hamilton, 2008). More specific, children and adults that are better at spatial tasks, also perform better on tests of mathematical abilities. Also, as Cheng and Mix (2014) found, the training of spatial skills leads to better performances in mathematics.

1.1 Research Question

Based on the aforementioned studies, our research intends to combine games with education, in relation to cognition. In particular,

- To what extent, can a puzzle game that involves spatial skills, affect players' competences in mathematics.

In order to achieve the proposed goal, several sub-research questions needs to be discussed, as follows:

  - In what way can the game playing sessions influence the spatial abilities of the players?
  - Is there any correlation between game score and math/MR test scores?

2 RELATED WORK

Computer games practice enhance learning through visualization, experimentation and creativity of play (Betz, 1995) and often include problems that develop critical thinking and require cognitive skills. Multiple researches investigated the potential of computer games as tools for learning and especially games that are designed for educational purposes (Rebetez and Betrancourt, 2007). Since the current project also refers to games in education, and specifically the impact of game play practice on players' spatial abilities and math performance, the next paragraphs will present several studies that are related to the project's main goal.

2.1 Video Games and Spatial Skills

The first body of researches is focused on measuring the effect of playing video-games on cognitive abilities. These studies are relevant to our project as their findings are based on testing the puzzle game *Tetris*, which is the classic game that served as a starting point for our project's game. Moreover, the studies intends to research the potential of *Tetris* game play on players' development of spatial skills.

In 1994, Okagaki and Frensch examined the relation between video game play and spatial skills among older adolescents. Two experiments were carried on (Experiment 1, paper-and-pencil method for measuring spatial performance, Experiment 2, computerized measures of spatial performance), in which the data was collected from subjects both before and after they practiced the *Tetris* video game. A total of 57 undergraduate students were involved in the first experiment and 53 students in the second one. All the test subjects did not have any prior experience in playing *Tetris*. In result, their study revealed that 6 hours of playing *Tetris* does have potential to improve mental rotation and spatial visualization performance in both female and male college students. Also, they suggested that spatial skills that are developed through video game practice or other spatial skills training tasks are direct linked to the practice setting.

Another study, conducted by De Lisi and Wolford in 2002 investigated the effect of computer game play on mental rotation (MR) of third grade students with age between 8 and 9 years. The study looked at the differences in MR performance on a paper-and- pencil test that was completed both before and after children had the game play sessions (11 separate 30-minutes sessions). The experimental group played a game that involved the use of MR skills – *Tetris* and the control group played “Where in the USA is Carmen Sandiego”, a game that did not entail MR. In the end, it was observed that *Tetris* players outperformed the children from the control group even if there were no differences in MR at the pretest. These findings implied that children’s MR performance was enhanced after playing the game for a number of weeks. Therefore it was concluded that computer-based instructional activities can serve as aids for improving spatial abilities of children in school environments.

2.2 Mathematics in Spatially Oriented Studies

This paragraph intends to present two different studies that are related to the current project’s proposed goals. The first one investigates the link between spatial abilities and mathematics, by testing with children of 6 to 8 years old, and the other one aims to teach third grade students about the skills and strategies of mental computation in their mathematics learning with a *Tetris* like game. Since our project also aims to test the players’ mathematics abilities through a game that involves spatial skills, it is important to present these two studies, and to relate to their findings, as they served as foundation for developing the research.

Cheng and Mix in 2014 tested whether mental rotation training, can improve math performance of middle class children. 58 participants were randomly divided in spatial training group (completed tasks that train their mental rotation skills) and non-training control group (solved crosswords puzzles). Both groups were pretested and posttested on a range of numbers and math skills. The training group outperformed the children from non-training group by getting a higher score on post testing calculation problems. Moreover, children that did not receive session of mental rotation training did not improve on any math tasks. Therefore, the obtained results proved that spatial cognition and mathematical reasoning indeed are connected.

Another research conducted by Yeh, Cheng, Chen, Liao and Chan in 2010, developed a learning game, *EduTetris* in order to teach mental computation. The game was designed as an aid for children to learn digits that sums in 10. The proposed goal was to find out if their game can enhance children’s abilities of computing mental arithmetic addition. 15 nine year old third grade students participated in the testing session (completed a pre-test, played the game and filled-out a post-test in the end). Their results showed an increased computing speed at solving math exercises at post-test than at the pre-test, and a slightly higher accuracy of the test results. Also the participants agreed that their performance in math can be improved by playing EduTetris.

3 THEORETICAL FRAMEWORK

Video games have the potential to be developed as effective and goal oriented tools that can allow players to be active agents in acquiring skills and knowledge, rather than passive consumers (Squire, 2006; O'Rourke, 2010). The way players gain knowledge from the game play sessions, depends on the game genre and its method of providing learning content. As this research is based on a *Tetris* like game, which does not provide educational content *per se*, according to related works (Section 2), its gameplay improves player's cognitive skills through implicit learning. More specific, the knowledge is not consciously gained (Kihlstrom, 1994), as the players are not aware of the learning content when matching random tiles, but their spatial skills are improving at each training session and this performance leads to further improvements in math abilities.

In order to get a deeper understanding of the theoretical notions that are significant for this project, the sections below will review the most relevant of them. Therefore, the material is divided in two parts, where the first one presents concepts about cognition in games, while the second one explains the connection between spatial skills and mathematics.

3.1 Cognition in Games

Video games now compete with movies and TV as a form of entertainment, and attract enthusiasts that spend many hours playing. This activity has the potential to affect players' cognitive abilities (Subrahmanyam and Greenfield, 2008). Cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" (Cognition, 2016). Human cognition depends on several distinct mental components, such as spatial, verbal and analytical being some of the most important (Spence and Feng, 2010).

One of the first formulated definition for spatial cognition as an independent component of the human cognition was done by Thurstone in 1938. He defined spatial skills, as the ability to hold the image of an object in mind, and to rotate and move it in such a way, that it matches another object. The process of manipulation and storage of the spatial information is primordial for proper motor behavior, as it enables the necessary mental representation of objects' positions and relationship between them (Spence and Feng, 2010).

In their research, Linn and Petersen (1985) suggested that spatial skills consists of three different spatial information-processing components: *spatial perception*, *mental rotation* and *spatial visualization*. *Spatial perception* represents the capability to understand the orientation of an object in space in relation to its own orientation. More specific, this ability aids to perceive and visually understand spatial information such as shapes, position, properties and motion (Simmons, 2003). *Mental rotation* is the skill that facilitate people to imagine how a two or three dimensional object would appear after its rotation of certain amount of degrees around an axis (De Lisi and Wolford, 2002). Finally, *spatial visualization* is the ability that comprise the two above stated components as it involves both the perception and rotation of objects. It is described as "spatial ability tasks that involve complicated, multistep manipulations of spatial presented information" (Linn and Petersen, 1985, p.1484).

In regards to video game experience, all the spatial skills components are essential to navigate the environment and to understand specific objects' size and how to handle them. Gentile (2005) defined five game specific dimensions that can affect players' cognitive abilities: *amount, content, effect, form* and *mechanics.* The *amount* refers to the amount of time that is spent for playing and the habits of play. *Content* is described as the effect of the message that is transmitted through the game environment. *Effect* is represented by the influence of the games on player's behavior (negative like violence and aggressiveness and positive as health promotion). *Form* describes the way game deliver its material (e.g. need to scan the screen, rotate the device). And the last one, *mechanics* address the mechanical input-output that devices uses (e.g. phone, tablet or computer).

The variety of the existing video games is widely different, as it is influenced by the provided dimensions. Based on *content* and *form,* games are categorized in multiple genre such as puzzle, action, strategy, sport, racing and others. Learning to play a game leads to improvements in the component skills required in the game. As an example, *Tetris* is a well-known puzzle game that requires the use of mental rotation skills and spatial visualization in order to succeed in playing. The players must mentally visualize the given shapes and imagine how it needs to be rotated in order achieve the best fit (Okagaki and Frensch, 1994).

3.2 Spatial Abilities and Mathematics

Mathematics is one of the basic educational skills that begin to develop in yearly years, even before formal schooling (Kyttala, Aunio, Lehto, Van Luit and Hautamaki, 2003). The developing of number sense is assumed to occur already in infants, and is based on understanding the concept of numeracy (Starkey and Cooper, 1980). Intellectual development and mathematical progress are closely connected, as in order to comprehend specific mathematical concepts, children need to have a certain level of intellectual development (Kyttala et. al., 2003). According to National Association for the Education of Young Children (NAEYC) (2002), children need mathematical skills and abilities not only in mathematics classes, but also in science, social studies and other important domains. Therefore, in order to enhance opportunities and options for shaping a bright future, children should be exposed to mathematics from their early live years.

Despite the importance of early numeracy development, the educational growth of the cognitive components such as spatial reasoning and visualization skills are also essential in the process of learning math (Jordan, Levine and Huttenlocher, 1995). The connection between space and math may underlie on the fact that similar brain areas are activated when people process both spatial and number tasks (Hubbard, Piazza, Pinel and Dehaene, 2005). Moreover, as spatial abilities and mathematics skills are strongly correlated, many studies proved that people with high level of spatial skills, have better performance in mathematics (Delgado and Prieto, 2004; Casey, Nuttall and Pezaris, 2001). Thus, the development of spatial skills is significant, as it showed a beneficial impact for improving mathematics, and recently the National Council of Teachers of Mathematics (2010) recommended integrating spatial reasoning into elementary mathematics curriculum.

As it was stated before, spatial cognition consists of several components and each of them is linked to particular mathematics tasks. For example, strong visuospatial working memory is related to good performance on counting tasks (Kyttalla et al., 2003), on line estimation (Geary, Hoard, Byrd-Craven, Nugent, Numtee, 2007) and non-verbal problem solving (Rasmussen and Bisanz, 2005). It was also observed that mental rotation abilities are indeed related to math skills in adolescents (Reuhkala, 2001). But as the ability to mentally rotate images improves with age (Kosslyn, Magnolis, Barret, Goldknopf and Daly, 1990), a proper training of these skills from even early years can lead to high performances in mathematics.

A possible explanation for the importance of mental rotation in mathematical scores is solving strategies. Many mathematical problems can be solved using analytical strategies or visualization. Two kinds of such problem solving ways were found: one based on algorithm memorization and automatic application, and the other one based on visuospatial representation of the problem (McGuiness, 1993).

In summary, the existing studies provides a solid foundation to conclude that spatial ability and math performance are connected even from the early years (e.g. when a child counts on fingers).

4 SYSTEM DEVELOPMENT

One of the primordial part of this project is System Development, as it contains detailed presentation and explanation of how the project was developed and what technologies were utilized in order to achieve the expected results. The whole process of realizing the game from the beginning until the final product is related in this chapter. The material is structured in two big paragraphs, each containing subsections that are describing both technical and design parts.

Therefore, the chapter is divided as follows, first paragraph illustrates the game's interface, by describing the approached design concept and the required technologies and methods that were needed for implementation. The second paragraph discusses the technical side of the game, by presenting and explaining the most important scripts and the way they were constructed.

4.1 Design Implementation

Designing a game represents an art of applying aesthetics and design in order to create game's interface that would facilitate players' interaction with the environment. Also, game design refers to the creation of game's rules, challenges and goals, vital elements that defines a game (Brathwaite and Schreiber, 2009).

The current project aims to investigate to what extent a puzzle game that trains spatial skills can lead to improvements in children's math abilities. As it could be inferred from the Related Studies section, *Tetris* is the game that was used the most, in researches which explored the effect of game play on players' spatial abilities. That is why, *Tetris* stands as the basis of this project's developed game.

Same as in the original *Tetris*, the game scene includes a playing field and several shapes composed of different square blocks. Whereas in *Tetris*, the playing field's dimension is 10 cells wide by 20 high, and the shapes are made up of four square blocks (Figure 1a.), the current game has a smaller playing field (eight by eight) and only three square blocks per shape (Figure 1b.).

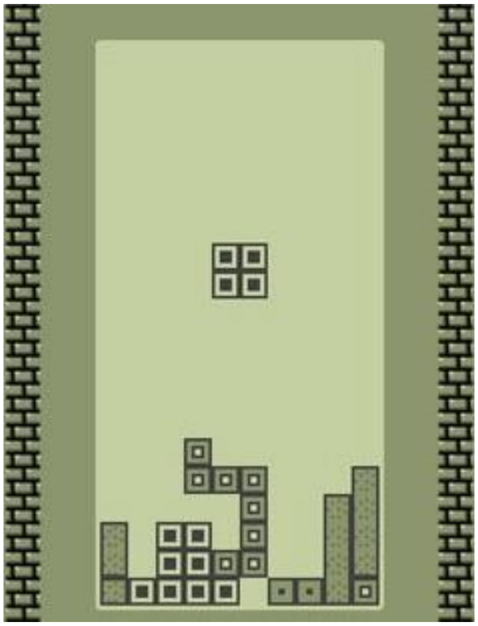


Fig. 1a. Example of *Tetris* playing field

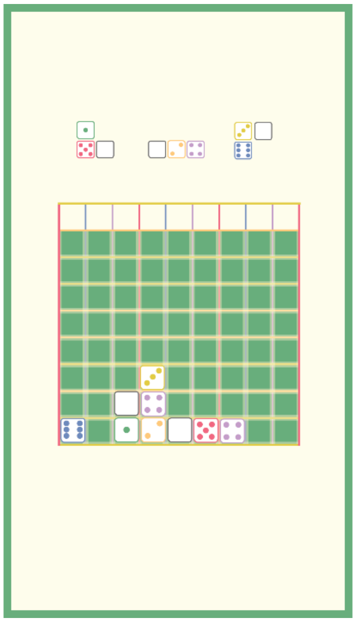


Fig. 1b. Trinos playing field

Moreover, the blocks that form the shape have spots on them or are blank, similar to *Dominos* (Figure 2). These variations to the original version, inspired the name of the game, which comprises the Greek numerical prefix *tri-*, for the three square blocks per shape (like *tetra-* in *Tetris*), and *-nos* which is the suffix for *Dominos*, and stands for the spots on the blocks. Thus, the game was entitled as Trinos, and further on in the report, the game will be addressed by this name.

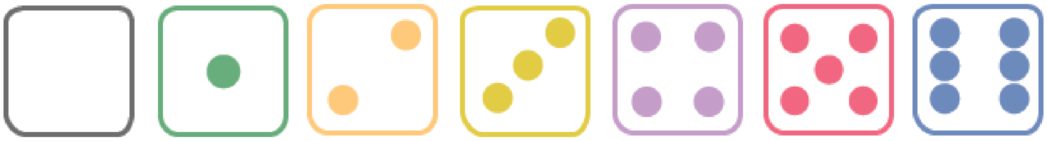


Fig. 2 The blocks that form the shapes

As the concept of the game is limited to one established game scene, the one with the field, there were not so many possible variation of the way it should look like. The playing field was placed in center as it is not as big as in the original version, and the shapes were positioned above the field, for an easier visualization and a more convenient way to interact with them. Unlike the *Tetris* unicolor design, Trinos was made based on a *color pallet* including seven different colors (Figure 3). It was thought, that a colorful interface, would make the game more dynamic by offering an attractive and lively look.

Fig. 3 Color palette for designing the game interface

For designing the interface and the rest of the game elements, the *Adobe Illustrator* software was chosen. It was the most suitable program to use, as it allows to create vector images that can be scaled up and down infinitely without losing the quality (Rowan, 2014). Also, it offers the possibility to save images in different formats (.jpg, .png and others) which facilitates the process of exporting the necessary data for further development.

4.1.1 Game Rules

One of the game's scene includes an overview of the games rules. This was done in order to offer the players a better understanding of how the game needs to be played. The rules scene could be accessed from the main menu, by pressing the *RULES* button. As the main goal of the game is to earn as many points as possible, the established rules intends to teach the players how to score higher.

Three different screens with intuitive illustrations were created, in order to explain the basic game rules. The navigation between the scenes was possible by swiping horizontally on the screen. For monitoring the current rule scene, three rounded buttons were added at the bottom of each screen. Thus, the rules were formulated as follows:

- Match the same tiles (Figure 4a.)
  - When matching two tiles with the same number of spots on them, they disappear and their sum is added to the total score
- Rotate the piece (Figure 4b.)
  - When pressing on the rotating button, the shape rotates 90 degrees clockwise
- Fill up a line (Figure 4c.)
  - When a line is filled up with shapes, it disappears and all the point are added to the total score

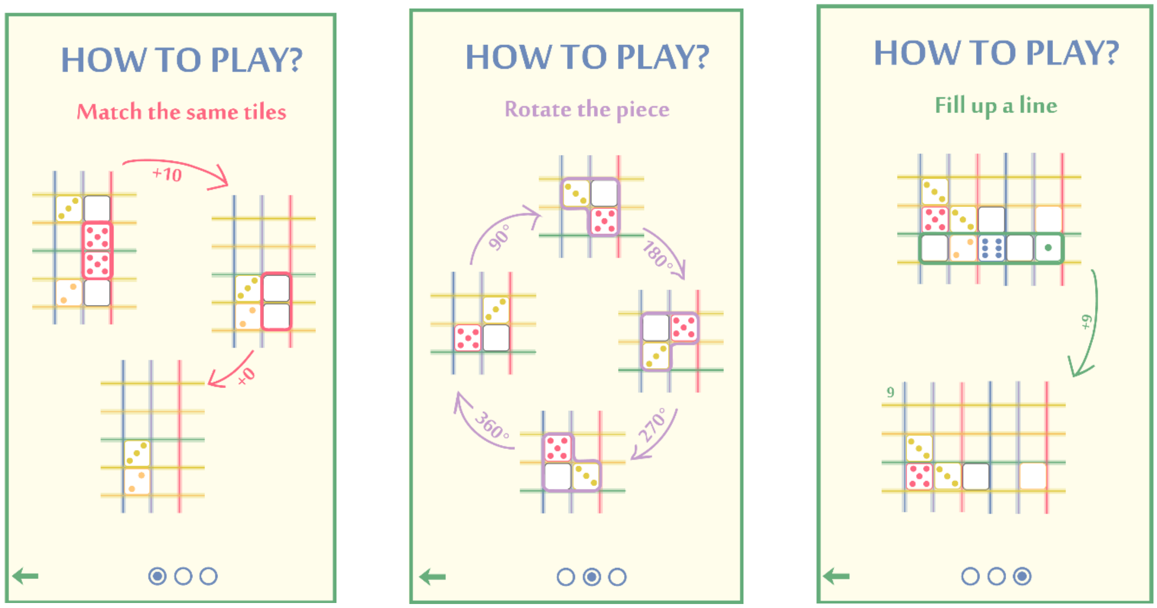


Fig. 4 (a, b, c). The illustrations of the rules scenes

4.1.2 Game Controls

The way players interact with the game environment is fully managed by the game control methods. More specific, each game has its own control methods that depends on the devices on which the game will be running. Therefore, in order to decide what kind of controls needs to be created for Trinos, it was necessary to settle the device on which the game will be tested on.

As mobile phones are the most common devises on which games like Trinos are running on, and because the original *Tetris* game was also mostly played on hand held devises, it was decided that the game will be played on a smartphone. Thus, the handiest method for interaction with the game was thought to be based on touch screen feature of the device.

Because the playing field occupies a small area of the background, there remains enough space for placing the control buttons at the bottom of the screen. In this way, the buttons could be easily pressed during the game play, while holding the phone with both hands. Four *rounded rectangles* with specific drawn arrows were created and positioned near to each other (Figure 5).

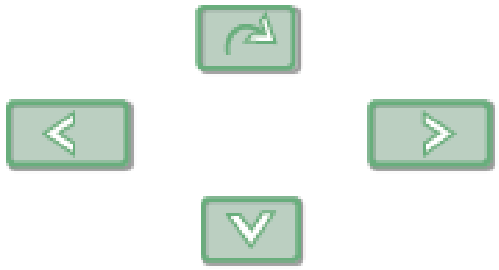


Fig. 5 Game controls

The left and right arrows moves the shapes to the left and right within one cell, the down arrow drops the shapes down and the rotate button turn the shapes 90 degrees clockwise. The colors were consistent with the rest of the design by combining green and white for a better contrast.

As the game allows the players to choose the most promising shape out of three available to be falling on the field, one more button for this feature needed to be implemented. It was thought that the most intuitive method for interaction with the shapes is by pressing on the desired one. This would facilitate the choosing process and would keep the design clean and easy to follow by avoiding to add another button.

For interrupting the game play session, a green arrow with “back” function was added (Figure 6a.). By pressing it, the game is paused and the newly appeared window offers the options to continue, restart or quit the game (Figure 6b.). These possibilities help players to control and play the game in their own way.

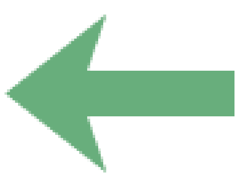


Fig. 6a. Back button

Fig. 6b. Option menu

4.2 Technical Development

As the goal of the project was to create a puzzle game, *Unity3D* game engine was selected as the primary tool for development. This specific software was used, because it combines a powerful visual editor and the possibility to change objects behavior through scripting (Geig, 2013). *Unity3D* supports three programming languages: *C#*, *UnityScript* and *Boo*, and since *C#* is the only mainstream language, all the coding was done in it. Another benefit of using this specific software, was that it allows to build the project for multiple platforms: PC, Mac, Android, iOS and others. This offered the flexibility in the testing process, as a single project could run the same on different devices.

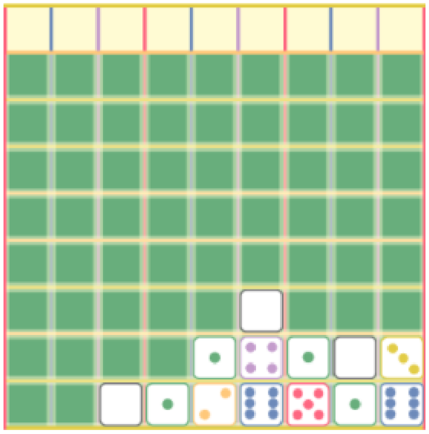
The technical development process was divided in two parts, one of them referred to the playing field and shape controls, and the other one is related to the algorithm behind earning points. Therefore, the next subsection aims to explain how the game was made from a programming point of view.

4.2.1 Playing Field and Shape Controls

As settled from the beginning, the shapes were made up from three square blocks (two with spots and one blank) arranged as a line or as a corner. Therefore, 144 possible combinations were constructed and stored in an array. The shapes were represented as strings with established configurations. "l" or "c" standing for the shape's form (line or corner), followed by three numbers which represents the number of spots on each block. Based on these strings, the actual falling shapes were created and available in game in a random order (Figure 7).

Fig. 7 Shape storing

The playing field was thought to be represented as a nine by nine matrix, called *landed*, in which the current state of the field was stored. Every falling shape that landed, was memorized in the matrix, at its corresponding position (Figure 8). This representation facilitated the access to the shapes, because it offered a convenient visualization and tracking of the changes on the field.



```
[[-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1,-1,-1,-1,-1],
 [-1,-1,-1,-1,-1, 0,-1,-1,-1],
 [-1,-1,-1,-1,  1, 4, 1, 0, 3],
 [-1,-1, 0, 1,  2, 6, 5, 1, 6]]
```

Fig. 8 The playing field and its matrix representation. -1 corresponds to an empty slot in the matrix

Once the player chose a shape, it starts to fall down, until it reaches the bottom of the board, or another shape that was already positioned. In order to control this movement, a custom script was assigned to the shape in order to check, if the falling is possible.

```
public int[,] shape = new int[2, 2] { { 1, 1 }, { 0, 1 } };
public int[] potential = new int[2] { 2, 3 };
for (i = 0; i < shape.GetLength(0); i++)
      {
          for (j = 0; j < shape.GetLength(1); j++)
          {
              if (shape [i, j] != 0)
              {
                   if (landed[i + potential[0], j + potential[1]] != -1)
                   {
                       occupied = true;
                   }

               }

           }

       }
if (occupied==false)
      {
          shape.FallDown();
          potential = new int[2] { potential[0]++, potential[1] };
      }
```

The starting position of each falling shape, was pre-established with the [1, 3] (first row and third column) coordinates for the top-left square of the shape, and *potential*, in this case being [2, 3], which are the coordinates after a potential move down. The code above is called every half a second, for looping through all the positions in the *landed* matrix in order to find the new potential position for the shape. This was done with the help of the shapes configuration, which is composed of 1 if occupied, and 0 if empty. While the *occupied* variable remains false, the shape falls one row down, and the checking starts again, otherwise, the falling stops, and the shape is placed. The same checking process is followed for implementing the shapes' movement (left, right and rotate).

4.2.2 Matching Blocks and Filling up Lines

In order to score, two possible methods of earning points were implemented, matching blocks with the same number of spots, and filling up a line. The block matching was done using the *FindSameBlocks* function, which is called with the *indexes* variable that contains the coordinates of the blocks that landed recently. For each block, the *FourNeighbors* function searched for neighbors that had the same number of spots, and when found, added them to the *neighbors* list. When all the neighbors were checked, the elements from the *neighbors* list were deleted and the number of spots are summed and added to the total score.

```
void FindSameBlocks(int[][] indexes)
    {
        List<Transform> neighbors = new List<Transform>();

        for (int i = 0; i < indexes.GetLength(0); i++)
        {
            int[] start = indexes[i];
            int number = landed[start[0], start[1]].number;
            FourNeighbors(start, number, neighbors);
        }
        if (neighboors.Count > 0)
        {
            DestroyBlocks(neighbors);
        }
    }
```

The line filling up feature was done by looking at each row of the playing field, and checking if it is fully occupied with blocks. The *CheckRow* function was called after the *FindSameBlocks* function was finished, and it inspected if every cell of a row, contained a block.

If yes, the row was cleared and all the spots from the blocks were added to the final score, otherwise, the function looked at the next row.

```
void CheckRow()
    {
        for (int i = 0; i < landed.GetLength(0); i++)
        {
            bool full = true;
            for (int j = 0; j < landed.GetLength(1); j++)
            {
                if (landed[i, j] == null)
                {
                    full = false;
                    break;
                }
            }
            if (full)
            {
               DestroyRow(i);
            }
        }
    }
```

These two functions (*FindSameBlocks*, *CheckRow*) are called every time a new shape lands, and results in changes on the playing field, as after every score, block squares disappeared, and the ones that remained above, fell down.

In order to update the current state of the playing field, the *Flood Fill*[1] algorithm was implemented as a search method for finding clumps (a group of several blocks) that needs to fall down after a line completion or block matching.

```
void FloodFill(int i, int j, Clump clump)
    {
        if (i - 1 >= 0)
        {
            if (landed[i - 1, j] != null)
            {
                 clump.clumpShape[i - 1, j] = landed[i - 1, j];
                 FloodFill(i - 1, j, clump);
            }
        }
        landed[i, j] = null;

    }
```

[1] An algorithm that determines the area connected to a given node in a multi-dimensional array

The presented part of script shows how the algorithm works for blocks in the up direction. The *FloodFill* function with the parameters *i, j* (block coordinates) and *clump* (structure that will contain all the blocks that need to fall down) is called every time a block disappears. The search process begins by checking if there is a block in a neighbor cell, and if found, it is added to the *clump* and deleted from the *landed* matrix. The searching process is called recursively with the coordinates of the newly found neighbor, and results in obtaining all the connected blocks that need to fall down.

5 METHOD

This section aims to describe the way the project was conducted and what methodologies were approached. First part consists of a brief overview of the data gathering process and the involved target group. The second part follows with a more insightful view of the testing procedure, which includes details about the test setup and the required series of steps. Therefore, this part of the report intends to show *what* was done and *how* it was conducted.

5.1 Participants

The current research was conducted in order to investigate the effect of a puzzle game on players' spatial skills and math abilities. The connection between math and space is well documented (Jordan, Kaplan, Ramineni and Locuniak, 2009) and is especially related to children from early grades (Cheng and Mix, 2014), when differences in spatial skills development occur and can be observed (De Lisi and Wolford, 2002). Moreover, since spatial skills are not an explicit part of the curricula, it was beneficial to bring a way of training this in a school environment, as it helps children to develop alternative strategies when solving mathematical problems.

A class of 20 children from *Esbjerg International School* participated in the testing process. A total of 12 boys and eight girls with the age between eight and nine years old (Figure 9) together with their teacher were involved. However, the final data was considered only for 17 participants, as three children did not take place in all the testing procedures. Being an international school, the class consists of children of different nationalities with a variety of educational backgrounds. The teacher had a significant role, as she guided the children during the testing procedure which made them feel more comfortable.

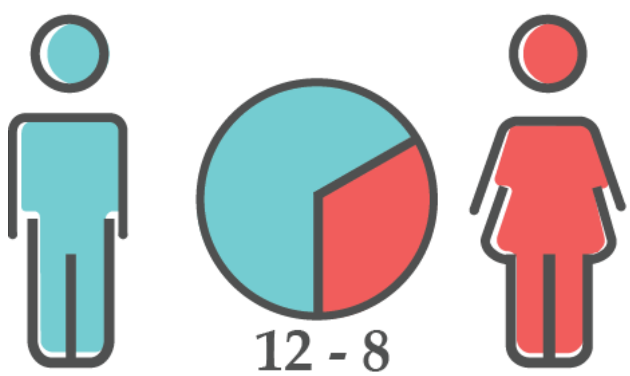


Fig. 9 Gender Distribution

5.2 Materials

In order to answer the proposed research questions, it was necessary to assess participants' level of spatial skills and math abilities. As the project had a comparative character, the assessments were done before and after the training period. Two tests were used for measuring the mental rotation and mathematical skills of the children. Therefore, this section contains details about the test materials that were utilized in the testing process.

5.2.1 Mental Rotation Test

Being a component of spatial skills (see 3.1), mental rotation abilities can be measured using several different types of tests: performance tests, paper-and-pencil tests, verbal tests and film or dynamic computer-based tests (Lohman, 1996). As the paper-and-pencil test is the most frequently used, the same type was used for this research.

The Card Rotation Test developed by French, Ekstrom and Price (1963) was chosen to be used as a tool for measuring mental rotation (MR) accuracy. The original version of the test has 112 items where each of them is displayed in rows. A standard figure is at the left margin, followed by a series of its variations that are either rotated or mirrored. Given the figure to the left, the participants need to check whether the figures are the same (S) of different (D) (Figure. 10).

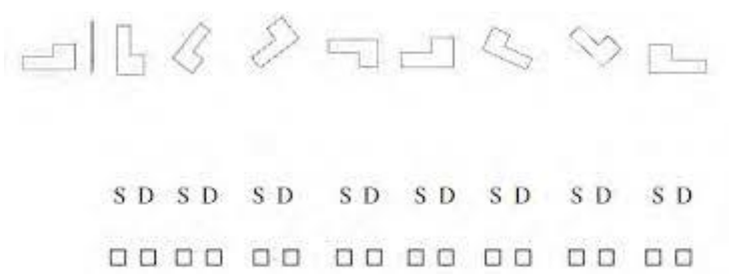


Fig. 10 Card Rotation Test Example

As the participants were young children, some modifications were done in order to fit their age, in a similar way to De Lisi and Wolford (2002). The test was shortened to 39 items, with each figure being paired with only one comparison figure. Therefore the children were given a seven pages test, with six pairs per page, and the first page proving a three pairs warming-up phase. The figures were of three types, and assembled a total of 19 "same" and 20 "different" items (Figure 11).

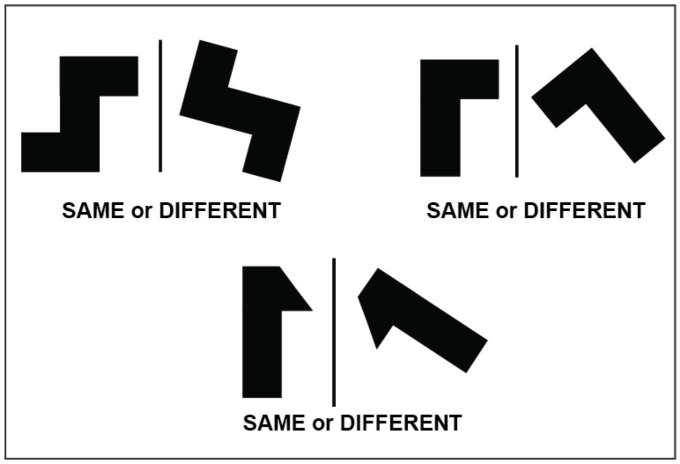


Fig. 11 Warm-up MR test page

5.2.2 Math Exercises

In order to measure children's level of math, a set of 27 addition and subtraction exercises were formulated (Appendix A). The problems were of three types: single-digit problem (e.g. 14+9=_), double-digit problem (e.g. 46-15=_) and missing term problem (e.g. 15+_=33), alike Cheng and Mix (2014). On the paper, the exercises were written in a random order, so the children would not get too used to a specific type of problem.

5.3 Test Setup

The game for this project was developed and designed to be running on a hand held device (smartphone or tablet). Thus, the first thought for organizing the testing process was to use the school's tablets. However, we did not take in consideration the fact that our game, needs a license for being installed on iOS[2] devices. That is why, the school's tablets (iPads) could not be used and it was necessary to reconsider the initial test setup.

As the testing was thought to be carried out with a whole class of children, it was important to stick with their schedule. Being in the 4th grade, their day was organized with activities and a new task for them would interfere with their usual program. Therefore, their teacher suggested to use the ICT[3] laboratory, as it is a big class with enough computers for every child. Moreover, the

[2] iOS – mobile operating system created by Apple
[3] ICT – Information and Communications Technology

ICT teacher agreed to share the room during breaks and even conducting the testing at his lessons. Thus, the lab computers appeared to be the best option for testing the game.

The initial version of the game, could not be used for the computer system, that is why, some changes in the game design and mechanics were required. The previous touch screen buttons were transformed to work with mouse clicking, and the movements were adapted for the computer's keyboard. The game window was kept small and not full screen, in order to save the original ratio of the initial design. With the final changes implemented, the game was installed on each computer and was ready for being played.

5.4 Procedure

Based on Uttal et al. (2013), a study that trains spatial skills must endure longer than a few days, in order to provide valid results and must follow several criteria:

- The study must have at least one spatial outcome performance measure
- The study must try to improve the performance on a spatial task
- The study must use a pretest and posttest for assessing the outcome differences
- The study must be focused on a nonclinical population

Therefore, the current research followed the above-mentioned criteria for sustaining the trustworthy value of it. Further, the testing procedure is described by presenting the completed steps which are in line with the Uttal et al. (2013) guidelines.

It was decided to conduct the testing process for a period of one school week with an amount of 20 participants. The playing time was settled to be at least 15 minutes a day during the teacher's pre-established time plan.

For the pretest, the participants had to solve the MR test and Math Exercises (see 5.2). The activity took place in their school's "homeroom" which made them feel comfortable and kept them focused. The MR test was the first to be administered and started with a warm-up session. The children were given instructions for understanding the logic of the test, by explaining the first sheet of paper that had three warm-up examples (one from each figure type). The teacher guided the children during the test and helped the ones that had questions or misunderstandings. The test completion took about 3 minutes after which the papers were collected, and the second test was prepared. The math exercises were given to the children without any instruction, as they are familiar with such tests. The completion took 3-4 minutes, as some of the children finished faster.

After the pretest, in the same day, the children were led to the ICT laboratory. As stated in Test Setup section, the Trinos game was installed on each computer, so each child can play individually on his own machine. In order to present and explain the game, the children were offered a brief tutorial of how to open and start the game. After the main rules were showed, the children started to play. During the playing sessions, each player’s score and name was saved in a local file, so it could be analyzed afterwards.

The posttest took place after four playing days, in the same day with the last game play session. The children completed the same tests as at the pretest (MR test and Math Exercises) and the data was collected for the following comparison. As a reward, the children got sweets and were thanked for their participation.

6 RESULTS

The collected materials were gathered in a big database and structured for further analysis. As there were multiple data sources, each of them was stored in a separate spreadsheet and was examined individually. Therefore, this section will present the obtained results, by unveiling the acquired findings through diagrams and outcome measures.

6.1 Mental Rotation Test Outcome

The same MR test were given to the children at the pretest and posttest sessions, and after their completion, the papers were collected and the total number of correct and wrong answers were counted. In order to create an overview of the obtained results, the data was stored into an Excel[4] table where the columns represented the items number and the rows stood for the participants' number. For each item, from both pretest and posttest, the corresponding participants' answers ("S" or "D") were saved and the total of correct answers were counted with Excel function *COUNTIF*. The resulted findings were summarized and illustrated in the chart below (Figure 12).

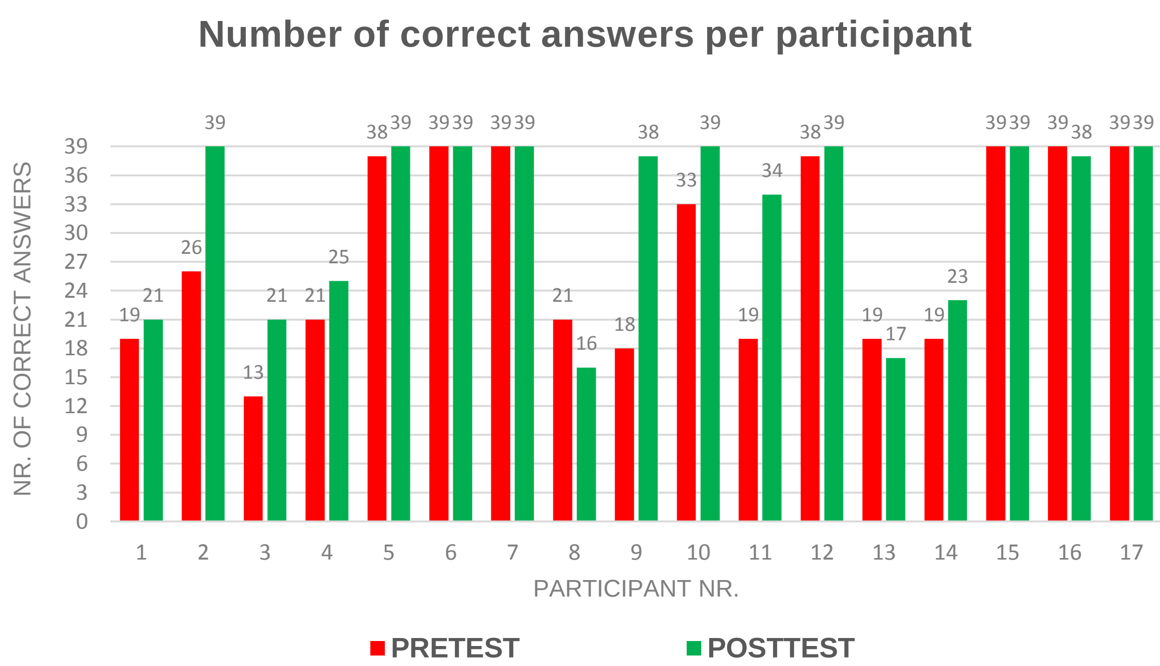


Fig. 12 Pretest and Posttest results from MR tests

[4] Excel – spreadsheet application developed by Microsoft

From the graphic above, it can be seen that, the majority of the children (64.7%, 11 out of 17) chose the right answer for at least half of the items at the pretest session. A higher percentage (88.2%, 15 out of 17) was observed at the posttest, with an increase of 23.5%. Thus, a total of 10 children had an increased score at the posttest, only three participants had a decreased score and four of them got the same score which was the highest possible. In the end, the total percentage of correct answers were 72.2% versus 82.2% in favor of the posttest results.

6.2 Mathematic Exercises Results

In order to measure children's level of mathematics, math tests were given, both at the pretest and at the posttest sessions. The tests had different exercises, but kept the same exercise types and the same level of difficulty, so the results would be more valid, as the children could not remember answers from previous test. The collected tests were checked and the answers were stored in a database and synthesized after. A similar chart as the one for MR test was constructed, and it aims to illustrate the obtained results, by showing participants' number of correct answers from both pretest and posttest, for a better visual comparison (Figure 13).

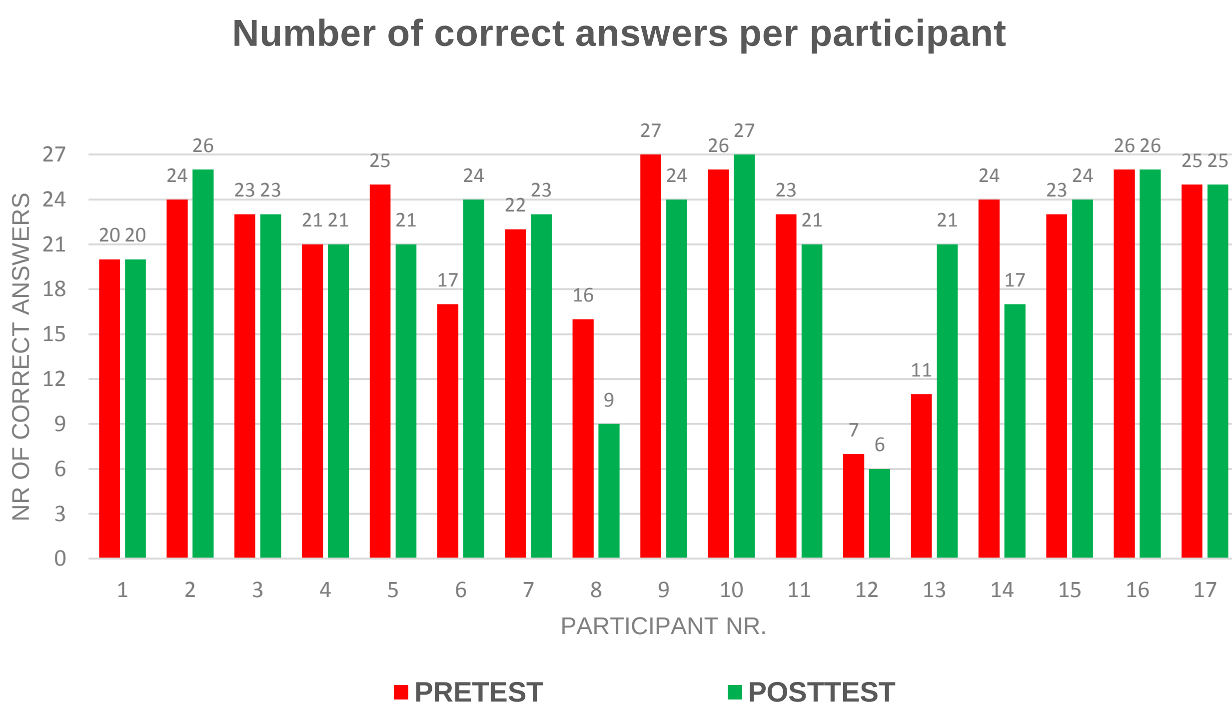


Fig. 13 Pretest and Posttest results from Math Exercises

One of the predominant facts that can be observed from the above chart is that the majority of the participants had a high level of math abilities as 13 of them (76.4%) solved correctly at least 20 out of the 27 exercises at the pretest session. The posttest session resulted in a slightly increased outcome, as 14 (82.3%) participants solved more than 20 exercises correctly. All in all, after comparing the results, it was found that five participants kept the same score, six of them saw an increase in their results and the remaining six participants had a decreased result. Therefore, the final results revealed a difference of 0.4% in favor to the pretest results (78.4%) when comparing to posttest (78.0%).

6.3 Game Scores

During the training sessions, the participants' score for each game play were saved in a separate file. This was done in order to monitor the players' progress over the testing period, as one of the proposed research question intends to find out if there is any correlation between the game score and children's math abilities.

Usually, the children played more than one time a session, as they could not survive until the end of the game, or the game was over or other technical problems. Therefore, for the final data only the proper scores were selected, so there would not be erroneous results. In the end, the obtained scores were averaged per participant for each playing day and the graph below illustrates the findings (Figure 14).

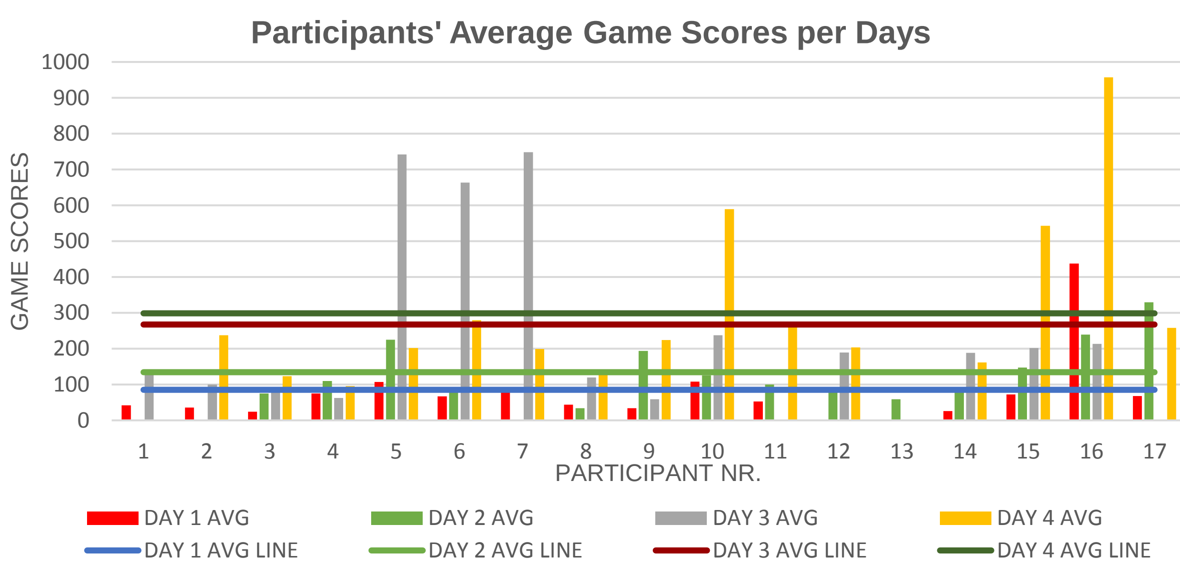


Fig. 14 Participants' Average Game Scores per days

Some of the participants do not have game scores for each day which means that they were absented on that day and did not play the game. Thus, a total of 10 out of 17 participants played the game all four days, five of them played the game for three days, and only two children played the game less than three days.

More observations can be made by looking at the chart's average line. For the first day, the average score was the lowest (84.7), as the players acquainted themselves with the game, however the player number 16 got a 437 score on this day. The second day average scores were 134.4 with the average line being closely situated to the first day, but positioned above it. The day number three revealed a significant progress, especially for the participant number five, six and seven which got their high scores. For the final testing day, the average score was the highest (298.5), as it can be seen from the average line that is situated on top of the other days.

7 ANALYSIS

In order to prove that the obtained results did have a statistical significance, the data was analyzed with several statistical tests and the revealed findings are described in the section below. The results from MR tests and math exercises were tested for both conditions (pre and post) to observe if there is any relationship between the two of them or they were obtained by chance. Furthermore, the correlation between the game and tests scores was calculated and is illustrated beneath.

7.1 Data Analysis Using Statistical Tests

As a first step in starting the statistical analysis of the data, was to find out which tests are appropriate to perform. For this, it was important to know how the data is distributed, as this is one of the requirements when choosing a specific test and getting reliable and valid outcome.

The three common procedures for assessing the distribution of a dataset are: graphical methods (boxplots, histograms), numerical methods (skewness and kurtosis) and formal normality tests (Razali and Wah, 2011). For the current project, the Shapiro-Wilk (SW) test was chosen to be used in order to check the normality of the distribution, as it was found that this test is the most powerful for all types of distributions and sample sizes (Razali and Wah, 2011).

The SW test is based on the null-hypothesis principle and checks whether a sample $x_1, \ldots, x_n$ comes from a normally distributed population. The null-hypothesis of this test is that the data is normally distributed and in order to reject or accept it, the necessary calculation needed to be done. Thus, for both the MR test dataset and math exercises, the p-value was calculated (MR pretest 0.002; MR posttest 0.0003; math exercises pretest 0.007; math exercises posttest 0.001) and it was smaller than the chosen alpha level ($\alpha = 0.01$) Therefore the null hypothesis was rejected and it was concluded that both datasets are not normally distributed. As a visualization for the obtained normality of the datasets, the below histograms were created (Figure 15).

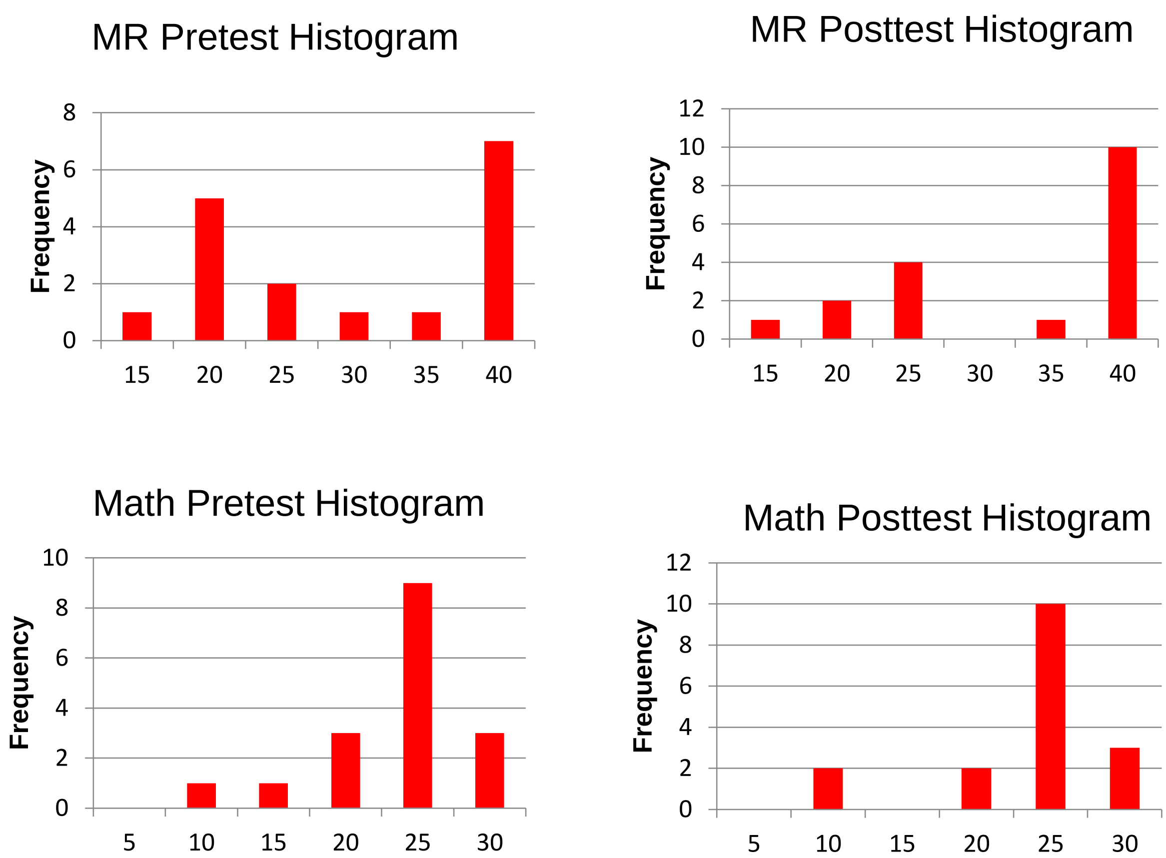


Fig. 15 Histograms for the Math and MR test scores distribution

A histogram is a graphic representation of the output of the FREQUENCY function, which is a summary table that shows the count of each value in a range. In order to have a normally distributed sample, the histogram needs to have a "bell" shape with the peak positioned in the center (Tague, 2005). Therefore, from the figure above, it can be seen that the histograms for the MR tests are opposite of the bell shaped figure because of the dates frequency, and the other two histograms, for the math tests, have a bell shaped form but are left skewed. This means that both datasets are not normally distributed and the histograms serve as a visual proof.

Once the distribution of the datasets was found, the only type of tests that could be performed were the non-parametric ones. The non-parametric tests are hypothesis tests that are useful when the sample is strongly non-normal and resistant to transformation (Understanding nonparametric tests, 2016). For checking if there is any statistical significance in the MR test and Math Exercises results the Wilcoxon signed-rank test was used.

The Wilcoxon signed-rank test is non-parametric statistical hypothesis test that is used when comparing two related samples, or repeated measurements on a single sample, to evaluate if whether the mean ranks of the population differs (Woolson, 2008). The test was applied separately on each dataset (MR test and Math Exercises), by comparing pretest scores with posttest.

Firstly, the null hypothesis was formulated, and it stated that the two groups of data are not different, i.e. there is no significant difference between the two scores, more specific, the training session did not influence the final outcome. For rejecting or accepting the null hypothesis, the W statistic needed to be calculated. This was done throughout several steps:

1. The DIFFERENCE column was calculated (the pretest values were subtracted from the posttest values).
2. The difference scores were ranked in ascending order, based on their absolute values and written in a new column named RANK.
3. The SIGNED RANK column was computed by assigning "+" or "-" sign to the values from RANK column based on the values from the DIFFERENCE column. In particular, the values sign from DIFFERENCE column was passed on to the values from the new SIGNED RANK column.
4. The W statistic for the Wilcoxon signed-rank test was defined as the smaller of the W+ (sum of all positive signed ranks) and W- (sum of all negative signed ranks).
5. The W statistic was compared with the critical value of W which was read from the Wilcoxon signed-rank test table.

After completing the above stated steps, the Wilcoxon signed-rank test revealed a significant difference between the two MR tests scores (Appendix B). The null hypothesis was rejected with a probability of 95%, as the obtained statistic $W = 14.5$ with $p < 0.05$, is smaller than its corresponding critical W value of 17. This means, that the obtained results did not occur by chance, but were indeed influenced by the playing sessions.

For the math exercises dataset the same Wilcoxon signed-rank test was applied, and the findings differed from the MR test results (Appendix C). The null hypothesis was accepted with the statistic W= 35 for $p < 0.1$ which is bigger than the critical W value of 17, which means that the obtained data could have happened by chance. Therefore, it cannot be concluded that the training process did have any influence on children's results on the post test.

7.2 Correlation between Data

In order to find if there is any correlation between the game scores and posttest outcome, the Spearman's Rank Correlation coefficient was used. Because the data is not normally distributed, this coefficient was the most appropriate to use, as it is a non-parametric measurement of statistical dependence between two variables (Pirie, 1988).

For each participant, their average game score for all the days was computed and correlated with the posttest results of the MR test and math exercises. The procedure of calculating the correlation between the datasets was carried out as follows:

1. Calculating the ranks values with the RANK.AVG function from Excel. Each sample had a corresponding RANK column where the data was stored.
2. For every pair of columns (Math Posttest/Game Score and MR Posttest/Game Score) the difference between ranks was determined in the DIFFERENCE column.
3. The DIFFERENCE column was squared and the results were placed in the SQUARED DIFFERENCE column
4. The values from the SQUARED DIFFERENCE column were summed up in a separate variable ($\sum d^2$).
5. The Spearman's Rank Correlation formula was applied, where n is the number of values in the sample.

$$1-\left(\frac{6 * \sum d2}{n(n * n-1)}\right)$$

In the end, it was found that the Math exercises results and game scores are moderately positive correlated, with the Spearman's Rank Correlation coefficient being 0.47 and p-value = 0.054 (Figure 16).

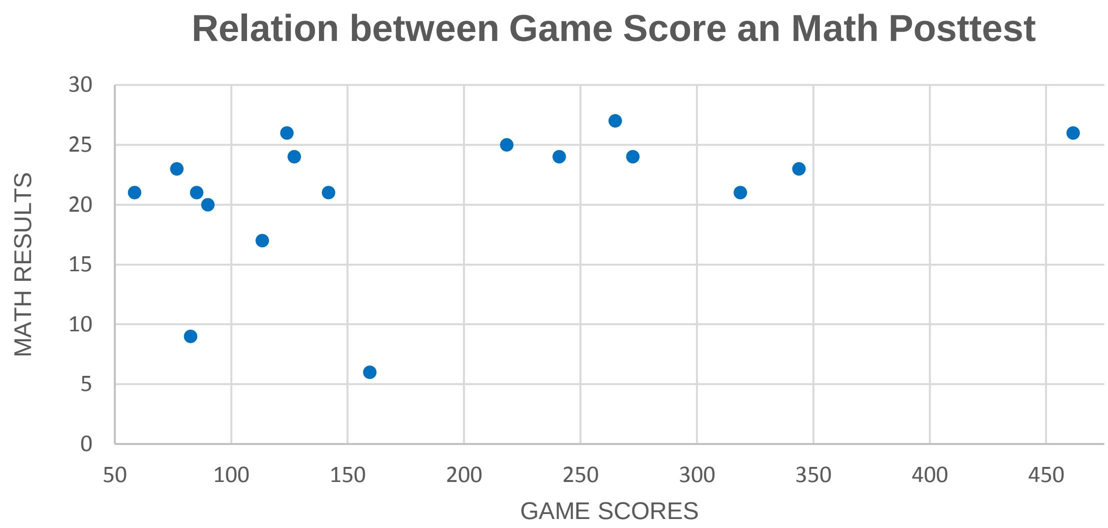


Fig. 16 Scatter plot of the relation between game scores and math posttest

As it can be seen from the figure above, the relationship between X axis and Y, in this case game scores and math results are shows a uphill linear pattern but the points are somewhat scattered in a wide band. This means that when one value grows, the other one is growing accordingly.

For the case of MR test and game scores, the results of the correlation test showed that the two dates are strongly positive correlated, with a coefficient of 0.79 and p-value = 0.0001 (Figure 17).

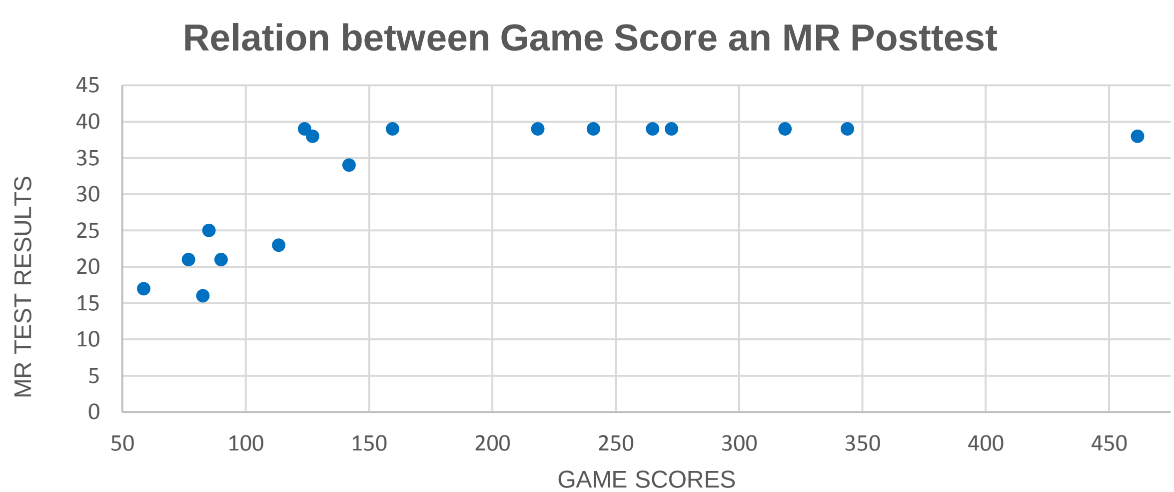


Fig. 17 Scatter plot of the relation between game scores and MR posttest

The same type of plot was constructed for the second pair of samples, and the representation shows a strong uphill linear pattern (steeper than in the Figure 16), which corresponds to a higher correlation coefficient.

In the end, it can be inferred that the MR test results are more closely correlated to the game scores, as it has a higher correlation coefficient value while the math results are less correlated with the game score. As a conclusion, it can be stated that a high game score predicts a high result in children's mental rotation skills. On the other hand, the same high game score cannot predict with the same precision a high level of math abilities, as the correlation coefficient is smaller.

8 DISCUSSION

After developing the game and conducting the testing process, the results and their statistical analysis were done. The revealed findings needed to be discussed and referred to the rest of the report. That is why, this section was structured in order to present and clarify some of the arisen aspects. The first paragraph will relate to the similarities and differences between the outcomes of this project in consistency with the ones stated in the related work section. Subsequently, the next paragraph follows with a description about the benefits and limitations of the utilized methodology. After what, the last two subsections intends to explain the encountered problems throughout the developing process of the project and what could be the solution for implementing in the future work.

8.1 Consistency with the Related Work

The foundation of this project was created based on several related works that investigated similar research questions as ours. As stated above, Trinos intended to train children's MR skills, which afterwards would led to improvements in their math abilities. With these proposed goals, the expectations were to obtain similar results as in the related works. To what extend does our findings resemble the related ones, is presented further in this paragraph.

Okagaki and Frensch (1994) investigated the relation between game play and spatial skills by using *Tetris* and pre/post tests for measuring participant's spatial abilities. The same assessment tools were used in our project, just replacing their game with Trinos which is basically a variation of the same classic *Tetris*. Their findings proved that a spatially oriented game does have potential to improve late adolescents' mental rotation skills, which are in line with our results, that showed improved MR scores at the post test than at the pretest, even if our participants were younger children.

The second study conducted by De Lisi and Wolford (2002) examined the effects of repeated *Tetris* game play sessions on participants' mental rotation skills. Their testing process revealed evidence that sustain the positive benefits of *Tetris* games on the MR abilities. The training period with Trinos also resulted in improvements, as the final scores showed a significant difference favoring posttest over pretest. Moreover, as the testing procedure was based on the same paper-and-pen MR tests and targets the same age group, the similarities between the obtained results can confirm the useful value of Trinos as a game that indeed trains players' spatial skills.

To test the connection between mathematics and spatial abilities, Cheng and Mix (2014) carried out a study in which participants were pre and posttested for measuring their math level. In contrast to our study, they trained the spatial skills using one 40 minute training session that consisted of tasks that practiced mental rotation. Moreover, their target group was children of 6 to 8 years old, while our participants had 8 to 9 years. This dissimilarities led to difference in the final results, as they saw an increase in math performance, whereas our findings revealed no significant difference. The reason behind this could be based on the training procedure, as their method trained directly mental rotation with specialized tests, but Trinos, like *Tetris*, had an indirect impact, by providing tasks that could be solved, not necessarily with MR abilities. Also, their testing group may be more malleable to training, as they are of a younger age, while our participants had already a high developed level of math.

The last related study by Yeh, Cheng, Chen, Liao and Chan (2010) developed a game that aimed to facilitate students' arithmetic computation. As a primary feature, their game used numbers in a similar manner to regular exercises, because they needed to be summed up to ten, whilst in Trinos the only math were in the earning points process. Thus, the math training with their game was more straightforward, while the spatial skills took a back seat, as only the spatial visualization were invoked. With all this stated, their *EduTetris* had an impact on participants' speed, but no so much on their overall score, which is similar to our results, that did not show much improvements in children's math performance.

8.2 Benefits and Limitations of the Utilized Methodology

It is known that all the studies that involves testing with participants need to take in consideration the margin of error in the obtained results, as it can influence the value of trustworthiness. As stated by Niles (2006), the bigger the sample size is, the smaller the margin of error becomes. Our project targeted children with the age between 8 and 9 years old, so when searching after participants, we found only one class of 20 children from *Esbjerg International School*, as they had no more, that fitted our need. Therefore, from the beginning it was known that the margin of error would be a high one, even more so, when the final number of participants fell to 17, as not all the children could take part in both pre and post testing sessions.

The utilized materials that were given to the participants in the pre and posttests included MR tasks and math exercises. In the case of the MR, the modification of the original Card Rotation Test (French et al., 1963) was an appropriate one, as it contains less figures than the original and offered pairs of only two shapes for comparison. In this way, children could easily comprehend the task and could solve it quicker. On the other hand, the drawback of the proposed math exercises was the level of difficulty. Because, the exercises were made without the teacher's input, the obtained test did not present a big enough challenge for the children to solve, and this was seen in their responses at the pretest session. Thus, this influenced the posttest results, as the scores did not grow because of the children's already high level of math.

In regards to the research design, the testing process of the project implemented the *within-subjects-only* design (Uttal et al., 2013). More specific, a single group of participants were tested before, and after the training session. The limitation of this methodology was the lack of a control group that would provide more precision to the final measurements of the found improvements. Moreover, as Uttal et al. (2013) stated, the absence of the control group could lead in confounding the training and retesting effects. However, we chose the *within-subject-only* design because it was more appropriate to work with, based on the participants. By having only one class of children that would play the game in the same class, dividing them in two separate groups, would distort the established procedure, as there would be a need to have two separate classes for playing or to set different playing hours for each group. Also, if dividing the class in two groups, the training group would consists of 10 children only, which would be a too small number for gathering enough results.

The data was collected by approaching a quantitative method. Pre and posttests for measuring both MR and math abilities were used as primary materials, which allowed flexibility in the treatment of data, in terms of statistical analysis. As the proposed research questions could be answered only with quantitative materials, no interviews or observations were made, as they were not significant for the proposed goals. However, because of some abnormal results (participant number 12 with very low score for both math tests, and participant number 8 and 14 with a strong decrease in their math scores) the entire dataset was affected. That is why a qualitative approach would have helped in terms of finding out the reason behind this cases. If interviews would have been conducted, the participants would get a chance to explain their experience, from which we could deduce a possible explanation for their scores, and take this into account when analyzing the entire sample.

8.3 Future Work

Based on the encountered problems and above stated limitations of the used methodology, possible solutions for future implementation arose and are described in this paragraph.

In order to get a more accurate result, with a smaller margin of error, a bigger number of participants would help, as it would offer a more complex data which could reveal more observations and wider conclusions. Collaboration with several schools could offer the opportunity to find more participants from different environments that would experience the game differently. If a bigger testing group could be found, the possibilities in the research design would also grow, and this would give the possibility to apply the *mixed* method design which includes a control group and a more precise result.

Another possible improvement for the testing procedure could be made to the training period. In our project, the training process took place during four days, as this was the most suitable period for the children and also for the teachers. When testing with a whole class of children that already have a well settled schedule, it is important not to disrupt too much their agenda and still include your activity as a regular task in their graphic. However, a longer period of training, could offered more benefits, as it would developed children's playing skills more and this could lead to a higher level of gained MR abilities and math improvements.

9 CONCLUSION

The project's main goals were to investigate the impact of a *Tetris* like game (Trinos) on children's mental rotation (MR) skills and mathematic abilities. More specific, the game itself was created as an educational aid, by providing numerical content and requiring spatial abilities (rotation of the shapes) in order to succeed in game play. In order to answer the proposed research questions, the testing procedure was carried out, during which the necessary observation were made and the data was gathered. After analyzing the obtained results, the following conclusions were formulated. The main research question was

To what extent, can a puzzle game that involves spatial skills, affect players' competences in mathematics.

The developed game, Trinos, had an insignificant impact on players' mathematics competences, based on the conducted testing procedure. The posttest scores were not increased, and even saw a decrease of 0.4%. Therefore, based on our testing group, a *Tetris* like puzzle game, cannot be concluded to influence children's level of math abilities, by providing mainly spatial skills training.

In what way can the game playing sessions influence the spatial abilities of the players?

In regards to spatial skills, the game had a positive effect, on children's mental rotation abilities. After the training session, children's measurements of MR showed an increase of 10% favoring the posttest. Moreover, Wilcoxon signed-rank test proved with 95% probability that this difference did not occur by chance, but was influenced by the playing sessions.

Is there any correlation between game score and math/MR test score?

Based on the Spearman's Rank Correlation coefficient, it was found that the game scores are moderately correlated with math results, as the coefficient was 0.47. On the other hand, the coefficient for game score and MR tests results was bigger, with the value being 0.79. This means that the game score is a better predictor for the MR level than for the math abilities.

Although the outcome of this project did not answer positively to the main research question, it is encouraging in the case of spatial skills training. By having a game that trains mental rotation skills through playing, with improvements after four days of testing, it can be inferred that further investigations can results in improvements upon mathematics as well. However, it is worth mentioning that the acquired findings are based on a sample of only 17 participants, which is not enough to define a trustworthy results. That is why the formulated conclusions cannot be used as a generalization for bigger samples.

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APPENDIX A

Mathematic exercises test

1) 14 + 9 = _____

2) 25 + 18 = _____

3) 18 - _____ = 11

4) 46 – 15 = _____

5) 43 – 6 = _____

6) 28 + 17 = _____

7) 13 - ______ = 6

8) 9 + 8 = _____

9) 41 – 18 = _____

10) _____ + 17 = 29

11) 39 + 27 = _____

12) 16 – 7 = _____

13) 43 + 19 = _____

14) 15 + _____ = 33

15) 33 – 15 = _____

16) 9 + 29 = _____

17) _____ - 7 = 12

18) _____ + 13 = 45

19) 8 + 19 = _____

20) 34 - _____ = 5

21) 22 – 7 = _____

22) 46 – 18 = _____

23) 31 + _____ = 56

24) 25 + 16 = _____

25) 17 – 9 = _____

26) 25 + 14 = _____

27) _____ - 31 = 16

APPENDIX B

Wilcoxon signed-rank test results for MR test

<table>
<tr><th></th><th>PRETEST</th><th>POSTTEST</th><th>DIFFERENCE</th><th>POSITIVE</th><th>|DIF|</th><th>RANK</th><th>SIGNED RANK</th><th></th></tr>
<tr><td>1</td><td>19</td><td>21</td><td>2</td><td>1</td><td>2</td><td>4.5</td><td>4.5</td><td></td></tr>
<tr><td>2</td><td>26</td><td>39</td><td>13</td><td>1</td><td>13</td><td>11</td><td>11</td><td></td></tr>
<tr><td>3</td><td>13</td><td>21</td><td>8</td><td>1</td><td>8</td><td>10</td><td>10</td><td></td></tr>
<tr><td>4</td><td>21</td><td>25</td><td>4</td><td>1</td><td>4</td><td>6.5</td><td>6.5</td><td></td></tr>
<tr><td>5</td><td>38</td><td>39</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td><td></td></tr>
<tr><td>6</td><td>39</td><td>39</td><td>0</td><td>0</td><td></td><td>#N/A</td><td>#N/A</td><td></td></tr>
<tr><td>7</td><td>39</td><td>39</td><td>0</td><td>0</td><td></td><td>#N/A</td><td>#N/A</td><td></td></tr>
<tr><td>8</td><td>21</td><td>16</td><td>-5</td><td>-1</td><td>5</td><td>8</td><td>-8</td><td></td></tr>
<tr><td>9</td><td>18</td><td>38</td><td>20</td><td>1</td><td>20</td><td>13</td><td>13</td><td></td></tr>
<tr><td>10</td><td>33</td><td>39</td><td>6</td><td>1</td><td>6</td><td>9</td><td>9</td><td></td></tr>
<tr><td>11</td><td>19</td><td>34</td><td>15</td><td>1</td><td>15</td><td>12</td><td>12</td><td></td></tr>
<tr><td>12</td><td>38</td><td>39</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td><td></td></tr>
<tr><td>13</td><td>19</td><td>17</td><td>-2</td><td>-1</td><td>2</td><td>4.5</td><td>-4.5</td><td></td></tr>
<tr><td>14</td><td>19</td><td>23</td><td>4</td><td>1</td><td>4</td><td>6.5</td><td>6.5</td><td></td></tr>
<tr><td>15</td><td>39</td><td>39</td><td>0</td><td>0</td><td></td><td>#N/A</td><td>#N/A</td><td></td></tr>
<tr><td>16</td><td>39</td><td>38</td><td>-1</td><td>-1</td><td>1</td><td>2</td><td>-2</td><td></td></tr>
<tr><td>17</td><td>39</td><td>39</td><td>0</td><td>0</td><td></td><td>#N/A</td><td>#N/A</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>76.5</td><td>POSITIVE SUM</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-14.5</td><td>NEGATIVE SUM</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>14.5</td><td>TEST STATISTIC</td></tr>
</table>

APPENDIX C

Wilcoxon signed-rank test results for math test

	PRETEST	POSTTEST	DIFFERENCE	POSITIVE	|DIF|	RANK	SIGNED RANK	
ISABELLA	20	20	0	-1		#N/A	#N/A	
OLIVIA	24	26	2	1	2	5.5	5.5	
BENJAMIN	23	23	0	-1		#N/A	#N/A	
SILJIE	21	21	0	-1		#N/A	#N/A	
VIKTOR	25	21	-4	-1	4	8	-8	
SILJE B	17	24	7	1	7	10	10	
CHRIS	22	23	1	1	1	2.5	2.5	
LOUIS	16	9	-7	-1	7	10	-10	
LOUISE	27	24	-3	-1	3	7	-7	
RASMUS	26	27	1	1	1	2.5	2.5	
ALICE	23	21	-2	-1	2	5.5	-5.5	
DIMITRI	7	6	-1	-1	1	2.5	-2.5	
SOLVEIG	11	21	10	1	10	12	12	
JAKE	24	17	-7	-1	7	10	-10	
SIMON	23	24	1	1	1	2.5	2.5	
VLAD	26	26	0	-1		#N/A	#N/A	
SEBASTIAN	25	25	0	-1		#N/A	#N/A	
							35	POSITIVE SUM
							-43	NEGATIVE SUM
							35	TEST STATISTIC