PigScape: An embodied video game for cognitive peer-training of impulse and behavior control in children with ADHD

Yulia Gizatdinova
Faculty of Information Technology
and Communication Sciences,
Tampere University, Tampere, Finland
julia.kuosmanen@tuni.fi

Vera Remizova
Faculty of Information Technology
and Communication Sciences,
Tampere University, Tampere, Finland
vera.remizova@tuni.fi

Antti Sand
Faculty of Information Technology
and Communication Sciences,
Tampere University, Tampere, Finland
antti.sand@tuni.fi

Sumita Sharma
INTERACT Research Unit, University
of Oulu, Oulu, Finland
sumita.sharma@oulu.fi

Kati Rantanen
Faculty of Social Sciences, Tampere
University, Tampere, Finland
kati.rantanen@tuni.fi

Terhi Helminen
Faculty of Social Sciences, Tampere
Univesrity, Tampere, Finland
terhi.helminen@tuni.fi

Anneli Kylliäinen
Faculty of Social Sciences, Tampere
University, Tampere, Finland
anneli.kylliiainen@tuni.fi

ABSTRACT

This paper describes a therapeutic full-body controlled video game for children with attention deficit / hyperactivity disorder (ADHD). The game supports a co-located gameplay with a depth-sensing camera and a large media screen. Children play the game in pairs for improved impulse and behavior control, self-monitoring, peer-communication, and emotion regulation. The gaming was implemented as a part of a neuropsychological group intervention for children with confirmed deficits in attention or diagnosed ADHD. We present a final design of the game and associated gaming routines, explain anticipated health benefits of the gaming, outline how the gaming can be used for research and therapeutic purposes, and provide directions for future research.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Interaction techniques; Gestural input; Interaction design; Interaction design process and methods; User centered design.

KEYWORDS

Child-computer interaction, Game design, Active gaming, Embodied techniques, Gesture-based interfaces, Kinect, Depth camera, Children, Attention deficit, hyperactivity disorder (ADHD), Impulse control, Inhibition, Cognitive training, Rehabilitation

1 INTRODUCTION AND BACKGROUND

Many children with attention deficit / hyperactivity disorder (ADHD) have a challenge of high distractibility. Yet, the core ability for maintaining goal-directed behavior (e.g., completion of tasks, performing on-task behavior) is inhibition of inner and outer impulses and stimuli [1]. Examples of useful interventions for children with ADHD focus on the recognition of patterns of problems and managing own thoughts, behaviors, and emotions (e.g., learning how to concentrate on a task, not blurting out answers before the questions have been completed, thinking about consequences of own actions, etc.) [9].

Lately, computerized and otherwise technologically-enhanced gaming has started to be leveraged for ADHD treatment. Indeed, gaming that is fun yet educational and skill-building could complement traditional intervention schemes or serve as a stand-alone mean of ADHD rehabilitation, monitoring, and diagnostics [11]. Among various computerized solutions for ADHD such as, for instance, desktop or mobile/touch-based support for therapies [8], virtual classrooms [5], and biofeedback [4, 15], only few applications exist that go beyond the desktop paradigm and encourage children to physically move in a space [6, 10]. These applications, usually designed as proper games, utilize embodied technologies for tracking of body/hand gestures and movements, thus, enabling interaction with objects on a large media screen.

It has been shown that while playing immersive body-controlled video games, children with ADHD achieve equal or even superior results as compared with their neurotypical peers [3]. This is a promising result for the development of training applications that engage children with ADHD in mental and physical skill acquisition [13]. Noteworthy, energy expenditure during embodied gaming is comparable to that associated with light to moderate physical
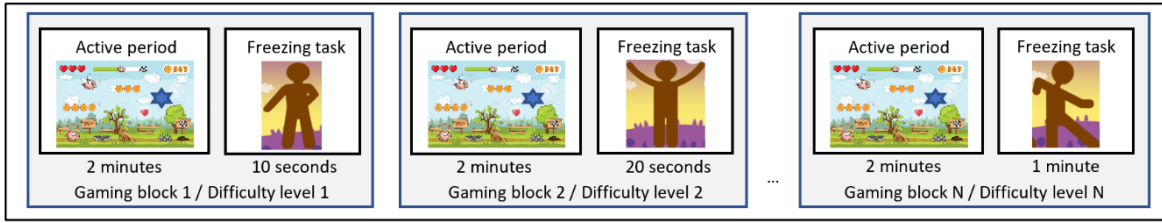
Figure 1: A PigScape game session overview with gaming blocks of consecutive physically active periods and freezing tasks. Game graphics (graphiriver.net and our own assets) is royalty-free with a license allowing redistribution for non-commercial use.

activity and can improve physical functions (e.g., motor skills and postural control) of children [e.g., 2]. Active physicality of embodied gaming benefits children with ADHD who may not yet be able to control their hyperactivity and impulsivity to that extent as to commit to regular and prolonged sedentary therapy sessions. Embodied gaming as a mean of learning is suitable especially for those children who have developed hyperactivity as a compensatory mechanism - these children need to physically move to stay focused on a task [12, 13].

In this paper, we present an embodied game called PigScape for cognitive impulsivity training and measuring a child's ability to inhibit impulses. The game is a product of working in close collaboration child neuropsychologists, HCI researchers, graphics designers, and specialized school teaching staff. Children (N = 4; two of them had a formal ADHD diagnosis) helped to customize game graphics, adjust difficulty levels, create game narration, and define a gesture vocabulary to control the game. Next, we present the core design of PigScape game, explain its anticipated therapeutical effects, and outline how the gaming can be used for research and therapeutic purposes.

2 PIGSCAPE GAME APPLICATION

The logic of the game is based on a well-known physical go/no-go exercise in which a child stays motionless for a predefined time. The freezing is performed on demand, usually after a short period of active movement (like dancing or running). This exercise, with a purpose of suppressing excessive movement in a state of high arousal, is recommended for children with ADHD for strengthening their impulse control and, therefore, behavioral regulation in the end [1]. Variants of this go/no-go task are used in neuropsychological assessment batteries of attention and executive functions widely accepted in professional society [e.g., 7].

In our design, the game includes physically active periods of play lasting a few minutes and much shorter freezing tasks (Figure 1). The protagonist is a pig escaping from a pigsty. In active periods, the pig runs from left to right while collecting coins and other items on its way in a side-scrolling obstacle course (Figure 2, left). A child player performs a jump to control the pig avatar, avoiding obstacles and reaching higher collectibles. Optionally, jumping with both hands up grants the avatar wings, allowing it to jump even higher and reach further collectibles. At some point, the running pig encounters a human silhouette of a predefined shape. A child's task is then to repeat the posture and remain perfectly still for maybe

ten seconds to start with. After a freezing task, an active period carries on followed by another freezing task, and the game continues this way. The freezing tasks get gradually longer, increasing, for instance, from ten seconds to one minute as Figure 1 illustrates. Another factor contributing to the difficulty of play is a freezing posture that can vary during the game to maintain engagement and make the game suitably challenging to play (Figure 2, right).

2.1 DESIGN CHOICES FOR ADHD

Next, we outline some of the design choices to support children's motivation and learning with PigScape gaming.

- **Co-located gameplay**. In group games, children with ADHD often interfere with each other and may easily get distracted by the peer's behavior. Our wish was therefore to support a co-located gameplay so that children play the game in pairs. This offers a learning environment in which the children receive support and guidance on improving their peer-communication, self-control, and emotion regulation from the neuropsychologists attending the gameplay. The game can be organized either competitively or collaboratively.

- **Ease-of-use and child satisfaction** directly affect therapeutical efficacy of the gamified training. To achieve high intensity of the training in terms of weekly hours, the gaming needs to be fluent and motivating. Maintaining engagement and motivation are critically important for supporting a child's perception of the gaming as her/his own personal choice (as opposed to a treatment or therapy). Thus, the game always starts from a physically active period that has self-explanatory graphics and logic with many elements of traditional, recreational gameplay. It was our intention that no special knowledge or skills are required from children to engage with the game right from the start.

- **Success is rewarded, failures ignored.** Due to altered motivational processing (i.e., reward and punishment sensitivity), children with ADHD benefit greatly from immediate and positive feedback [14]. For freezing tasks, at first, we designed that if a child moves, the game "notices" it and gives an immediate "penalty" (e.g., takes away powers or decreases a score). After piloting the game with children with ADHD we realized that a less strict condition that would not affect the score directly would work better. Therefore,
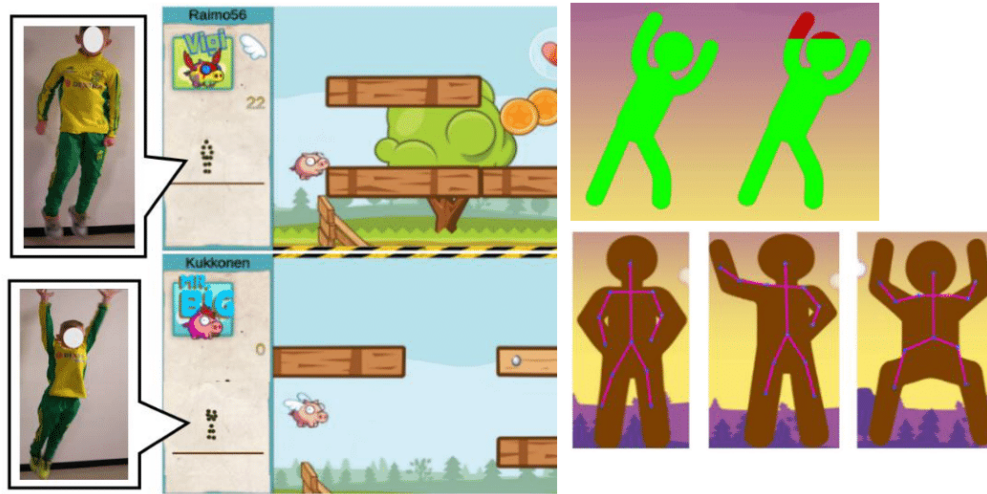
Figure 2: Left: Active gaming for two players. Children bodies are visualized as dotted silhouettes. Top-Right: 100% success of the freezing task (left) and 86% success of the freezing task (right). Bottom-right: Body postures of different difficulty. Game graphics consists of royalty-free assets with a license allowing redistribution for non-commercial use.

the game counts a success in the freezing task as a percentage from 0 to 100% and visualizes the result to a child, as Figure 2, top-right illustrates. The game is adjustable, for example, it detects only large movements and disregards small "fidgeting".

- **Re-joining the game** implies that the game continues automatically, even if a child for some reason stops controlling the game, which may happen in case of a technological failure or moments when a child refuses to play. In this case, the pig still continues to run an obstacle course (without a dramatic decrease in the score or powers). Since children play in pairs, it may be important for them to perform well in front of each other. Failures to demonstrate a good gaming performance to a peer may negatively affect self-esteem of a child, motivation, and, consequently, effectiveness of the training. Therefore, games that allow and motivate players to re-join the gameplay without "reputational losses" are preferable in ADHD rehabilitation.
- **A personal best and daily scores of a child** (e.g., as compared to the scores of all other children participating in a rehabilitation program) are visualized because it is a strong motivational factor for children with ADHD.

2.2 SYSTEM DESCRIPTION

The game is played with a large projector screen, a depth camera Microsoft Kinect Sensor V2 for Windows, and a powerful laptop (e.g., MSI GT72S Dominator Pro with Windows 10, 2.7GHz Intel Core i7-6820HK, and 16 GB RAM). A recommended distance between the sensor and the players is ~2.5 meters. The game software prototype was created using Unity 2018, while the gesture tracker was implemented using Kinect for Windows SDK 2.0 C++ wrapper. Twenty body-joint positions obtained by Kinect API were tracked in the freezing tasks. In jump detection, positions of the player's head,

shoulders, and hands were processed. The gesture tracker broadcasts the body-joint positions through UDP to the game software, where they are normalized for the screen space.

3 PRELIMINARY RESULTS & DUSCUSSION

The PigScape gaming was implemented as a part of a neuropsychological group intervention, called Rehabilitation of Executive Function and Attention (EXAT, TOTAKU in Finnish [9]) at the Psychology Clinic of the Tampere University. The intervention is designed for school-aged (6–12 years) children for improved executive function and attention. The analysis of 6-weeks-long clinical evaluation and 3-months-long far transfer effects of the PigScape gaming with children with ADHD and attention deficits (N = 10) is still ongoing. A number of game metrics were derived to analyze and visualize the evolution of children performances in a game and a sequence of games. This will support the work of child neuropsychologists in monitoring children development and ADHD-related behavioral markers during the intervention program. There is a preliminary evidence based on the heart rate variability measurements concerning effectiveness of the PigScape training in terms of enhanced attentional regulation and response accuracy towards monotonous and go/no-go tasks.

A decrease in number of children taking part in the gaming as a part of their prolonged rehabilitation program is a general indicator of their overall motivation and engagement into the training activities. During the six gaming sessions, none of the children dropped out the gaming that manifests high motivation of the children to continue with PigScape training. As final feedback after the last sixth gaming session, seven children (70%) mentioned that the time of the gaming passed too quickly, they would participate in the training again, and they would recommend the training to their friends. Most children (80%) deemed the game as easy to understand and/or control by body movements.

When asked at the end about the most interesting and positive experiences in PigScape gaming, four children noted that they liked jumping. Noteworthy, while jumping with hands up was an optional feature of the game, children enjoyed it: "*I have got to jump with a pig and score points. Kept hands in the air while jumping (received wings)*" [J1] and "*It was fun to be able to fly*" [P1]. Three children mentioned that it was fun to perform the freezing tasks. One child specifically mentioned that he liked to win: "[It was nice to] see my name going up in the list [of all other players]" [L1]. When asked about negative experiences, four children mentioned that the freezing task was physically demanding for some of the postures: "I broke my neck" [L1]. Four children mentioned game functions related to jumping as a negative experience (this was mostly related to technical problems).

4 FUTURE WORK AND CONCLUSIONS

The overarching aim of our work would be to develop prescriptive guidelines for ADHD game-like therapies and define appropriate measures to evaluate the training outcomes. This work is still in progress. Based on the results so far, we recommend implementing games, like PigScape, primarily as a part of psychosocial group therapy for children with ADHD, for example, children play the game during weekly group meetings of their rehabilitation program. Because children with ADHD have difficulties in completing assignments without direct supervision, it is advisable to start with a fully supervised gaming (where a trained child neuropsychologist facilitates the gameplay, provides assistance and guidance) and gradually teach children self-instructions of staying on a task during independent work. Thus, the gaming can subsequently be translated into online or parental-supervised home therapy programs.

ACKNOWLEDGMENTS

REFERENCES

[1] Erin Ruth Baker, Qingyang Liu, and Rong Huang. 2019. A View from the Start: A Review of Inhibitory Control Training in Early Childhood. In S. Palermo and M. Bartoli (Eds.). Inhibitory Control Training - A Multidisciplinary Approach. IntechOpen. https://doi.org/10.5772/intechopen.88700

[2] Elaine Biddiss and Jennifer Irwin. 2010. Active video games to promote physical activity in children and youth. Arch. Pediatr. Adolesc. Med. 164, 7, 664–672. https://doi:10.1001/archpediatrics.2010.104

[3] Stéphanie Bioulac, Stéphanie Lallemand, Colette Fabrigoule, Anne-Laure Thoumy, Pierre Philip, and Manuel Pierre Bouvard. 2014. Video game performances are preserved in ADHD children compared with controls. J. Attention Disorders, 18, 6, 542–550.

[4] Franceli L. Cibrian, Kimberley D. Lakes, Arya Tavakoulnia, Kayla Guzman, Sabrina Schuck, and Gillian R. Hayes. 2019. Supporting self-regulation of children with ADHD using wearables: Tensions and design challenges. In Proceedings of the 2020 CHI conference on human factors in computing systems, 1–13.

[5] Unai Díaz-Orueta, Cristina Garcia-López, Nerea Crespo-Eguílaz, Rocío Sánchez-Carpintero, Gema Climent, and Juan Narbona. 2014. AULA virtual reality test as an attention measure: convergent validity with Conners' Continuous Performance Test. Narbona J. Child Neuropsychology 20, 3, 328–342.

[6] Jesús Gallardo, Carmelo López, Antonio Aguelo, Belén Cebrián, Teresa Coma, and Eva Cerezo. 2018. Development of a pervasive game for ADHD children. In Proceedings of the International Conference on Interactivity, Game Creation, Design, Learning, and Innovation. Springer, Cham,526–531.

[7] Korkman M., Kirk U., Kemp S. 2008. NEPSY-II Lasten neuropsykologinen tutkimus [The NEPSY-II: Children's neuropsychological investigation], käsikirja II. Helsinki, Psykologien Kustannus.

[8] Joana Lobo, Matsuda Soichiro, Futamata Izumi, Sakuta Ryoichi, and Suzuki Kenji. 2019. Chimelight: Augmenting instruments in interactive music therapy for children with neurodevelopmental disorders. In Proceedings of the International ACM SIGACCESS Conference on Computers and Accessibility, 124–135.

[9] Kati Rantanen, Elina Vierikko, and Pirkko Nieminen. 2018. Effects of the EXAT neuropsychological multilevel intervention on behavior problems in children with executive function deficits. Cognition and Neurosciences, 59, 5, 483–495. https://doi.org/10.1111/sjop.12468

[10] Chang Hyun Roh and Wan Bok Lee. 2014. A study of the attention measurement variables of a serious game as a treatment for ADHD. Wireless Personal Communications, 79, 4 (Dec. 2014), 2485–2498. https://doi.org/10.1007/s11277-014-1744-9

[11] Katta Spiel and Kathrin Gerling. 2021. The purpose of play: How HCI games research fails neurodivergent populations. ACM Transactions on Computer-Human Interaction, 28, 2, 1–40. https://doi.org/10.1145/3432245

[12] Ari Tuckman. 2013. Understand your brain, get more done: The ADHD executive functions workbook. Independent Publishers Group.

[13] Jaap J. van der Meere, Norbert Börger, and Jan R. Wiersema. 2010. ADHD: State regulation and motivation, Psychiatry, 21, 1, 14–20.

[14] Saskia van der Oord and Gail Tripp. 2020. How to improve behavioral parent and teacher training for children with ADHD: Integrating empirical research on learning and motivation into treatment. Clinical Child and Family Psychology Review, 23, 577–604. https://doi.org/10.1007/s10567-020-00327-z

[15] Zheng Hui, Pattiya Mahapasuthanon, Yujing Chen, Huzefa Rangwala, Anya S. Evmenova, and Vivian Genaro Motti. 2021. WLA4ND: A wearable dataset of learning activities for young adults with neurodiversity to provide support in education. In the Proceedings of the International ACM SIGACCESS Conference on Computers and Accessibility, 1–15.