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Gamification of Neuropsychological Tools as a Multi-Sensory Approach to Education. Stroop's Paradigm

Gkintoni[2], E., *Halkiopoulos[2], C., Antonopoulou[2], H., Petropoulos[2], N.

[1] *Entrepreneurship & Digital Innovation Laboratory, Dept. of Management Science and Technology, University of Patras, Greece*

*Corresponding author: E-mail: halkion@upatras.gr

Abstract. The Stroop test is a neuropsychological assessment that is worldwide recognized for its sensitivity and reliability in assessing frontal activation and executive function control. The Stroop test was conducted in this research effort using the Unity machine in a virtual test with the identical application approach and outcome measurement as in the physical test. The new visual "ustroop" test was conducted to a large enough sample of persons to allow comparisons to the initial test. Subsequently, more game scenarios in the form of a play script were added to evaluate the player's reaction to color, brand name, and words. To summarize, neuropsychological evaluation techniques can be used to promote and evaluate visual gaming, and the current project's findings can be developed upon. Though, scientific fields such as cognitive neuroscience, neuropsychological assessment tools, and gamification techniques can effectively increase learning and cognitive function through continual exercise and can be an asset in the educational process.

Keywords: Gamification, Neurocognition, Executive Functions, Stroop, Unity, Education

1. INTRODUCTION

Game-based techniques are predicated on the premise that specific human skills and behaviors can be more effectively promoted when training takes place in a playful and exciting environment, such as that provided by video games. Gamification, serious games, and applied games are modern and novel techniques for investigating human behavior modification via video games. Additionally, clinical settings have incorporated game-based interventions to increase adherence and cognitive ability in both healthy and clinical populations. Game elements, which are directly influenced by conventional games, are a collection of video game components that include patterns, objects, principles, models, and methodologies. Points, difficulty levels, badges, a storyline and plot, progression depending on success or failure to accomplish the game's objectives, and multiplayer components are just a few instances of gamification that are frequently seen in video games. Furthermore, is ongoing to investigate the critical role of gamification as a important tool in multi-sensory learning in educational process, due to the fact that last decades a large amount of students have video games as a main occupation in their leisure time (*Fereira-Brito et al., 2019*). Gamification has been shown to improve executive functioning. Gamification appeals to users' basic desires and expectations based on the notion of status and accomplishment. Executive functions are essential in various circumstances, regardless of whether a student is playing a computer game or a board game.

2. LITERATURE REVIEW

2.1. Neuroanatomic basis of executive function in cognitive tasks

The executive functions are boosted by games, which include parameters that appear to be engaged due to repeated practice of interactive virtual game scenarios. At this point, a quick review of the neuroanatomy of the executive processes that appear to be improving during cognitive testing is beneficial. These activities are mediated primarily by prefrontal function and are modulated by dopaminergic, noradrenergic, serotonergic, and cholinergic neurotransmission. Due to these neurotransmitter systems' capacity to control executive processes, cognitive behavior may be changed in response to environmental changes (*Gkintoni et al., 2017*). More precisely, the dopaminergic system has been connected to switching and shifting attention; the serotonergic system has been associated with response inhibition. The cholinergic system has been linked to the coordination of all executive function activities. Thus, knowing the neuroanatomy of the prefrontal cortex is critical for elucidating how it controls and coordinates all executive processes. The two functional areas of the prefrontal cortex, the dorsal outer frontal cortex, and the orbital frontal cortex, together with their connections and interactions with other brain structures, are critical for executive processes and associated behavior (*Minzenberg et al., 2019*). Four distinct regions have been identified in the prefrontal cortex based on their connections and the activities they perform: memory-based and generated from the environment b) the dorsal outer frontal cortex, which is responsible for working memory, logical processing, and executive control; c) the middle frontal cortex, which is responsible for the design, prediction, and executive control; and d) the frontal pole, which is responsible for adaptive design and self-awareness (*Orellana & Slachevsky, 2013*). Executive functions are classified as higher-order cognitive functions because they encompass the decision-making and cognitive control characteristics that have been essential to transformational leadership training (*Antonopoulou et al., 2020*). Thus, educating young individuals in cognitive tasks that boost executive functions, such as Stroop that is analyzed in the current study, improves their future decision-making abilities, capacity for creative problem solving, and ability to conduct effective leadership (*Antonopoulou et al., 2021*).

2.2. Neuroplasticity: The Basis of Learning in Educational Process

Since the creation of nervous systems throughout the evolution of the human brain, neurons have evolved to specialize in collecting environmental information required for the human body's survival. The mechanism by which these effects are directed is due to the evolution of a single property: neural plasticity. The notion of neuroplasticity describes how the brain continually adapts to a changing environment through tiny physical, structural, and functional changes that occur when we learn, have an idea or recall something. In other words, this skill is critical for learning and memory processes. The brain is not static but is constantly remodeling: the number of neurons fluctuates, some are lost, and others are created, although this is not true in all brain parts. Additionally, both the number and strength of neuronal connections vary during development.

Santiago Ramon Cahal defined *plasticity* as the cellular foundation of memory for the first time: "Mental training stimulates the formation of neural structures in the areas of the brain where they are employed. Thus, the expansion of nerve terminals can improve pre-existing conditions between groups of cells. Similarly, Eric Kandel, an Austrian neurobiologist given the 2000 Nobel Prize in Medicine for his research on the molecular mechanisms underlying memory and learning, views memory as "an internal representation of knowledge gained via learning." Spatial and temporal information is encoded spatially and temporally in brain circuits via changes in the response characteristics of neurons." Naturally, the peak of the brain's adaptability occurs during its development period. However, throughout childhood, the production of neurons and synapses is excessive, and as a result, a process is known as "pruning" occurs, which is critical for removing non-functional synapses. This precise pruning is also associated with neuronal death, a process that continues well after puberty. Although one may believe that plasticity does not allow for such drastic structural reconfiguration in maturity, in actuality, it can change some regions. For example, repetitive stimulation of the left index finger results in the gradual growth of the sensory cortex region responsible for this response. Teaching a new motor skill increases the motor cortex areas responsible for regulating the acquired motions. Similarly, consistent practice of multisensory cognitive activity, such as visual games, appears to encourage what we refer to as neuroplasticity. Each brain is altered on a microscopic scale during learning as a result of engaging in cognitive activity. This is because learning activates many chemical processes and can potentially permanently alter the brain's architecture. Thus, our family, our culture, our friends, the films we saw, and all the discussions we had all leave permanent and minute imprints in our neurological system that contribute to our nature.

2.3. Stroop Test

The Stroop Color-Word Test (Stroop, 1935) is a valid and accurate psychological evaluation instrument. Numerous Stroop test variants have been produced, each with a distinct color scheme and number of test items, as well as a varied number of subtests and administration techniques. Despite these modifications, the Stroop test's fundamental paradigm has remained consistent: The performance of an individual on a fundamental task (e.g., reading color names) is contrasted against his or her performance on an identical activity in which a habitual reaction must be suppressed in favor of an atypical one (i.e., naming the ink color that incongruously named color words are printed in). The time required to complete the later task in comparison to the fundamental task is referred to as the "Stroop interference effect" and is used as a proxy for cognitive flexibility and control or executive functioning. These abilities deteriorate with age and dementia, making the Stroop test a common screening tool for individuals with suspected or proven brain disease. Due to the Stroop test's popularity in clinical and research contexts (*Benson, 1978; Lezak, 2000*), it is critical to ascertain the effect of age and age-related intrinsic variables on test performance. Previous research on the impact of schooling on Stroop test performance has been equivocal. The Stroop test performance was shown to be favorably associated with education. Stroop's paradigm, in particular, has been extensively used in neuropsychology and neuropsychiatry. The Stroop task assesses interdimensional competition and is perhaps the most commonly used test in neuropsychology. The significance of this exam stems not just from its long history but also from the numerous research done to decipher the test's underlying components. J. R. Stroop's 1935 study on color-word interference sparked a flood of research in cognitive and clinical psychology.

2.4. Stroop Effect

John Ridley Stroop was the inspiration for the Stroop Effect. Stroop, John Ridley was an American neuropsychologist who published his hypothesis "Studies of Interference in Serial Verbal Reactions" in 1935 in the Journal of Experimental Psychology, Vol. 18, pages 643-662.

His hypothesis postulated that there was interference with response time; precisely, based on its studies, the word's color does not match its semantic meaning (e.g., Red) and is delayed in recognition if there is a correlation (e.g., Red). Thus, experimenting with this phenomenon might shorten the time required for its recognition in the first instance. Stroop described three procedures—experiments—that aided him in developing his hypothesis. Initially, he chose red, blue, green, brown, and purple as his primary hues. Then, three factors were considered while adjusting the colors:

- Although no color had the same font color as the word, it was repeated in the same manner as the other four.
- The font colors and color words were chosen so that no subsequent line or column appeared.
- Each font color and each color word are displayed twice in total.

Stroop was not the first to consider this hypothesis. McKeen Cattell addressed this notion (Cattell, JM: The Time to See and Name Objects, Mind 11, 63–65 (1886)) and asserted that reading is a spontaneous activity that we engage in from an early age, that is, something uncontrolled, undesirable, and rapid. We cannot "deactivate" this feature, which is why we are obstructing attempts to identify the font color. Additionally, Peterson (1925) stated that the words elicited a single reaction, but the colors elicited numerous responses, resulting in the delay. Colin M. MacLeod published "Half-Century of Stroop Effect Research: An Integrative Review" in 1991, after analyzing, collecting, and arranging around 700 publications on the Stroop study. Additionally, new data from surveys and trials with Dunbar are included (1988). He claims in his paper that the longer a version of Stroop's experiment is conducted, the more complications it introduces in subsequent iterations.

2.5. Variations of Stroop's original experiments

Variations of Stroop's initial experiments were made before and after his theory. Below are categories of variants, as McLeon grouped them in the article "Half Century of Research on the Stroop Effect: An Integrative Review" (1991).

Different Scoring of the Test
Many scientists have made small modifications to the first experiment to deliver results in specific areas of psychology. Modifications differ in test materials, test delivery, time of administration, and score. Thurstone and Mellinger (1953) modified the original experiment by placing a black background instead of white and using four colors. Jensen (1956) attempted to grow card-stimuli, so there was no delay in changing cards. C (color) cards were 10x10 (columns x rows), while W and CW cards 5x25.

Sort and match
In this variation, the examiner must assign the stimulus cards to categories. In particular, two images/shapes appear in two colors. Thus, the first phase matches the cards to the correct categories according to their shape, while the second phase (Stroop inverse process) matches the cards to the categories according to their color.

Image-Word Process
One of the first theories about the Stroop phenomenon was a delay when there were images and words. Specific words appeared in paintings. There was a long delay when the words were directly related to the image, and it was not an independent word. The image can also be a word or many of the exact words that act as an image. This process is also done with left-to-right arrows, with the examiner recognizing the direction of the arrow. However, with geometric symbols where the word appeared, they had to choose the correct geometric shape. Examples are shown in Figure 1 (experiment variation with the Image-Word process).

Figure 1. Experiment variation with the Image-Word process

Stroop sound process
A variation on the theme of sound reaction and interference. The reproduction of low- or high-frequency noises and the subject's response to their recognition constitute a process. Another phase is recognizing the speaker's gender (male or female) as they pronounce words. Additionally, kids can do the procedure by identifying the pace, intensity, and duration of the words they hear.

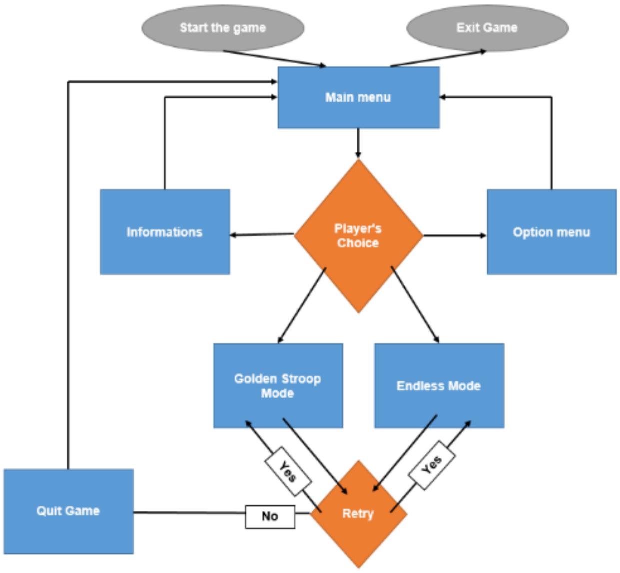
2.6. Unity – A Cross-Platform Game Engine

Unity is a game development platform used by developers, artists, and designers. It is primarily utilized in gaming, animated films and effects, virtual reality (VR), and augmented reality (AR) (AR). You work with big and small studios and global corporations across a range of technological industries, including Windows, Apple, Android, Xbox, Nintendo, Playstation, Steam, Facebook, Toyota, Audi, and Disney. The Asset Store is one of Unity's most important advantages. This enables us to search a vast collection of free and commercial materials provided by Unity Technologies and community members. Numerous models, hardware textures, model traffic, and editor extensions are included in the assets. Users may download them not only through the editor but also via their browser's explorer. Paid assets can also be utilized for promotion since you retain copyright. There are two types of free assets: those with limits and those without restrictions. The former may be used solely for educational and personal purposes, whereas the latter may also be used for commercial objectives.

3. METHODOLOGY

Unity was used to develop the electronic version of the Stroop Effect application. The suggested application's objective is to provide the Stroop test to the user modernly and by performing the test technique. In 1978, Charles J. Golden created a version based on the game. The distinction from the test itself is that the samples of words and colors are all randomly generated in order to function as a game without a repeated pattern. Numerous assets were utilized to develop the suggested audio, 2D, and 3D picture editing application. The game's original version only supports the English language. However, according to the flowchart (Figure 2), we can view almost all the program's choices.

Figure 2. Flowchart of Proposed Stroop Game



Initial menu
For the initial menu (Figure 3), some basic buttons were used, which refer to the program's essential operation, and some minor ones for information.

Figure 3. The Initial Menu of the Game

Key buttons:
[Golden Stroop / Endless Mode] These two buttons lead to the game's screen, or "Scene". There are two different modes/modes of play with other rules. [Options] The button displays the settings, such as turning on / off the sound and deleting the stored high score. [Exit] The button ends the application.

Scoring screen
The scoring screen shows the highest saved score for the two different application modes. Our rating screen (Figure 4) shows the highest saved rating for the two different functions of the application. Note that numbers 35 and 18 are examples of system operation.

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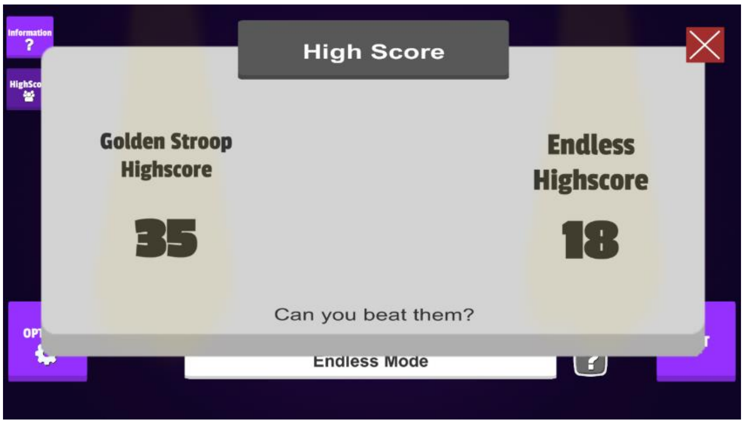
Figure 4. Third round of the Golden Stroop Operation

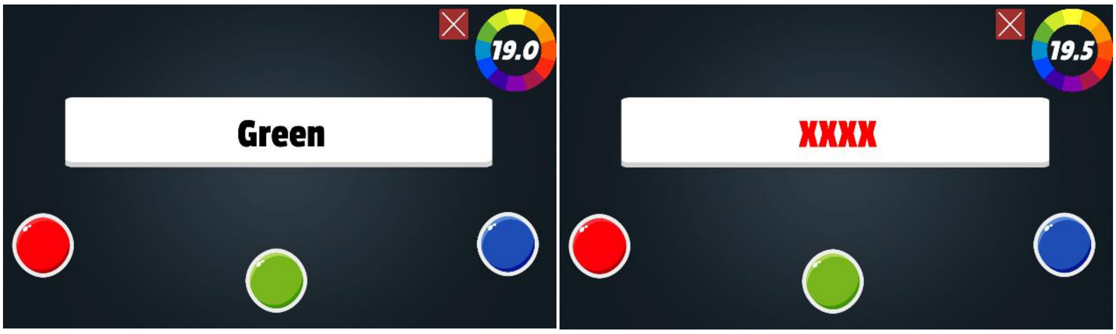


Golden Stroop mode

It is the primary function of the game. Next, on the upper right, our numbers indicate the remaining time. Next, the [X] button is the exit button, which returns to the original menu. In the middle, a white box diminishes continuously until it disappears, functioning as a graphical representation of time. The test will be displayed on the box, which will be discussed below. Finally, three red, green, and blue buttons serve the user to respond to the test.

The game consists of three rounds. Each takes up to twenty (20) seconds, and up to forty (40) color words appear. Every correct answer gives us a (1) point, and there is no effect on the wrong answer. The real test lasts one (1) minute, and the user can reach the maximum number of one hundred and twenty (120) points.

Figure 5. The first and second round of the Golden mode



In the first round, the game shows the words "Red", "Green", "Blue" in random order, and the player must choose the corresponding color from the buttons at the bottom of the screen (Figure 5). In the second round, the player is called to respond correctly according to the color, but the word "XXXX" with the red, green, and blue font is displayed. In the third and final round (Figure 6), the words "Red", "Green", "Blue" appear randomly, and, in addition, they are randomly colored in red, green, and blue. In order for his answer to be correct, the player must press the correct button according to the font color of the word and not according to what the word says. Below we see an example in which the correct answer is Green!

Figure 6: Third round of the Golden Stroop operation

Endless Mode Operation

It is called Endless because the words-colors do not stop appearing until the player makes a mistake or the time is zero. In this mode, we have a reminder of the previous High Score on the top left, which we are trying to overcome. Also, we only have two buttons: the right, green button, and the wrong, red button. If the word color that appears has the same font color, then the player must press the green "Correct" button. In any other case, the player must press the red "Wrong" button in order to answer correctly. In the example of the image, the user is asked to press the green "Correct" button since "Green" corresponds to the green color of the font.

Game Over Screen

It appears when a game ends. There are only two user options. [Retry] The user restarts the function by pressing the button, trying again from the beginning. [Quit] Pressing the button takes the user to the main menu.

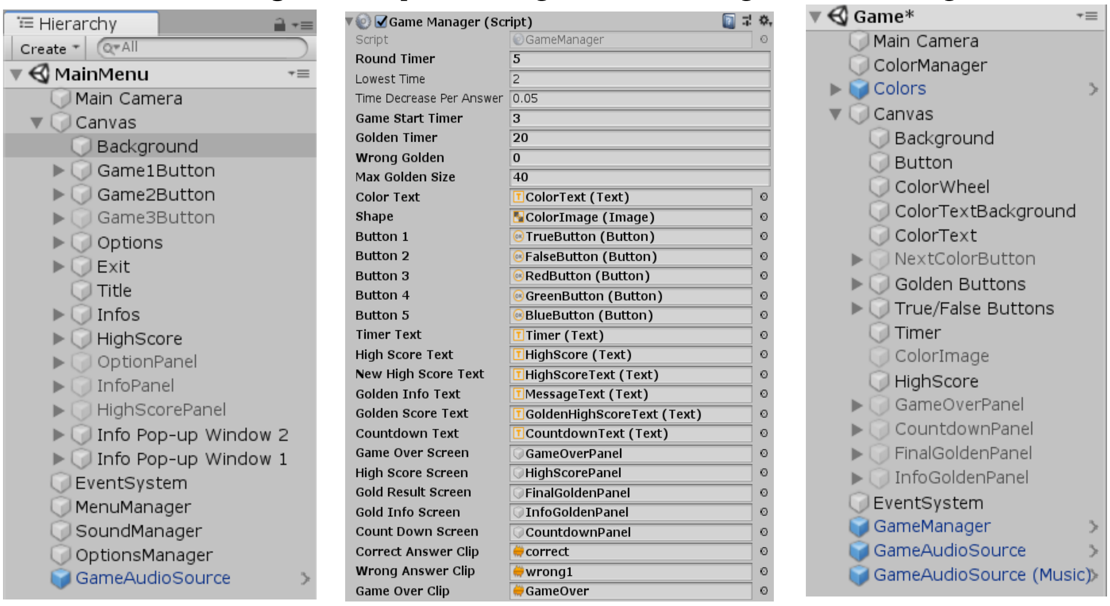
4. GAME IMPLEMENTATION

The programming language used is C #, which Microsoft created for the .Net Framework. Visual Studio 2019 was used to modify the code. Gimp software was used for image editing, while Audacity was used for audio editing. At this point, we quote a part of the code with the corresponding description mainly from the "Golden Stroop" function.

For the main menu, we use the "MainMenu" scene in Unity. We made the scene by putting it in the Game Objects Hierarchy, shown in Figure 7. The Game Objects in the Canvas category all work visually to the user as a UI, while the rest have C # script attachments, which help in the behavior and logic of the original menu. The UI Buttons do the functions of the buttons in Canvas. Each UI Button has different behavior and image since each one serves a different purpose. For example, OptionManager has functions and methods that are called when the user presses a button.

MindManager makes the selection of the two different Game Modes.cs. When one of the two buttons is pressed, it is called LoadGame (), which loads the next "Game" scene. The "Game" scene is used for both Game Modes. To achieve this, Canvas Game Objects are used, activated, and deactivated according to the user's choice. The following image is the scene's hierarchy, and we see that the Game Objects in gray are inactive.

Figure 7.1 Option Manager / Game Manager / Menu Manager



To define the colors, we used a ColorObject.cs class that has the color name attributes and the color itself in 32-bit format. Then ColorManager.cs manages the colors we want collectively. More specifically, we use three colors, with the characteristics of the ColorObject.cs class (name and color in 32-bit format), red, blue, and green. All the logic of the game is found in GameManager.cs. In the picture (Figure 7), we see the Game Manager in Inspector. At this point, we make all the reports managed by the GameManager.cs script. To display the reports in Inspector, we need to initialize them as public in C # script. Specifically, we have references to variables, images, and UI buttons, texts, Game objects, and finally, sounds. This makes it especially easy for variables because we can immediately change a value for testing without editing the script. The game manager helps us calculate time through FixedUpdate (). It belongs to the Unity libraries and is a method that we call constantly, and it runs 50 times per second. Because it is called so often, it is used exclusively for timekeeping, not to make the program "heavy". It is also not affected by system delays running the program. The following code shows two primary methods for the game. The first is NewGolden () and NextGoldenStage ().

NewGolden()

The method NewGolden() gives us the following color combination, namely font name, and color. Depending on what stage we are at, he chooses a random combination and displays it. The "GoldenColor" variable also helps control the user's response to CheckAnser () as a flag. Below we quote the corresponding code (Table 1)

Table 1. NewGolden () Method

```
    public void NewGolden()
    {
        //We need a color and word and don't want them to be the same, so we get two random references
        //in the array which will be used to determine the question and answer
        int randomWord = Random.Range(0, colorManager.m_GameColors.Length);
        int randomColor = Random.Range(0, colorManager.m_GameColors.Length);
        if (GoldenStage == 1)
        {
            m_ColorText.text = colorManager.m_GameColors[randomWord].m_ColorName;  //Gets a random color's name and shows on screen
            m_ColorText.color = Color.black; //Sets the font's color to black
            GoldenColor = randomWord; //Flag for Check answer

        }
        else if (GoldenStage == 2)
        {
            m_ColorText.text = "XXXX"; //The text that appears instead of color's name
            m_ColorText.color = colorManager.m_GameColors[randomColor].m_Color; //Gets a random font color and shows on screen along
with text
            GoldenColor = randomColor; //Flag for Check answer
        }
        else
        {
            m_ColorText.text = colorManager.m_GameColors[randomWord].m_ColorName; //Gets a random color's name and shows on screen
            m_ColorText.color = colorManager.m_GameColors[randomColor].m_Color; //Gets a random font color and shows on screen along
color's name
            GoldenColor = randomWord; //Flag for Check answer
        }
    }
```

NextGoldenStage()

The NextGoldenStage () method allows us to change the stage of the Golden Stroop test. Call when the words are finished (the word limit is set to forty) or when the time is up (the time limit is twenty seconds). It first checks what stage the user is at and displays the instructions window for the next stage. Works in conjunction with the CloseGoldenResultScreen () method, which is called when the user closes the window displayed by NextGoldenStage (). Below we quote the corresponding code (Table 2).

Table 2. NextGoldenStage() Method

```
    public void NextGoldenStage()
    {
        //Checks which stage we are on and make transition between stages.
        if (GoldenStage == 1 )
        {
            GoldenStage=2;
            m_GoldenInfoText.text = "For the " + GoldenStage + "nd Round, you have to choose \r\n the correct color based on
font color! \r\n You can do it!";
            m_GoldInfoScreen.SetActive(true); //Shows info and prepares for the next level
        }else if(GoldenStage == 2)
        {
            GoldenStage = 3;
            m_GoldenInfoText.text = "The fun starts now! \r\nFor the " + GoldenStage + "rd Round, you have to press \r\n the
correct color based on font color! \r\n Be careful, because the color's name \r\n can trick you and make you choose wrong!
\r\n Do you see a difference?";
            m_GoldInfoScreen.SetActive(true); //Shows info and prepares for the next level
        }else if (GoldenStage == 3)
        {
            //Handle the game over
            GoldenStage = 4;
            gameOver = true;
            isPaused = true;
            m_GoldenScoreText.text = "" + Gscore; //Shows the score of the round
            m_GoldResultScreen.SetActive(true); //Shows the result and prepares for the next level
        }
```

5. CONCLUSION

Through highly realistic three-dimensional (3D) settings and more natural ways of engaging with them, virtual reality promises to be a significant advance over traditional neuropsychological instruments in measuring the capacity to conduct everyday life tasks (ecological validity). With this in mind, it is unsurprising that this component was most prevalent in video games used for evaluation. In this area, diversity and consistency of stimulus display and performance measurement are required.

The application as implemented offers a great deal of potential for improvement. The next stage is to port it to other systems, such as Android and iOS. Additionally, it can improve the usefulness and efficiency of this exam by allowing participants to activate the buttons quickly

with their fingertips. Additionally, the Stroop effect is an interesting phenomenon that, in the form described in this study article, maybe a powerful tool in the hands of advertisers today when used to logo evaluation to arrive at safe and optimum conclusions about a company's logo selection.
Additionally, the translation of standard neuropsychological instruments or batteries into visual games using gamification approaches may be a beneficial strategy for the learning process of both young students-players and future seniors in terms of therapeutic rehabilitation. To summarize, cognitive neuroscience, neuropsychological assessment tools, and gamification approaches may all be used to enhance learning and cognitive function through continuous exercise and can be an addition to the educational process.

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