Can We Play with ADHD? An Alternative Game-Based Treatment for Inattentive Symptoms in Attention-Deficit/Hyperactivity Disorder

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Abstract Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder presenting in early childhood with persistent, pervasive and impairing symptoms. It is also associated with other problematic mental health issues and negative outcomes, such as aggression, difficulties forming relationships and academic and occupational problems. Current standard treatments for ADHD include pharmacological treatments with stimulants and other medications, psychosocial interventions such as behavioural modifications, or a combination of both approaches (multi-modal approach consisting of parent education, medication and behaviour management for the child). There is interest in understanding effective non-pharmacological treatments for ADHD, given the temporary effects of medication and recent controversies on over-medicating children with ADHD. The use of neurofeedback treatment and cognitive training offers a promising new area for clinicians. We present a brain–computer interface (BCI)-based neurofeedback and cognitive training programme targeting the inattentive symptoms of ADHD in this chapter. The concept of an individualized model of attention is one of the features of the BCI training system. Incorporating this attention model into an innovative game targeted at ADHD children is another unique feature of this system. Recognizing the importance of validating serious games for the use of therapy, we have conducted several trials testing out the validity and playability of the BCI game, including a pilot phase and a larger randomized controlled trial. Currently, the future of this BCI-based treatment for ADHD is promising and we hope

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that, through our research efforts, it may prove to be an effective and viable treatment option that also appeals to the game-playing nature of children.

Keywords Attention-deficit/hyperactivity disorder (ADHD) · BCI technology · Serious games · Alternative treatment

1 Introduction

Nathan rarely succeeds in finishing his math and language worksheets in class. He is in Primary 3 this year, and the workload at school is rapidly increasing. His teacher can see that he really wants to keep up, but he is finding it too difficult to sustain his attention on one thing at a time. He eventually ends up talking to his classmate next to him or running around in class. He has difficulty completing written assignments, misses out on questions, makes careless mistakes and forgets to do or hand in his homework. Though recognized by teachers to be a bright boy, he does poorly for the academic subjects and starts to lose interest in his studies. His classmates find him rough and noisy and are not keen to be his friends.

The description above is a rather common presentation of a child who has been diagnosed with ADHD. ADHD is a well-known neurodevelopmental disorder that is often associated with problematic outcomes throughout a person's life (Barkley 2002; Faraone et al. 2006; Young et al. 2010; Hodgkins et al. 2011). As it happens with most disorders, there is not only one, specific cause for the onset of ADHD, but it is better conceptualized as a combination of genetic, environmental and biological factors (Nikolas et al. 2010). The prevalence of ADHD worldwide is estimated to be between 5.9 and 7.1 % (Willcutt 2012; Polanczyk et al. 2014). In Singapore, ADHD is the third most serious public health concern for young people below 14 years old (Phua et al. 2009).

ADHD symptoms can be grouped under 3 major categories: inattention, hyperactivity and impulsivity. A child can be diagnosed to be either hyperactive/impulsive or inattentive or both inattentive and hyperactive/impulsive. We have included a full description of the clinical ADHD subtypes in Annex 1 (American Psychological Association 2013). Due to the symptoms described here, it is common for children with ADHD to struggle with everyday tasks. What is even more worrying for the child, however, is that these symptoms might cause disruptions in relationships with family, teachers and peers, academic difficulties throughout the school years, and in some cases, they may lead to school dropouts, delinquency and substance abuse in adolescence and adulthood (Barkley 2006; Biederman 2008; Sibley et al. 2010).

Traditionally, ADHD has been managed by a comprehensive treatment plan that includes psychological, behavioural and educational advice with the option of pharmacological intervention (Fabiano et al. 2009; Charach et al. 2011). For many clinicians and most parents, medication is not a preferred first-line treatment and it is reserved only for the severe cases and for those who have denied or not responded to non-pharmacological interventions. Medication helps to reduce hyperactive–impulsive and inattentive symptoms in individuals with ADHD. In Singapore, the only available stimulant medication is methylphenidate (Ritalin), a psychostimulant that has been available in the market for over 50 years, and remains the most common medication for the management of ADHD (Gadoth 2013). Atomoxetine, a relatively newer non-stimulant medication for treating ADHD, has been available for use over the past decade.

There are many trials for ADHD medications, indicating a range of side effects that are mild in intensity and short lasting (Sangal et al. 2006; Abikoff et al. 2007; Mosholder 2009). Some of the most common side effects are appetite suppression, growth retardation and cardiac side effects (stimulant-induced increases in mean blood pressure, heart rate and QT interval). Despite the existence of sound empirical background in literature, numerous clinicians have expressed their concern on whether the true dangers of such medication are known and fully understood (Graham et al. 2011), especially possible side effects that are rare and severe. Sudden death for example would be extremely difficult to investigate, since large numbers of subjects would be needed for recruitment, due to its rarity as event (Berger 2004). Another situation that seems to be on the rise in the last few years is the diversion of medication for misuse and abuse, especially during adolescence (Faraone et al. 2007; Rabiner et al. 2009; Setlik et al. 2009).

Studies have shown that even though medication can improve ADHD symptoms effectively, the improvement in academic grades is more modest and limited. Medication does not provide a solution for the problems related to children's academic performance and relationships with significant others, with the latter being a major distressing factor in a child's life (Chronis-Tuscano et al. 2013). Parents also seem not to favour medication, understandably, out of concern over the associated side effects and are often willing to try out non-pharmacological interventions first. Medication is also not seen as a permanent solution as the child does not learn to control or manage these troublesome symptoms.

There are a number of studies suggesting an advantage of non-pharmacological approaches over those of pharmacological treatment in terms of efficacy. Fabiano's meta-analysis published in 2009 strongly supports behavioural treatments for long-term effects on attention. Their results were partially duplicated by Hodgson et al. (2012) suggesting similar findings. Their evidence favours behavioural treatments, especially behaviour modification and neurofeedback. A more recent study reported that neurofeedback outperformed drug treatment (methylphenidate) for ADHD when measuring academic performance (Meisel et al. 2013). Evans et al. (2013) reviewed the growing literature on training interventions and provided guidance for conceptualizing the treatment research. According to them, there is a clear distinction between behaviour management and training interventions with the former being well-established treatments (e.g. behavioural parent training, behavioural classroom management and behavioural peer interventions). Training interventions, on the other hand, appear to be lacking strong, supporting evidence. A systematic review and meta-analysis by Sonuga-Barke and his colleagues (2013) on non-pharmacological interventions for ADHD strongly suggests the accumulation of additional evidence for the efficacy of behavioural interventions, neurofeedback and cognitive training.

An overview of reviews compared the efficacy and safety of non-pharmacological treatments to those related to drug therapies and control conditions of cognitive and behavioural symptoms of ADHD (Foisy and Williams 2011). The authors conclude that, for all interventions assessed, there was a lack of high-quality randomized controlled trials using standardized tools to measure clinically important outcomes over adequate periods of time. In the meantime, non-pharmacological interventions are becoming increasingly popular as people are more vigilant of the adverse effects of stimulant therapy. This increased demand for non-pharmacological therapies must be accompanied by rigorous scientific research in order to assess their efficacy.

Neurobiological studies, in an attempt to map the ADHD brain, show evidence suggesting that the brain of ADHD children is actually wired in a different way than non-ADHD children (Konrad et al. 2010; Loo et al. 2013). The latest approach in literature has overcome the idea of certain regions of the brain being dysfunctional. We are now talking about dysfunctional connectivity among regions; so, it appears to be more of an organizational matter rather than some specific areas of the brain not functioning properly (De la Fuerte et al. 2013). Some researchers have also differentiated the profiles of ADHD children in terms of cortical and subcortical abnormalities. Many children with ADHD seem to have an excess of theta wave activity and not enough beta activity (Arns et al. 2013). Theta waves are traditionally associated with internal focus and drowsiness, whereas beta waves are associated with external focus and alertness (Cortese 2012). It is also common to see an increase in theta activity when ADHD children are focusing on a task that is repetitive or uninteresting to them (Shiels et al. 2010).

It has been hypothesized that computer-based training may improve certain cognitive abilities such as working memory or attention in ADHD and become further generalized into other settings and everyday tasks (Klingberg 2002, 2005). A very common training programme is the Cogmed Working Memory Training. Several reviews of studies as well as recent randomized controlled trials examining cognitive remediation training for children with ADHD suggest evidence that is inconclusive (Rapport et al. 2013). Cogmed did not show evidence of reducing ADHD symptoms or generalized improvement in other functional domains. Also, there is not enough evidence to suggest that even when there is an improvement, this can sustain over time (Holmes et al. 2009; Klingberg et al. 2010). Jaeggi et al. (2011), on the other hand, suggest that cognitive training can be effective and long-lasting, but that there are limiting factors that must be considered to evaluate the effects of this training, one of which is individual differences in training performance.

There is a need for more research to investigate whether teaching good learning habits when young, such as attention control, might have positive long-term consequences even in the absence of the intervention. This is particularly important when it comes to attentional control, since this is one of the last cognitive abilities to develop in a typically developing brain (Ruff et al. 2003).

2 The Need for Validity Studies in Games for Intervention

There is an increasing use of games in treatment with the advent of serious games. Serious games are defined as games that are developed for purposes other than entertainment. There is a dearth of serious games being backed up by concrete research (Kato 2010). Since the onset of ADHD is during childhood, games appear to be a more effective way to engage these young children, in whom other psychological therapy such as cognitive behavioural therapy is usually more limited due to their limited cognitive abilities.

A review on the use of educational games to enhance classroom learning by Blakely et al. (2009) showed that gaming methods did not improve classroom learning any more than traditional teaching methods. Additionally, marketing efforts will be severely compromised if evidence-based research was not conducted on serious games, A New York Times article by Gabriel and Richtel (2011) reported on the heavy criticism faced by classroom educational software in which their marketing claims were not backed up by sound adequate evidence. All these point towards a future direction in which serious games need to go hand in hand with evidence-based research to market a well-validated game that would benefit patients and users the best way it can.

In order to ensure that validation research maintains the integrity of having a measurable impact on outcomes, a few guidelines have been suggested (Kato 2012):

1. Having a strong theoretical basis driving the development of the game
2. Conducting a randomized controlled trial: the gold standard for a clinical trial comparing treatment to control group
3. Pre- and postoutcome measures have to be objective
4. Negative side effects of the game have to be closely monitored

With these guidelines in mind, we would like to describe a brain–computer interface (BCI) treatment game that was developed for ADHD.

3 Brain–Computer Interface: A Research in Progress

The conceptualization of this game started with an academic psychiatrist who was the dean of a new medical school bringing together a practicing child psychiatrist and a research scientist who worked in the field of BCI and neural signals. Prior to this, research on BCI was largely done on patients with amyotrophic lateral sclerosis, a progressive neurodegenerative disease that affects brain abilities and muscle control. Such patients could not move very much and needed a way to manipulate objects with their brains. This was the main motivation for BCI. The team was interested in looking at the BCI technology and merging it with promising evidence that suggested neurofeedback training could improve attentional control in children. This development was also motivated by the increasing concerns throughout the world that children have been receiving far too much medication to treat attentional difficulties (O'Conner 2001; Blue 2012).

Using the traditional neurofeedback systems as a starting point, the team then developed with an algorithm that would translate each individual's innate attentional abilities to a quantifiable number. Observing the use of traditional neurofeedback, the team found that the use of theta/alpha/beta brainwaves as an attention index was not sensitive enough to detect accurate attention levels. Traditional neurofeedback treatment is also based on a global preset model, rather than an individually tailored model. Furthermore, the cost of these treatments tends to be high and have a long learning period. A recent meta-analysis on 14 neurofeedback studies on ADHD children found that this form of therapy is classified under ‘probably efficacious’ (Lofthouse 2012), a result that is promising but not sufficient to conclude on its efficacy. The team developed a more sensitive attention index by creating an algorithm that is a subject-dependent and personalized detection of attention. The algorithm is developed by using a machine learning approach to derive attention levels. The process involved collecting electroencephalogram (EEG), while the subject performs an attention task and a relaxation task. A classification model is then built to differentiate the two types of tasks using a filter bank. An attention score is thus generated by mapping the classification score to the scale of 1–100 (Hamadicharef et al. 2009).

Part of fulfilling the need for the model to be individualized and not based on a global model is involving a calibration task to measure each individual’s level of attention. The colour Stroop task was chosen to calibrate the algorithm to each individual subject, in which a written colour name is different from the colour ink it is presented in and the participant has to choose the written colour name. The colour Stroop task is a well-established neuropsychological measure (Stroop 1935), especially in measuring response inhibition in ADHD children (Lansbergen et al. 2007); it was chosen for the calibration task with the assumption underlying it that in order for the participant to get a correct answer, they have to be using a significant amount of concentration to inhibit the dominant reading response of the colour ink. Hence, the attention levels measured while the participants are doing the task would be taken as their maximum amount of attention, while the periods in between the task in which they are instructed to rest their eyes by rolling their eyes across the screen would be taken as their baseline relaxation state. Artefacts created by eye and facial movements were addressed through two methods: a wavelet approach to remove the artefact directly and a multiple-model approach based on bipolar EEG which is able to cancel out eye-blink movements (Krishnaveni et al. 2006).

Based on this system, the team analysed the critical EEG parameters during the correct attempts made by the participants and compared that to when the participants are in the relaxation state, to derive an individualized EEG pattern that would represent the participant’s most attentive state. This model is a unique feed-forward system as it makes use of an individual’s direct attention to control aspects of a game.

4 Pilot and Phase 1 Trials

A small pilot trial was conducted to investigate the efficacy and feasibility of using this BCI-based training programme to improve inattentive symptoms of ADHD. Certain considerations governed the design of the game: for it to be repeatable and simple, not too distracting but engaging enough to sustain interest and finally, to examine the minimum sufficient time needed for the intervention to take effect. Using a traditional EEG set-up to administer the intervention, 10 ADHD participants were enrolled to play a simple two-dimensional car racing game for 20 sessions (2 sessions per week for 10 weeks) using the BCI technology, with another 10 participants recruited as controls.

Results from this small trial were promising. The inattentive scores on the ADHD Rating Scale IV (Dupaul 1991) were the primary outcome measure used in this trial. This ADHD Rating Scale is based on the DSM-IV criteria for ADHD and consisted of 9 inattentive and 9 hyperactive symptoms. Three measures can be obtained from this scale: an inattentive score, a hyperactive score and a total score, with higher scores indicating worse symptoms. The main outcome measures were changes in the inattentive scores. A nonparametric Mann–Whitney U-test was used to compare the intervention to the control group. Mean changes for the intervention group were −3.0 (SD = 4.8) and control group 0.8 (SD = 1.3), although the two groups did not differ significantly (Mann–Whitney $U = 16.0$, $p = 0.053$) (Lim et al. 2010).

After the pilot trial was completed, a more intensive BCI game training programme was investigated in a second trial to test whether training over a shorter period of 8 weeks would be as acceptable to parents. The number of training sessions and duration of training were increased from 20 sessions over 10 weeks to 24 sessions over 8 weeks. Additionally, preliminary analysis of the first pilot results appeared to suggest that improvements were sustained 3 months after intervention. The team decided to add booster training sessions, which follow the same BCI training procedures, of one session per month for 3 months. This would follow after the 8-week intensive training, thereby increasing the entire training programme to 20 weeks. A total of 20 participants were recruited for this second pilot trial.

Additionally, technical changes were also made to the device and system. The traditional EEG cap introduced a lot of artefacts in the EEG waves collected due to eye-blink movements. This was replaced with a dry EEG electrode device headband (see Fig. 1, NeuroSky, Inc, USA), with only 2 electrodes measuring brainwaves associated with attention at the prefrontal cortex. A grounding reference electrode is clipped to the ear, and the headband is connected to the computer through wireless Bluetooth technology. Game developers were also engaged to improve the design of the game and make it more interactive and appealing to children. A three-dimensional graphic game, Cogo^{TM} Land, was thus developed specifically for the purpose of the training game. Enhanced visual feedback was also included, and difficulty levels were introduced as an additional element to the game.

Results from this study were very positive (Lim et al. 2012). Parents were asked to complete the same ADHD Rating Scale IV at baseline (0 weeks), end of the treatment sessions (8 weeks) and after the follow-up session (24 weeks). There were significant reductions in the inattentive scores at week 8, with paired t-tests used to assess the changes in scores. At week 8, the mean (SD) change from week 0 was −4.6 (5.9) and median (range) change was −3.0 (−17.0, 4.0) which was statistically significant ($p = 0.003$). However, there were no statistically significant changes of parent-reported inattention scores after booster session. This suggests that although the

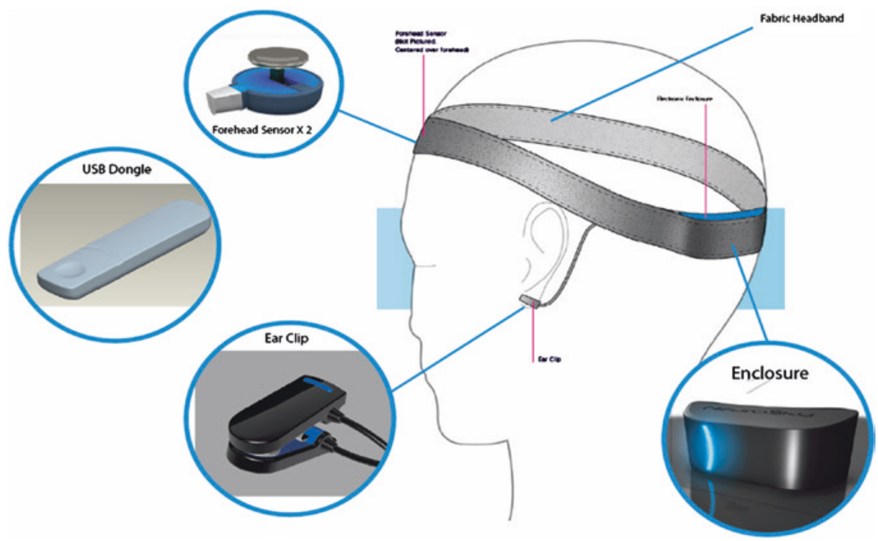

Fig. 1 Illustration of the BCI headband

booster sessions did not significantly improve symptoms further, they served to sustain the effects found from the 8 weeks of intensive training. We also found improved ratings in the hyperactivity score which could be due to the highly structured training environment and behavioural skills learnt through playing the game.

Following the encouraging results of the initial studies, a randomized controlled trial was planned to recruit 160 participants with ADHD. Study procedures and headband design were kept similar, and the study is currently ongoing.

5 Current Randomized Controlled Trial

In our current ongoing study, participants are randomized into either an intervention group or a wait-list control group. The study procedures are kept similar to the previous trials with 8 weeks of BCI training followed by 3 monthly booster sessions.

Participants who are randomized into the intervention group are started on the BCI training immediately, whereas participants in the control group were defined as wait-list controls and did not receive any intervention during the first 8 weeks. Instead, they are started on the BCI training from week 9 onwards. A wait-list group comparison, rather than a sham or placebo control, was introduced to address the ethical caveat of a subset of participants not receiving any form of interventions throughout the duration of their involvement. The time-points of week 1 and week 8 provide a direct comparison of participants who have gone through 8 weeks of intervention versus participants who did not receive any intervention for 8 weeks. Further details on this study can be found on the ClinicalTrials.gov Website (ClinicalTrials.gov 2014).

6 Game Design

The platform on which the BCI treatment is administered to the ADHD participants is known as Cogo^{TM} Land. In Cogo^{TM} Land, an animated bird avatar chosen by the participant will run around an island. The speed at which the bird runs will be based on the participant's level of concentration. This level of attention is measured through the headband device (see Fig. 1), which detects and sends the EEG signals to the computer. An algorithm-derived attention index is then generated and fed back to the participants in the form of a Brain Score from 0 to 100, with 100 being the highest level of attention. The participants are able to monitor their Brain Score changes on the screen as they play the game.

Participants are instructed to focus their attention in order to increase their Brain Score. Once their level of attention drops below their individually calibrated threshold, the avatar stops running until the participant focuses hard enough to get their attention levels above the threshold. The motivation in the game is thus to make the avatar run as fast as it can.

A point system is also integrated in the game, where participants are encouraged to score higher points through various means. There are 3 levels of difficulty in the game. In the first beginner level, the participant is required to run around an island using his concentration. They are rewarded points based on the number of laps they run around the island. In the second intermediate level, the participants have to press a button to jump and collect fruits while using their concentration to make the bird run. They collect the fruits in random order and are awarded points based on the correct attempts at collecting fruits. The final advanced level is the same procedure as the intermediate level, only at this stage; they are required to collect the fruits in a specific order. Again, points are given for correct attempts. Figure 2 shows screenshots of the game at the 3 difficulty levels.

A transference task, which consists of 20 academic questions adjusted for each child's grade level, is administered to the participant at the end of every alternate session. This transference task was added in due to huge concerns of academic impairment in ADHD children (Daley and Birchwood 2010), and there is interest in observing whether the participants would be able to generalize the behavioural contingencies learn through the BCI treatment to an academic setting.

7 Validating the BCI Treatment in ADHD

In developing innovative new treatments for ADHD, there is a need to identify important steps in doing this systematically.

1. Having a strong theoretical basis driving the development of the game
   In order to develop a cogent theory for exploring alternative treatments, the team conducted a series of brainstorming sessions with both basic scientists and clinicians to better understand the existing treatment modalities as well as gaps in the

Fig. 2 Screenshot depictions of BCI Cogo^{TM} Land gameplay

current systems of care. Extensive reviews on what neurofeedback and other cognitive training systems are currently available were also done. This then allowed us to develop the BCI system so as to improve what was already available.

2. Conducting a randomized controlled trial: the gold standard for a clinical trial comparing treatment to control group
   Smaller scale studies were conducted to observe the feasibility and effectiveness of the BCI game system on children. With promising results of parent-reported reduction in inattentive symptoms, a randomized controlled trial is currently being conducted to maintain the integrity in the results that were previously observed.
3. Pre- and postoutcome measures have to be objective
   The primary outcome measure of the studies is the ADHD-RS, which is a well-validated tool for measuring symptoms of ADHD. In phase 1 of our trial, we included teacher's ADHD-RS ratings as a 'blinded' measure to improve objectivity of the ratings. However, due to poor response rates, the teacher responses were inconclusive. In our randomized controlled trial, we improved on our design by making our research clinicians blinded instead of relying on teacher's ratings.

4. Adverse effects of the game have to be closely monitored
   Throughout all the trials conducted, participants were closely monitored in terms of any discomfort or issues faced. Aside from feelings of fatigue and minor headaches experienced by one or two participants, no adverse events were reported. Furthermore, the headaches experienced by the participants did not stop them from continuing with the treatment.

8 Back to the Future

Video games have taken the limelight away from Hollywood (Ryan et al. 2006; Yi 2004), as they now appear to be the world's most common entertainment medium. Their popularity varies according to certain socio-demographic factors, for example age, sex, religion, income and education (Williams 2008), but there is no doubt that a respectable number of people are hooked on online gaming. There are a lot of controversies surrounding the game industry and the consequences it might have on the person. Some of the negative effects might be immunity to the horror of violence (Sherry 2001), increase of body weight (Vandewater 2004) and poorer work/school performance (Gentile 2011). The DSM 5 has also included Internet game disorder as a possible diagnostic category for future versions. The positive outcomes of gaming are definitely the entertainment and fun factor and the fact that they provide a sense of control over a situation (Jones 2002). Some also suggest that video games are an optimal opportunity for learning purposes (Gee 2003). BCI technology allows game development to bring in an entire new dimension of control that players have. This is in line with the progress that games consoles such as the Nintendo Wii and the Xbox Kinect (and now Xbox One) have done.

In developing the BCI game to treat ADHD children we had to consider how the game, the person and the device that all work together in a continuous feedback loop which is self-adapting.

A unique element of the BCI game is the calibration feature; the participant performs the colour Stroop task so as to generate a personalized EEG profile of the user's optimal attentive state. Intervals of resting stage are also included so there are also data of the individual when he is relaxing, providing a pattern of their most inattentive state. Every person is different; therefore, the BCI mechanism achieves a regulation of attention that serves different individual needs. The tailored nature of the BCI is associated with an additional benefit. By being personalized, the treatment becomes both motivating and meaningful for the person. Gameplay is intrinsically motivating but receiving feedback that addresses only to your personal needs can mean extra motivation and surrounds the whole experience with explicit meaning. Subsequently, when an experience is both motivating and meaningful, it can also serve as an optimal opportunity to learn. And when we use the word 'learn', we do not restrict the term only to knowledge acquisition or skill practice, but we are also talking about exploration, critical thinking and problem-solving (Green 2012).

Video games offer players sensational action, competitive rewards and captivating stories, exactly what the ADHD brain demands. It is the sort of stimuli that can rarely be brought together in the real world. Most games that exist in the market have all the above but they also include the violent component. Anderson's meta-analysis in 2010 gathers strong evidence to support that violent video games have a causal relationship with aggressive behaviour and decreased empathy (Anderson 2010). He and his colleagues suggest that the effects of violent games on children do not seem to discriminate among different cultures or gender. Everyone seems to be equally susceptible to the effects of violence. For these reasons, it seems to be quite a relief when games targeted to children are designed without the violent factor, such as Cogo™ Land. This is an attempt to maintain the positive features of the game playing and leave behind the more controversial aspects of it.

Another benefit of the treatment game is generalizability: the ability to gradually build something stronger and then transfer this trained skill to other situations. The literature demonstrates that cognitive training works and that transfer effects may even persist over time, but we need to consider possible limitations that transference is bound to have individual differences for example. Games are supposed to be directly linked to enjoyment; however, this depends heavily on the user and the situation. While some consider challenges or competition as most enjoyable, others find enjoyment in repetitive and low challenging activities (Harrison 1992).

Some children seem unable to engage and benefit from the training. A plausible explanation might be lack of interest during training, or difficulty coping with the frustrations of the task as it becomes more challenging. This would suggest that though useful in many, the BCI game is not suitable for all. Some concerns have also been raised about whether this intervention can cause 'addiction' to computer games. This is highly unlikely considering that the game can only be played in a specific time and place leaving no space for excessive use. In addition, playing the game demands a sustained level of concentration which is hard to maintain for prolonged periods of time. Hence, the game has been designed to be addiction-intolerant. In addition to that, the time restrictions that this treatment offers can also help children with ADHD manage their time in a more constructive way. Time management is particularly important for individuals with ADHD, an element particularly fundamental when we are talking about quality of life.

This present game treatment, however, does not provide a panacea for all the difficulties that accompany ADHD. Except inattentiveness and/or hyperactivity, children with ADHD often have conduct problems, usually characterized by defiance and aggressive behaviour. Such problems make it difficult for the child to find his role at school, in peer relationships and within the family. Emotional problems may also be present, leading the child feeling isolated and experiencing low self-esteem. These behaviours may be more troublesome than the ADHD symptoms alone, and the game by no means claims to provide treatment for these issues.

Some of the challenges that accompany this research study relate to the content of the game. Although it has 3 difficulty levels, the actual game procedures do not vary much, resulting in a rather repetitive mode of playing. Therefore, some children seem to grow out of it relatively quickly. To encourage motivation, we have come up with a reward system, where the child collects stickers at the end of every session and he gets an extra sticker only if he scores better than his previous session. The stickers are eventually exchanged with a present. This reward system was incorporated into the game so as to increase and sustain motivation. For the same reason, we entered different levels of gaming, with an increasing factor of difficulty, so as to keep engagement levels high. Therapists who attend to the sessions are always in the assessment room together with the child, ensuring the proper conduct of the treatment and at times providing verbal encouragement to the participant.

We propose that future research should focus on the complexity of the software of the BCI treatment, creating increasingly more sophisticated simulations for the children to take part. We also suggest that the ultimate goal of the BCI treatment must be transference; therefore, the training techniques must be designed with this idea in mind. A more in-depth understanding of the profile of the individuals who will benefit from these types of intervention is also an area that has not been adequately investigated yet.

We now have a better understanding on how the brain works and the communication of different neural pathways that are involved when cognitive processes take place. The overall literature appears clear in that most positive effects on cognitive training come with suitable attentional allocation and resource management. However, application of these findings to education is still in an experimental stage.

Children spend most of their time either at home or at school, and they develop relationships with others within these environments. Ideally, treatments should be implemented at both home and school (Eiraldi 2012), and take into account the variables that we have discussed, which might hinder or enhance training.

Annex 1

DSM-5

A. Either (1) or (2):

1. **Inattention**:

Six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities:

Note: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility or failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least 5 symptoms are required.

(a) Often fails to give close attention to details or makes careless mistakes in schoolwork, at work or during other activities (e.g. overlooks or misses details, work is inaccurate).
(b) Often has difficulty sustaining attention in tasks or play activities (e.g. has difficulty remaining focused during lectures, conversations or lengthy reading).

(c) Often does not seem to listen when spoken to directly (e.g. mind seems elsewhere, even in the absence of any obvious distraction).
(d) Often does not follow through on instructions and fails to finish schoolwork, chores or duties in the workplace (e.g. starts tasks but quickly loses focus and is easily sidetracked).
(e) Often has difficulty organizing tasks and activities (e.g. difficulty managing sequential tasks; difficulty keeping materials and belongings in order; messy, disorganized work; has poor time management; fails to meet deadlines).
(f) Often avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort (e.g. schoolwork or homework; for older adolescents and adults, preparing reports, completing forms, reviewing lengthy papers).
(g) Often loses things necessary for tasks or activities (e.g. school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).
(h) Is often easily distracted by extraneous stimuli (for older adolescents and adults, may include unrelated thoughts).
(i) Is often forgetful in daily activities (e.g. doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments).

2. **Hyperactivity and impulsivity**:

Six (or more) of the following symptoms of hyperactivity–impulsivity have persisted for at least 6 months to a degree that is inconsistent with developmental level and that negatively impacts directly on social and academic/occupational activities:

Note: The symptoms are not solely a manifestation of oppositional behaviour, defiance, hostility or failure to understand tasks or instructions. For older adolescents and adults (age 17 and older), at least 5 symptoms are required.

(a) Often fidgets with or taps hands or feet or squirms in seat.
(b) Often leaves seat in situations when remaining seated is expected (e.g. leaves his or her place in the classroom, in the office or other workplace or in other situations that require remaining in place).
(c) Often runs about or climbs in situations where it is inappropriate (Note: in adolescents or adults, may be limited to feeling restless).
(d) Unable to play or engage in leisure activities quietly.
(e) Is often 'on the go', acting as if 'driven by a motor' (e.g. is unable to be or uncomfortable being still for extended time, as in restaurants, meetings; may be experienced by others as being restless or difficult to keep up with).
(f) Often talks excessively.
(g) Often blurts out an answer before a question has been completed (e.g. completes other people's sentences; cannot wait for turn in cwwwonversation).
(h) Often has difficulty waiting his or her turn (e.g. while waiting in line).
(i) Often interrupts or intrudes on others (e.g. butts into conversations, games or activities; may start using other people's things without asking or receiving permission; for adolescents or adults, may intrude into or take over what others are doing).

A. Several inattentive or hyperactive–impulsive symptoms were present prior to age 12.
B. Several inattentive or hyperactive–impulsive symptoms are present in two or more settings (e.g. at home, school or work; with friends or relatives; in other activities).
C. There is clear evidence that the symptoms interfere with, or reduce the quality of, social, academic or occupational functioning.
D. The symptoms do not occur exclusively during the course of schizophrenia or another psychotic disorder and are not better explained by another mental disorder (e.g. mood disorder, anxiety disorder, dissociative disorder, personality disorder, substance intoxication or withdrawal).

Specify whether:

314.01 (F90.2) **Combined Presentation**: If both Criteria A1 and A2 are met for the past 6 months
314.00 (F90.0) **Predominantly Inattentive Presentation**: If Criterion A1 is met, but Criterion A2 is not met for the past 6 months
314.01 (F90.1) **Predominantly Hyperactive–Impulsive Presentation**: If Criterion A2 is met, but Criterion A1 is not met for the past 6 months.

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