Designing VR Games with Gaze Control for Directing Attention of Children with ADHD

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Abstract—Within this paper, we want to present a new game concept that combines VR technology and gaze control to direct and train attention in ADHD children. Our approach combines the motivating ability of games with attention-demanding tasks, gaze control, and the high level of immersion of Virtual Reality to design a fun training game for children with ADHD. We describe our design process and give design recommendations for creating games with gaze control and games for children with ADHD.

Index Terms—Gaze Control, Virtual Reality, ADHD, Attention, Game Design

I. INTRODUCTION & MOTIVATION

In the field of medical treatments, digital games offer the advantage that patients a) accept games more likely than conventional treatments and b) in particular games motivate people to hold on [4], [18]. Especially Virtual Reality (VR) games offer the ability to draw the players into the spell of the virtual world, because of its high level of immersion. One successful application of digital games is the use in therapy of Attention Deficit/Hyperactivity Disorder (ADHD) (e.g. [7], [12], [17]). Children with ADHD suffer from inattention, deficits in executive functions, or altered reward sensitivity, which lead to problems in their everyday lives. Kerns et al. [23] highlighted that systematic training of attention-demanding tasks can increase attentional performances. For example, serious games can help children to learn things about real world situations [11]. An analysis by Craven and Groom [13] of different games that use gaze interaction showed that the oculomotor system is closely linked to attention and that strengthening gaze control also leads to an improvement in attention.

Hence, we combined the ability of VR to captivate the players with the power of gaze control to improve attention and create a game concept to see if the implementation of this combination works. Furthermore, we want to provide a thought-provoking impulse to make more games with this combination to help children with ADHD to train their attention.

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II. RELATED WORK

One of the most diagnosed neurobiological illness in children is the Attention deficit-/Hyperactivity disorder [3], [16]. It is characterized in particular by the three main symptoms: inattention, impulsivity, and hyperactivity. If the disorder is not treated, it affects the children’s school performance and social contacts. Generally, there are several ways to treat ADHD (drug or behavioral therapy, cognitive training [9], or psychoeducation [29]) but one relatively new approach is the use of digital games or serious games. Most of the games are based on standardized diagnostic tools like Stop-Signal, Go/No-Go Task, or the Stroop-Task [12]–[14]. A game developed by [17] includes the training of different executive functions. VR's high level of immersion can be beneficial for children with ADHD, as it can completely block out the real world and therefore also block out distracting stimuli. In addition, VR’s ability to draw the players into the spell of the virtual world lets the players focus on the challenges to tackle or the task at hand. Another advantage is that VR offers the ability to create realistic environments, in that patients can be tested and treated safely so that the treatment successes can be easily transferred to the real world [28]. Bashiri et al. [6] present a review of different VR applications for the treatment of ADHD. From 20 listed applications, only two were games, while most of them were simulations of classroom situations.

Children with ADHD show deficits in inhibition, action planning, and vigilance [31] as well as focused attention [8]. Munoz et al. [26] hypothesize that impulsivity, hyperactivity, and inattention are due to deficits in inhibitory control. Therefore, they compared participants with ADHD with healthy participants regarding their oculomotor abilities. Oculomotor tasks are well suited to test inhibitory control because the brain regions affected by ADHD and those responsible for saccade control would overlap. They recorded gaze behavior during pro and anti-saccade tasks. Their results showed that participants with ADHD had more problems suppressing unwanted saccades in the anti-saccade task. Thus, there is an altered gaze behavior. They conclude that particular deficits in the endogenous component of attention result from a lack of inhibitory control. Hence, we focus on the training of inhibition control and the endogenous part of attention,
focused attention, for the design of our application.

Since persons with ADHD show an altered gaze behavior [26], the application of eye-tracking and gaze control has also been used for the diagnostic of ADHD [15] and therapeutic games for ADHD [1]. The latter used a remote-controlled Eye-Tracker system to collect the gaze behavior. However, the approaches of [1] have used conventional output devices such as desktop screens. In our work, we therefore extend these approaches and combine gaze control with VR.

### III. Design Recommendations & Game Concept

In our literature review and analysis of related applications, we collect design recommendations that guide our design process. In particular, we have included important recommendations for the use of gaze control (G1-5) and aspects that are important when designing for children with ADHD (A1-11).

First, we present five design recommendations that are important when designing games with gaze control. Gaze control describes an input option in which information about eye movement and gaze direction, and pupil size are used. It is particularly interesting because the gaze indicates where the visual attention is currently directed to [25]. Gaze control offers several advantages over other inputs. It is faster and more effortless than other inputs since it does not have to be learned. It also allows for exceptionally smooth operation when combined with other inputs. A significant advantage of games with gaze control is increased immersion during gameplay [30]. A problem when using gaze control is the Midas Touch Problem [22]. It describes the use of the eyes as a direct substitute for a mouse, in the sense that any eye movement automatically triggers a computer command. The eyes are constantly in motion and thus permanently look at something. If an action is assigned to each eye movement, the eyes’ natural task, seeing, is disturbed. Hence, to create a comfortable gaze control, one should consider the following design recommendations.

**G1: Single Player**
To focus on the task, it is better if the game is a single-player game instead of a multiplayer game. In a multiplayer game, there are more different interactions between the players, which are difficult to realize all with gaze control [20]. So, single-player mode should be used.

**G2: Avoiding Midas Touch Problem**
To circumvent the Midas Touch Problem, the user should be able to decide when he wants to trigger a command and when he wants to look at the scene [22]. One possible solution is to use a second input modality, e.g., a controller. The selection is conducted by gaze control and then confirmed by pressing a button of the controller. So, looking at objects and triggering actions should be separated [19].

**G3: Dwell time**
The use of dwell time or buttons for the interaction with the game is helpful [1]. In a game, the players usually want to keep an eye on the environment. But if they have to change continuous parameters with the eyes, e.g., to move an object, the ability to observe the environment is limited [21]. Hence, dwell time is another possibility to avoid the Midas Touch Problem, as players can directly define when they are looking around and when they want to conduct an action.

**G4: Small amount of actions**
Due to the problems mentioned before, it is challenging to map different game actions to gaze controls [20]. Additionally, there are fewer other kinds of gaze actions (e.g., dwell time, fixation, saccades) available. Hence, a small amount of actions is recommendable.

**G5: Highlighting**
When using a controller or a mouse, players often get direct information on where the mouse pointer is pointing at. But where someone is looking at, one is often not even directly

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**Fig. 1.** Left: "Fast Phase", Right: "Focus Phase"
A9: Simple Design
The design should be user friendly as well as should avoid overstimulating visual design, and too much distraction [10].

A10: Coloring
Bright colors should be avoided for children with ADHD, as they can also appeal distracting [2].

A11: Sounds & Music
Quiet background noise and music should be used not to distract too much. [2].

Resulting from the design recommendations, we designed a single-player (G1) VR game for the HTC Vive Pro Eye. Players are sent to a space mission, that they have to protect their spaceship from asteroids and take care of enough fuel for the spacecraft to finish the space journey. We used the eye-tracking of the HTC Vive Pro Eye to let the players interact directly with the virtual world. The game carried out the main interactions in the game, which means players can select the object that they want to interact with by fixing them with their eyes. All things that the players can interact with are highlighted with visual feedback (G5, A8). To avoid the Midas Touch Problem by the object selection (G2), we used the following forms of interactions: Pressing the trigger button of the HTC Vive controller to shoot asteroids and the dwell time (G3) of the gaze to collect the fuel objects. In doing so, we have limited the number of possible actions to these two because it is challenging to implement many control options with gaze control (G4). So that the player knows which form of interaction is currently being used, it is permanently assigned to fixed phases and visualized clear (G5). Children with ADHD show improved performance as well as greater motivation when they are rewarded. Thereby, short-term rewards are preferred (A7). Hence, we choose a robot companion that accompanies the players. The robot gives the players instructions, feedback and praises them. In total, there should be six phases with slightly increasing difficulty and varying tasks (A5, A6). Thereby, a Fast Phase and a Focus Phase were designed, which are played alternately. The total playing time should not exceed ten minutes to keep the risk of cybersickness low (A1). Hence, we chose a playtime of approx—8 minutes (1.45 minutes per phase, six playing phases in total). The design of the game is deliberately kept simple (A9). We used muted colors (A10), and background music was omitted (A11). Only shooting asteroids and collecting fuel objects make a sound, which also serves as feedback (A8). We chose a space scenario since the ability to shoot something with the eyes is not questioned in such a scenario (A2).

A. Fast Phase
This phase is an active play mode that serves as an enjoyable onboarding and should increase the players’ motivation (A7). Players must direct their gaze at oncoming objects and then use the controller’s trigger button to fire a shot at them (G2). The players’ task is to destroy as many asteroids as possible within a given time to protect the spaceship. For each asteroid
the players shoot down, they get one point. The players see the asteroids flying directly in front of them through the window towards the spaceship. When the players look at an asteroid, it changes color to indicate that the selection is successful (A8). Once the players have confirmed the selection with the trigger button, the asteroid explodes and is destroyed.

B. Focus Phase

The focus phase is where the actual attention exercise takes place. Compared to the fast phase, it is quiet and slow. To contextualize this focus phase, we choose the process of refueling or recharging the spaceship as an action that requires patience and in which you can concentrate for a moment before the defense starts again in the fast phase (A2). The players must direct their gaze, and thus their attention, to specific objects. If they get distracted and averts their gaze, the progress made is slowly lost again. Children with ADHD have problems suppressing unwanted saccades and consciously controlling fixation. But these deficits can be counteracted through a repeated, targeted control of the gaze [26]. The players’ task is to keep their eyes on fuel objects and hold them there until the fuel is completely depleted. At this moment, we address the focused attention. If they get distracted by other objects and averts their gaze, the progress will be lost. If the players’ gaze is on the fuel object, it will slowly grow smaller, and if it loses focus, it will grow back to its original size. During this phase, the players’ gaze is visualized by a red crosshair (A8). Through this visualization, the players’ gaze is clarified and made aware. To increase the level of difficulty (A5), we added more distractions in each of the three Focus Phases (e.g., astronauts or stars flying through space while the players have to fix the fuel objects with their gaze). By adding the distractions during the attention task, we also address the inhibitory control.

IV. Discussion and Future Research

We created a VR game for children with ADHD that combines gaze interaction to focus attention and a playful virtual environment that should maintain the players’ motivation. Guided by theory, we have established design recommendations that will serve as a basis for designing games for children with ADHD and games with gaze control. There is both research on VR games for ADHD children and games for children with ADHD that use gaze control, but - to our knowledge - no game designs yet combine both. Our game prototype shows that the design recommendations can be implemented well. We created the focus phase that includes the actual attention task. The players’ gaze has to be used purposefully by keeping the eye and the attention on an object for a longer time. For the motivation and to maintain fun during the game, we also created the fast phase, which reminds us of a simple shooter game, which is usually rated as fun [10], [13]. In the next step, we plan to conduct an evaluation in which we will subject children with ADHD to a training phase and compare attention performance before and after that. Before that, we want a few ADHD children to test the game first to see how they get along with the gaze control and if we need to make any adjustments to the game design before we can evaluate its impact on attention.

We present a new game concept to help children with ADHD train their attention. For this, we combine the high immersion of VR technology and especially the gaze control as an operation. The combination of these three elements seems to be a promising method for use in ADHD therapy. We also collect design recommendations from the literature that might help designing future applications.

REFERENCES


