Eye-Controlled Games for Behavioral Therapy of Attention Deficit Disorders

Ashwag Al-Shathri[1], Areej Al-Wabil[2], and Yousef Al-Ohali[1]

[1] Computer Science Department
College of Computer and Information Sciences, King Saud University, Saudi Arabia
[2] Software Engineering Department
College of Computer and Information Sciences, King Saud University, Saudi Arabia
ashwag.alshathri@gmail.com, {aalwabil,Yousef}@ksu.edu.sa

Abstract. This paper describes an eye-controlled game designed for behavioral therapy of ADHD. A user-centered design approach was adopted in the development cycle of these games in close collaboration with domain experts and target user populations. The games have an Arabic language interface and include multimodal interaction. Game scenarios were designed with increasing complexity depicted in visual design, dwell time for controlling elements within the games, and combinations of key presses with eye-control at higher levels of attention training. The visual design, interaction design and the system's conceptual designs are discussed.

Keywords: Eye tracking, Serious Games, Attention Deficit, ADD, ADHD.

1 Introduction

The proliferation of computer usage in medicine and rehabilitation has changed the way health care is delivered. Attention Deficit Hyperactivity Disorder (ADHD) is a neurobehavioral developmental disorder and is one of the most common disorders of childhood, with a reported prevalence of approximately 3–9% [1]. It is characterized by hyperactivity, short attention span, and impulsiveness, which is thought to contribute to learning disabilities and many behavioral problems. This consequently affects all areas of an individual's life. ADHD is a persistent and chronic condition, however behavioral modification strategies have been shown to be effective in remedial interventions with individuals. ADHD can be challenging for a parent or caregiver with an individual who has this disorder. Interventions often include medications for individuals with ADHD to control the neurotransmitter imbalance that has an impact on brainwave activation patterns. However, these medications only work a relatively short period of time and often cause unwanted side effects. A number of systems have been developed to improve the attention span of children and adolescents with cognitive or behavioral problems and help them to increase the focus and concentrate on some tasks for long periods of time. These projects offer patients the behavioral intervention treatment which when combined with other therapies can provide improvements in the specific deficits associated with ADHD for these patients.

Tarkeezy 'تركيزي' is a game focusing on exploiting existing eye tracking technologies to leverage the potential of creating engaging behavioral therapy programs. Tarkeezy's design is based on incorporating unobtrusive stand-alone eye tracking devices that capture eye gaze of individuals and using that to control objects embedded in interactive computer games. The objective of the proposed behavioral intervention program with games that can be controlled solely through movement of the eyes is to help individuals with ADHD to improve focus, visual and auditory attention, and concentration and learn to ignore distractions.

2   Attention Deficit Disorders

Attention Deficit Hyperactivity Disorder (ADHD) is the most common neurobehavioral disorder of childhood that affects neurobehavioral functioning and development. ADHD is a life-long chronic problem. It is believed that up to 50% of children who were diagnosed with ADHD continue to have symptoms into adulthood. This disorder is characterized by inattention, hyperactivity and impulsivity and associated with impairment affecting various aspects of an individual's life [2]. Considerable evidence has accumulated showing that ADHD is linked to impairment in working memory capacity, which refers to the ability to hold goal-relevant information and skip goal-irrelevant for brief periods of time. Individuals with ADHD often seem immature for their age and unable to control their impulsiveness and hyperactivity. They have difficulty forming friendships with others and may have difficulty understanding the social consequences of their actions [3].

Although ADHD is considered a relatively mild disorder, the negative effects of untreated ADHD can have very serious and long-lasting consequences. People with ADHD often feel depressed or anxious. They often have substance abuse problems. Since they have problems forming friendships, it follows that adults with ADHD may have marital issues as well. People who have ADHD easily feel overwhelmed and have low motivation. In addition to these issues, children and adults with ADHD often have problematic employment histories. Difficulties in school are also common among teens and adults with ADHD. Hence, early diagnosis and treatment is essential for people with this disorder to minimize the risk of such serious impacts upon all aspects of life [4]. A range of interventions and therapies for individuals with mental health problems have been explored to develop appropriate behavior and adequate social skills according to rules and societal norms. Some commonly used remedial programs for individuals with ADHD include interventions such as pharmacological, behavior, cognitive behavior, neural-based, and play. Each one has its own merits and demerits and quite often a combination of two or more interventions are sought by the clinicians in treating individuals with ADHD. Some individuals with ADHD take stimulant medications to correct the neurotransmitter imbalance that affects their brainwave activation patterns. However, medications only work for a short period of time and often cause unwanted side effects. In recent years, interventions for ADHD often consider treatment plans that involve behavioral interventions, neurofeedback, non-invasive, drug-free approach to rehabilitating brain function and overcoming ADHD [5,6].

Play is an important part of childhood development and the natural context within which children develop complex social behaviors and competence. The use of play as an intervention plan to treat individuals with cognitive difficulties and mental health disorders may bridge the gap between the exceptional individual's mental health needs and the available services. Play acts as a medium to help therapists interact with individuals and help them express their feelings and emotions [7]. Play therapy is widely used as an intervention for individual's behavioral, cognitive and emotional disorders because it's focus on the developmental needs. As noted by the Association for Play Therapy [8], play therapy is "a systematic use of a theoretical model to establish an interpersonal process in which trained play therapists use the therapeutic powers of play to help clients prevent or resolve psychosocial difficulties and achieve optimal growth and development". It is an intervention based on the cognitive, social, and emotional development. Evidence suggests that play therapy is effective with individuals who experience social, emotional, behavioral, and learning problems.

In recent years, research studies have also demonstrated that play therapy is effective with individuals with ADHD in particular, and that it has a positive impact on self-concept, self-efficacy, depression, anxiety, general behavioral problems, and treatment compliance. The individuals participating in play therapy have been shown to be less stressful, emotional distress and difficulties with withdrawal [9].

3   Eye Tracking: Diagnostic and Interactive

Eye tracking is a technique that allows users to determine where individuals are focusing their visual attention at a given time. The point being focused upon in an inter-face is called a gaze point. Tracking eye gaze of users has been used in the design and development of assistive technologies and in diagnostic contexts of HCI research. The direction of gaze indicates the direction of attention. In this way we can gain insight into what the observers looked at, what they might have perceived, and what object drew their attention [10]. Eye tracking is a computerized remote video-based corneal reflection device that captures individual's gaze without being attached to them [11]. Gaze control is a feasible alternative to hand-based interaction that gives users the ability to control the computer in situations when hands-off control is desired. It has recently become of central concern in several application domains of disciplines such as biology, medicine, psychology, and neurology [12]. Recently, two lines of research have emerged that involve eye tracking. The first one is diagnostic eye tracking which examines human cognition and perception through experimentation; application domains for this type of research are HCI, psychology, medicine, and neurosciences. The second line is interactive eye tracking which integrates gaze within applications to use the eyes as a control mechanism; application domains for this type of research are gaze-controlled games, biometrics, and assistive technology [11]. Recent discoveries in the field have led to an abundance of new applications. New improvements in interactive methods of using gaze control and eye movement have the potential to make human-computer interfaces faster and more efficient. This potential could benefit users with and without disabilities.

4   Tarkeezy

The Tarkeezy program is a behavioral intervention serious game designed to be controlled solely through movement of the eyes using eye tracking technology to help individuals with ADHD to improve attention, concentration and learn to ignore distractions. This program depends on objective gaze metrics gathered by corneal-reflection eye trackers (e.g. gaze coordinates, fixation duration, and the number of fixations) for the purpose of controlling objects embedded in the games. The system is comprised of a pre analysis stage in which the specialist selects and configures the games with the suitable dwell time and size of area of interest (AOI) according to the subject's disorder severity. This step includes: design sessions' procedures according to the subject's needs, select the game, the level, and set the dwell time and the size of AOI. The system also includes a playing and data analysis component which processes the gaze measurements that are read from the eye tracker's live stream to control the game such as the gaze coordinates after mapping game window's coordinates to the eye tracker coordinates, fixation duration, and the number of fixations. The final component of the system is the reporting component which analyzes the data derived from the sessions to produce progress charts for the specialist, and to print reports. Before the session, the specialist will register the subject and enters their demographic data. After logging in to the system, several tasks can be performed to manage the subject. Calibration follows before launching the games as depicted in Fig 1.
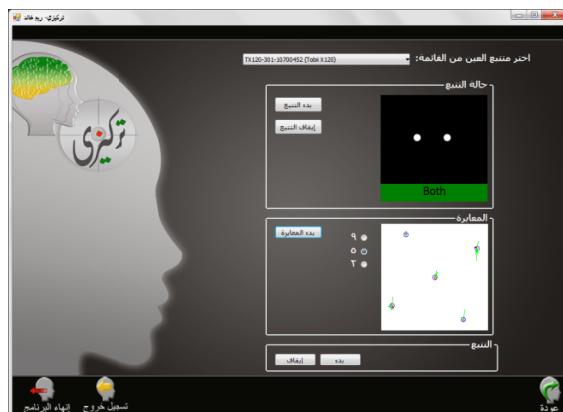

Fig. 1. Calibration of the eyes in the Tarkeezy games

The specialist will select the game and appropriate level for the subject. Then, the user starts using the system. After starting the game, the system will read the data from the stream of gaze captured with the eye tracker to facilitate gaze interaction with controlling objects within the game. The specialist can show data in a graph format to monitor the individual's progress across game sessions. Games were designed with increasing complexity to introduce challenge at progressive levels in the games. Complexity factors include increasing distraction with background images,

manipulating dwell time to increase the difficulty of controlling objects or avatars within the games, and adding elements of control to increase the complexity (e.g. combining a key press with visual attention on objects to manipulate them within the game scenario).

5   Conclusion

This paper described the design of eye-controlled games for behavioral therapy of attention deficit disorders. The system was designed in UCD design cycles and underwent initial user-acceptance testing. Preliminary evaluations demonstrated good usability measures by heuristic evaluations of specialists and target user populations. The testing phase is underway. Future work involves conducting user evaluations of the effectiveness of these games in the context of behavioral therapy for ADHD.

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