Developing an educational programming game for children with ADHD

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***Abstract*—Over the past few decades, computer programming education has come through many stages. Programming has shifted from being a specialization for the few, to a career choice available to many. Understanding the benefits that programming skills can bring, there have been attempts of integrating programming courses into school curricula, in a systematic manner. However, children with learning disabilities are often deprived of the chance to expose themselves to such courses. Either by not being able to keep up with the rest of the classroom, or due to the inability of school environments to adapt to their specific needs, they may be excluded from the learning process. With this in mind, there is a need to provide novel learning methodologies, better suited to learners with known deficiencies. In this study, we revisit the theoretical background of Attention Deficit and Hyperactivity Disorder (ADHD), and exploit methods and techniques used with children sufferers, by integrating them into a novel education game for teaching computer programming.**

***Index Terms*—ADHD, serious games, game-based learning, children, programming literacy, 21st century skills**

I. Introduction

Acquainting children with programming logic carries a lot of benefits. One of the most obvious is the fact that it prepares them for one of the most widely applicable trades in nowadays society [1]. Furthermore, getting involved with programming at an early age fosters abilities such as analytical and abstract thinking, as well as complex problem solving ([2], [3]), besides providing motivation and making traditional learning approaches more appealing ([4], [5])

However, when it comes to whether children should be exposed to programming at a young age, there are different views. Particularly, in [6], Morgan states that, despite being a programmer himself, he will not teach his kids programming and nobody should. He supports his argument with the fact that programming is much more complex than the way it is presented in the teaching books for kids and it is not enough to teach programming logic in the conventional way. In his eyes, writing code has to do with trying different things, observing how it works and trying again as, in reality, there is no ideal solution, like the books and the programming exercises aimed at children, suggest. In contrast, Resnick states that programming can be seen as a tool for self-expression, especially in primary school, and not necessarily the basis for a future career [7].

Bearing in mind the ambiguous views on the teaching of programming to children, something on which the scientific community has yet to reach consensus and is based largely on the personal opinions, this study focuses on proposing an improved tool for programming education of children with ADHD and does not take a stand on whether it is right or not to teach programming to children. In this work, we stydy the teaching methodologies of children with ADHD, as well as the technology that is currently being used in this domain, with the aim of creating a programming teaching game shaped appropriately to facilitate the educational experience for these learners.

II. Theoretical background

The Attention Deficit Hyperactivity Disorder - widely known as ADHD - is one of the most common neurobiological disorders diagnosed at young age, which continues to affect a significant percentage of sufferers into their adult lives [8]. According to studies, ADHD results in a different way of brain functionality, which subsequently influences the sufferer's learning ability and behavior. In fact, in can be observed at nursery age without being able to be diagnosed yet and becomes more apparent with the introduction of the child to the school environment and the responsibilities that come with it [9].

Also in [9], we see that children sufferers of ADHD often struggle to begin studying or engage in a learning activity, frequently interrupt it to occupy themselves with another activity, or to say something not relevant, that they just remembered. Further indications that should not be ignored are the fact that their optimal study hours tend to be from noon to night, many mistakes owing to lack of attention, as well as indications of hyperactivity (e.g. spinning on the chair).

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A. Manifestations of ADHD

As stated in [10], the official acronym of "ADHD" comprises the major visible symptoms of the disorder, which involve inattention, hyperactivity and impulsiveness. In this study, the major types of ADHD are distinguished and presented:

- ADHD, combined type. This constitutes the most common type of ADHD and is characterized by impulsive and hyperactive behaviors as well as inattention and distractibility.
- The impulsive/hyperactive type. This is the type of ADHD that is characterized by impulsive and hyperactive behaviors without inattention and distractibility.
- ADD, inattentive and distractible type. This type of ADHD is characterized predominately by inattention and distractibility without hyperactivity.

1) Characteristics of ADD: This type refers to cases where sufferers show mainly symptoms of inattention, something that burdens them with the feeling that their behavior may be mistaken as "laziness" or "lack of effort". Usual symptoms of the students that suffer from the specific disorder, that need to be taken into consideration for the creation of a game-based, educational tool, based on the analysis documented in [10], are:

- Easy distraction of attention by external stimuli (e.g. Sounds)
- Difficulty memorizing and following orders
- Inability to follow orders (not on purpose or due to weakness of understanding them)
- Lose of interest
- Difficulty with organization
- Lack of sense of time
- Lose of attention when studying (especially when the text is hard, boring, or does not pick their interest)
- Difficulty solving problems due to weakness of retaining attention during all of the steps

2) Characteristics of the impulsive/hyperactive type: The second type of ADHD refers to sufferers that face strong symptoms of hyperactivity and impulsiveness. A number of typical behaviors of children that suffer from that type of the disorder have to be taken into consideration, as they may hinder the process of using an interactive educational tool. According to [10], these are:

- Excessive energy (borderline non-stop movement)
- Need to have something in their hand
- Difficulty in cases where they need to remain patient
- Difficulty waiting for their turn in games and activities
- Acting before thinking
- Lose of interest
- Impatience
- Indifference towards correcting a mistake

3) Additional ADHD characteristics: [10] states a few more characteristics that should be taken into account along with the previous findings for the reinforcement of the educational game's goal. These are the following:

- Strong feelings (outbreaks, anger, sadness, irritation)
- Susceptibility to confusion
- Impulsiveness
- Difficulty changing and adjusting to routine
- Indiscipline
- Inability to work for long term goals/rewards
- Low self esteem
- Difficulty finding motivation

B. Teaching children with ADHD

In [8], practical instructions are given, concerning teachers, for a more efficient teaching experience of children with ADHD. These instructions are not targeted specifically towards the creation of an educational game. However, we are going to utilize them in order to obtain important information on how to handle a sufferer of ADHD, what aids their education, as well as what makes it more difficult ([11], [4]).

Some of these instructions can be intuitively implemented in an educational game. More specifically, [8] documents the need of children with ADHD for a heavily structured environment, in order to prevent distractions. It also states the importance of rewarding and the way it is carried out, explaining that the compliance with the rules should also be frequently rewarded as well as the completion of assignments. On the other hand, punishing should be less frequent, due to the susceptibility of children with ADHD to disappointment. In addition, specific behaviors should be praised, by congratulating the learner and making the reason for the praise as specific as possible. When it comes to rules and following them, it is important that the rules of class behavior should remain simple and straightforward. It is also important to avoid conflict with the student.

When it comes to visual stimuli, big letters, clear topics and the use of colors and shapes are among the suitable design suggestions. It is also more preferable to have more frequent tests and avoid extensive exams. Students need to have a clear view of the instructions before they engage an exam, and to not hesitate to ask for help. It must be always clear that sufferers of ADHD need attention and help for longer periods of time, compared to average students ([12]). Finally, a student with ADHD may take longer to complete an assignment, and this is why we should reward precision, rather than quantity ([13]).

The above instructions, although meant to be implemented in a school environment, can be adapted to other forms of teaching as well, i.e. in a gaming environment. Books and course material can be replaced with the game's content. The ultimate goal is to construct the game's environment accordingly, use methods of rewarding compliance with the game's rules and avoid the player's excessive "punishment". A reward system for the completion of levels should also be designed. Simple and straightforward rules and long term goals should be set, always avoiding conflict with the player and the appearance of help messages when needed should be promoted. A valuable asset would be smart detection of correct player behaviors as well as rewards in a targeted way.

III. Related works

In this section, we will study some of the most representative examples of programming education environments primarily used with children. Up until now, a number of programming teaching platforms/applications have been created. Scratch and Code.org are typical examples and will be further presented below. It is noticeable, however, that these applications do not take into particular consideration the needs of children with learning difficulties (specifically children with ADHD) and do not offer accessibility functionalities for them. The ultimate goal is to incorporate the merits of these frameworks into a game that will also be suitable for sufferers of ADHD.

A. Scratch

Scratch is a block-based visual programming language, accompanied by an online community aimed for use by children, developed by MIT. It has been translated in more than 70 languages and is being used in many countries [14]. According to Scratch's official statistics website, over 42 million pieces of work have been created, shared with over 42 million users, as well as the official website received more than 48 million visits, as of June 2019. It was studied due to its extensive usage in the domain of teaching programming to the young children. Figure 1 shows a typical interface of the Scratch programming environment.

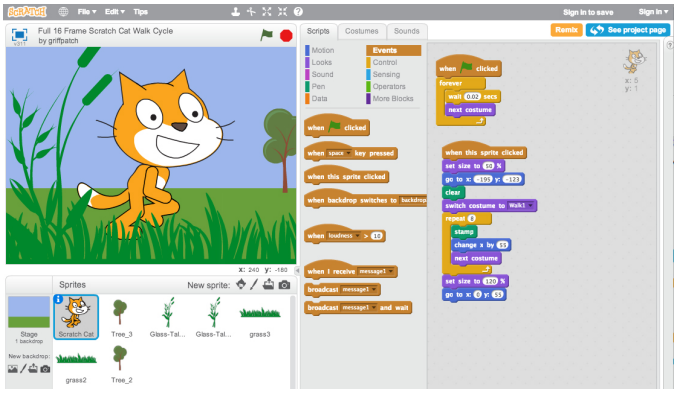

Fig. 1. Scratch 3.0 Environment.

B. Code.org

Code.org[1] is a non-profit organization with the aim of extending the accessibility of computer science in schools, as well as approaching minority groups. The vision of the organization is for every child in every school to have the chance to expose themselves to computer science, and it has funding support of big companies like Google, Facebook, Amazon and Microsoft [15].

Code.org also provides an online platform that offers interactive programming teaching lessons for learners above the age of four, and also supports the Hour of Code[2], a movement about introducing novice learners to computer science, which aims to urge anyone to accumulate basic knowledge about information science and programming. One of the interactive lessons provided for the Hour of Code and was studied was "Minecraft: Voyage Aquatic"[3], depicted in Figure 2. In this game, the player needs to guide their avatar in a virtual island and complete tasks, using visual programming blocks.

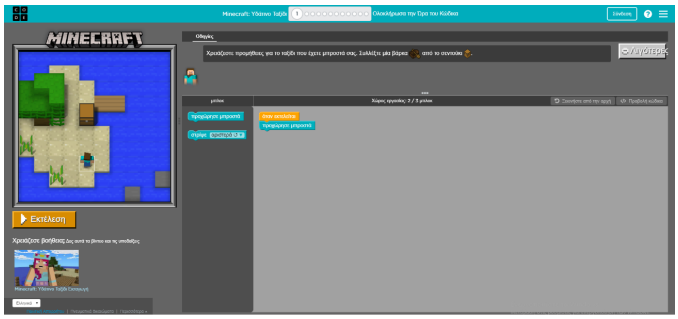

Fig. 2. Minecraft: Voyage Aquatic in the Code.org environment.

By studying this specific lesson, we can observe that, according to the theory of ADHD, a child with the disorder would struggle to keep up with the requirements. The recommended guidelines were not followed, meaning that the possibility of disappointment and resignation of the student is not eliminated. In detail, the problems observed in this platform were:

- When all commands are executed, there are no specific cues by the program, which awaits the action of the user. As we have established, feedback is important in all cases.
- Although colors are present, shapes and a more engaging environment are less so. It has been shown that students with ADHD are aided with the use of shapes (commands such as "move forward" could be replaced by arrows, etc.), as well as noticeable, pleasant color choices.
- The font size is small, without a configuration to make it bigger. It is known that readers with ADHD find it helpful when the letters are big.

C. Blockly

Blockly[4] is a JavaScript library for building block-based visual programming languages and editors. It is a project of Google and is the framework on which many relevant applications are built. Code.org is one of them. Blockly Games[5] is a series of educational games that teach programming, built on top of Blockly. They are designed for children with no programming background and with different themed levels that teach basic programming knowledge and skills. One such game that was particularly studied was "Maze" and is depicted in Figure 3. Its logic is quite similar Minecraft: Voyage Aquatic. This was another reason to show it here, as it

[1]https://code.org/
[2]https://hourofcode.com/gr/en
[3]https://studio.code.org/s/aquatic/reset
[4]https://developers.google.com/blockly
[5]https://blockly.games/

demonstrates the same shortcomings with Minecraft: Voyage Aquatic, with respect to its suitability for learners with ADHD.

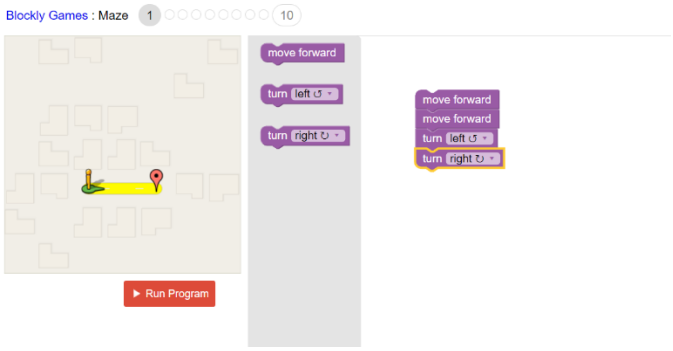

Fig. 3. Blockly Games: Maze.

D. Comparison

Table I shows a brief comparison between the platforms and tools mentioned above, after a closer inspection. When marked with ✓, a specific feature is implemented in a framework/tool to a satisfactory degree, whereas when marked with ✗, this feature is not implemented. ∼ means that this feature is present, but not to a satisfying degree.

Scratch features a quite structured environment, with clear and well organized functionalities. Code.org consists of much fewer choices which are also structured well. Blockly-Games features a simple environment as well. However, as in Code.org, it is not very helpful and guiding. Scratch makes use of shapes, to some extent, mainly for specific commands. Code.org uses fewer shapes and Blockly-Games even fewer. All three, however, utilize colors to a satisfactory degree.

Rewarding in Scratch is present, as users witness their creation come to life. In Code.org, there is the fun of exploration. In Blockly-Games, rewarding is somewhat deficient. On a different note, Scratch does not target rewarding, as it depends mainly on the player's creativity, without specific goals. Code.org and Blockly-Games share a common form of targeted rewarding, only after the user finishes the level.

Rules and gameplay can be considered simple and easy to follow in all three platforms. However, when it comes to offering help, they anticipate users to understand their mistake by themselves. Finally, we should mention that none of these games evaluates the time it takes user sto accomplish a task. In terms of interfacing, although all three use textual information, only Scratch offers font resizing configurations.

IV. Requirements and Development

The main challenge we have to deal with is the lack of proper functionality in programming games in order to support accessibility for children with ADHD. Deficiencies on that matter were observed in the aforementioned programming games.

The aim of these games is to introduce young children to programming logic. However, the lack of ADHD accessibility can result in the deprivation of this opportunity to a significant

TABLE I
Frequency of Special Characters

	Scratch	Minecraft: Voyage Aquatic	Blockly Games: Maze
Structured environment	✓	✓	∼
Use of shapes	∼	∼	✗
Use of colors	✓	✓	✓
Correct use of rewarding	✓	✓	✗
Praising specific behaviors	✗	∼	∼
Reward system	✓	∼	∼
Simple and straightforward rules	✓	✓	✓
Providing help when needed	✗	✗	✗
Rewarding quality instead of quantity	✓	✓	✓
Big or resizable fonts	✓	✗	✗

part of the target group of these games. In the United States alone, 6.4 million children between the ages of four and seventeen have been diagnosed with ADHD, and a 42% increase in recent diagnoses is an indicator that there is an increase in awareness about the disorder [16].

Research on ADHD and programming teaching initially led to studying the Scratch paradigm. For the development of our proposed game, the original idea was to reconfigure Scratch and add functionality for children with ADHD. This was not possible, however, so our focus shifted to other platforms. By studying Code.org as a teaching programming platform, as well as its modification and repurposing capabilities, it was discovered that the platform, at its basis, utilizes the Blockly library. This meant that in order to modify the Code.org platform and in particular the Minecraft: Voyage Aquatic application, the library itself had to be modified. Through Blockly Games, many open source games were found, which could be used for easier code modification.

However, as the Blockly Games code should be individually processed and refactored at a large scale, it was decided that creating an application from the beginning, in Unity 3D, would be easier, faster and more efficient. This game, entitled **Snak3D**, is loosely based on the well known *Snake* game and will serve as the code base for developing suitable mechanics for sufferers of ADHD.

V. The Complete Game

In the following paragraphs, we will make an attempt to briefly showcase the main game elements of the application. The complete build, accompanied by technical information, is publicly available online [6].

When the game starts, the main menu appears (Figure 4). This gives players the opportunity to play the classic or the educational version of the game. Particular attention should be payed at the "Skin" toggle, with which the player can configure game aesthetics.

In a normal snake game, the player needs to guide the snake in the level, as it eats the collectibles (mice), without touching obstacles or the sides of the play area (Figure 5).

[6]https://christosgaleos.weebly.com/snak3d.html

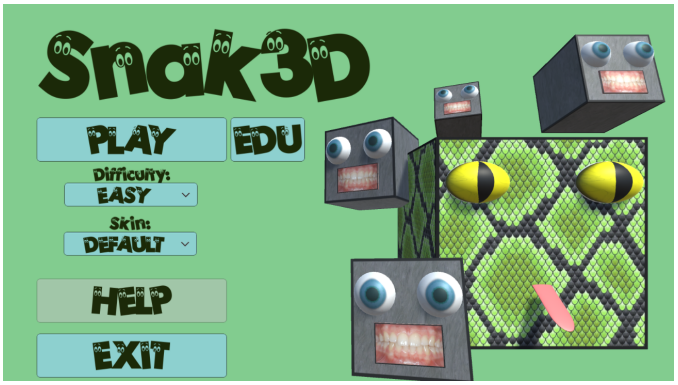

Fig. 4. Main menu

Fig. 6. Losing screen.

In the educational part, players need to complete 16 levels of increasing difficulty, in which they encounter a top down view of the same terrain, as well as a workbench (7). Here, they have to guide the snake in the level by dragging and dropping in the work area a combination of the action symbols shown in the lower left part of the figure. These are: ”move forward”, ”turn left”, ”turn right”. The ”play” and ”stop” offer the appropriate functions.

If the player is successful, they are prompted accordingly, using visible textual cues, as well as a sub-menu, shown in 8. Otherwise, they are prompted accordingly.

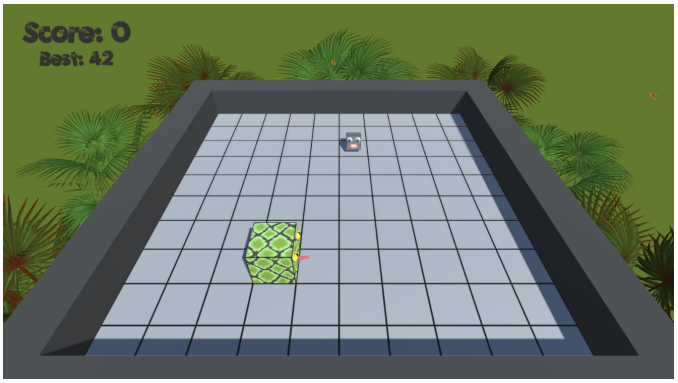

Fig. 5. Main game area during gameplay.

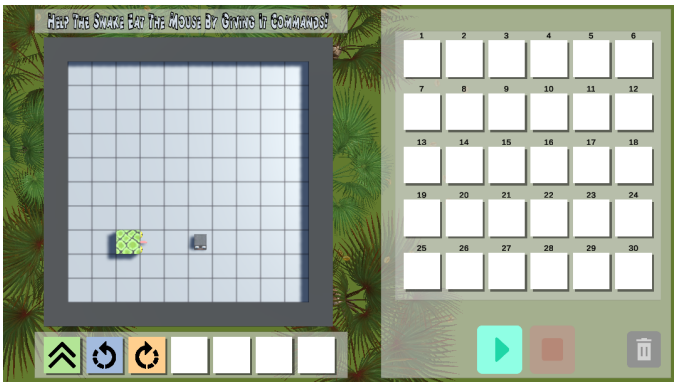

Fig. 7. Programming workbench.

A. *Integrated ADHD-related elements*

The construction of the game’s environment was done carefully, with the use of symmetry, implementing the need for a significantly structured environment. Distances between scene objects are balanced in order to not cause attention loss. The use of panels is apparent.

Reward methods which ensure proper compliance with the rules are in the form of encouraging messages, the feeling of satisfaction that comes with solving each problem and unlocking the next level, while further rewarding needs teacher intervention. Punishment of the player is avoided. Furthermore, rewarding is more frequent than punishment.

Rules are clear and simple. The user must avoid barriers and eat mice in each level, using the available commands, executed in the order in which they are selected. Help messages are constructive and comprehensive, are repeated when needed, assisted by a system that detects correct or incorrect user behaviors, displaying corresponding prompts. Special care has been given to messages of praise and complement. For example, when completing a level, instead of showing a plain ”Congratulations!” message, a more encouraging ”Congratulations! You completed the level!” is shown.

In each level, the user learns at most one command, or is introduced to at most one new function. Commands and functions are displayed with colors and shapes, avoiding the use of plain textual information. A progress evaluation system in the form of a game-test in between the levels was not implemented as it was not deemed necessary, as the levels themselves can be considered tests. The teacher’s encouragement to make sure that every child has understood the instructions remains necessary.

No help offer button was designed, but the ”smart” help message system is present (Figure 10), providing assistance without request by the user. Finally, the completion of the level is decoupled from the time taken to complete it.

VI. Conclusion

In this paper, we revisited the complexities which are inherent in an educational framework aimed at children with ADHD, and identified the design elements that a game-based

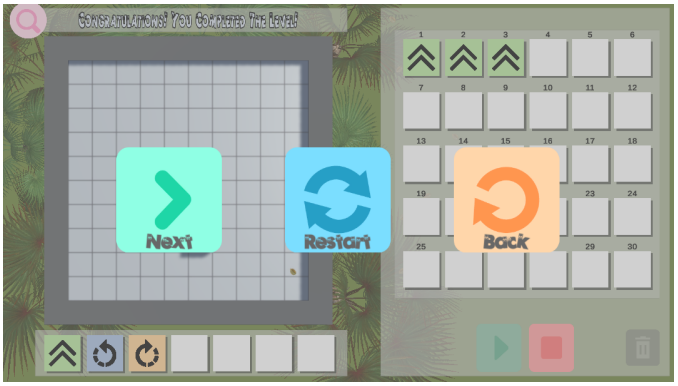

Fig. 8. Level completion screen.

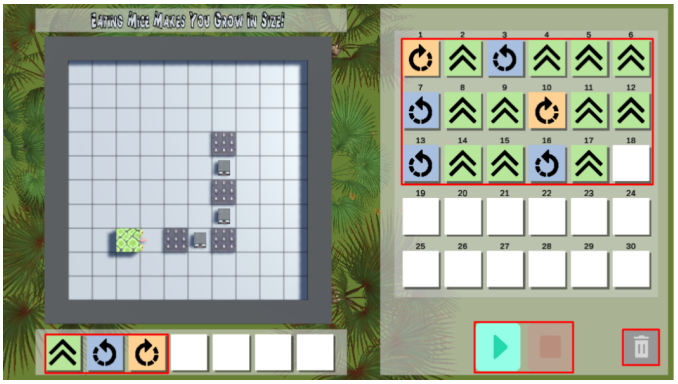

Fig. 9. Organized play area. Color and shape utilization

learning application should possess in order to be suitable for use in such an audience. Our aim was in teaching programming applications, due to the fields popularity and growing utilization in school curricula.

We presented a list of relevant state-of-the-art applications for teaching programming and showcased the areas at which they are suitable for use in an ADHD-targeted environment, as well as those at which they are not. Finally, we presented a game which incorporates the majority of these elements in a clean and organized manner. The game is available online.

As future steps, more levels could be designed and a teacher/authoring mode could be offered, where instructors will be allowed to create their own learning scenarios. Another interesting direction could involve procedural content generation, by taking into account the player's performance (time/tries until completion) and other factors, in order to generate a more personalized experience [17].

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Fig. 10. Smart message system

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