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Monographic Article

Virtual Reality Applications in Attention Deficit Disorder with Hyperactivity: An Approximation

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Summary:

The goal of this work is to analyze the areas of application of virtual reality in attention deficit disorder with hyperactivity. Taking into account the brief and recent history of this technology in the area of childhood, we have reviewed all publications dealing with the topic from 1990-2012. Based on our research, we have distinguished two basic applications: 1) virtual reality as an instrument for the assessment and diagnosis of this disorder; 2) virtual reality as a procedure for intervention and treatment. In this case, virtual reality can be applied as the sole technique or as part of multimodal programs, combined with cognitive-behavioral techniques or with neurofeedback. This work presents the advances and drawbacks of this technology with respect to attention deficit-hyperactivity disorder.

Key words: Virtual reality, hyperactivity disorder, assessment, treatment.

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Introduction:

Virtual Reality (referred to here as "VR") is a dynamic technology that can be used to generate three-dimensional environments where individuals are immersed in a virtual environment or "world" in which different senses are stimulated. In terms of the virtual tools and environments as well as the field of application and proposed objectives, VR is constantly evolving (Sherman and Craig, 2003).

In the 1990s, VR was incorporated to the area of childhood and adolescence, especially in the field of education (García Ruiz, 1998). In this field, VR made a positive contribution in terms of getting students' attention and having a positive influence on their learning curve (Sherman and Juckins, 1992). At the same time, the three-dimensional graphic representations allowed students to navigate graphic models, interact with these models and appreciate more details than they would in the real world, thus stimulating their concentration and motivation (Pimentel and Teixeira, 1992). These were the advantages noted in the first studies on the use of VR, but further research revealed certain drawbacks and side effects associated with VR applications, especially nausea and social isolation (Carr and England, 1995).

At the same time, VR has been increasingly used in the area of psychological alterations and disorders diagnosed during childhood. Problems such as test anxiety (Knox, Schacht and Turner, 1993), developmental disorders, autism (Kijima, Shirakawa, Hirose and Nihei, 1994; Strickland, Marcus, Hogan, Mesibov and McAllister, 1995; Bauminger, Gal and Goren-Bar, 2007; Mitchell, Parsons and Leonard, 2007; Herrera et al., 2008) and brain damage (Reid, 2002; You et al., 2005; Bryanton et al., 2006; Fluet et al., 2009) are some of the areas where VR research has been done. In terms of health psychology, VR applications designed to help patients deal with and gain control over the pain caused by invasive medical procedures (Hoffman, Patterson, Carrougher and Sharar, 2001; Steele, et al., 2003 Loreto-Quijada, Gutiérrez-Maldonado, Gutiérrez-Martínez and Nieto-Luna, 2011), pediatric burns (Hoffman, Doctor, Patterson, Carrougher and Furness, 2000; Das, Grimmer, Sparnon, McRae and Thomas, 2005; Markus, et al., 2009) and childhood cancer (Schneider and Workman, 1999; Gershon, Zimand, Lemos, Rohtbaum and Hodges, 2003; Wolitzky, Fivush, Zimand, Hodges and Rothbaum, 2005) have been supported by numerous studies published over the past decade. These studies have shown the potential for the use of VR in the field of pediatric neurorehabilitation (Parsons, Rizzo, Rogers and York, 2009; Wang and Reid, 2011).

The use of VR technology in attention deficit-hyperactivity disorder DSM-IV-TR (APA, 2000) has been preceded by studies and debates centering on two main questions in this sphere: a) the accuracy of the diagnoses made with traditional tests and tools (DuPaul, Power, Anastopoulosy Reid, 1998) and b) the limited effects of the usual treatment modes (pharmacological treatment and behavioral therapy). For decades, the controversy around the diagnosis of the disorder and the therapeutic results has stimulated new developments in assessment and treatment based on the technological advances made over the past years.

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The studies published on VR and ADHD allow us to distinguish three courses of action: a) the development of software that uses virtual settings to recreate classrooms and other school settings (desks, virtual professor, blackboards, windows with street access, etc.) in order to reproduce the natural context and reduce the attentional deficits that characterize children with ADHD in these settings (Rizzo et al., 2000; Gutiérrez-Maldonado, 2002; Gutiérrez-Maldonado, Alsina-Jurnet, Carballo-Beciú, Letosa-Porta, Magallón-Neri, 2007; Gutiérrez-Maldonado, 2009; Gutiérrez-Maldonado, Letosa-Porta, Rus-Calafell and Peñaloza-Salazar, 2009; Gutiérrez-Maldonado, Magallón-Neri, Rus-Calafell and Peñaloza-Salazar, 2009), b) the application of this technology for the assessment and diagnosis of minors diagnosed with ADHD (Rizzo et al., 2006) and *c)* the use of VR in the treatment of basic and associated symptoms. In this case, studies seek to determine the effects of this tool as the sole therapeutic tool or when combined with other procedures and alternatives.

In this context, the objective of this work consists in making an initial assessment of the research done to date on the application of VR technology to attention deficit-hyperactivity disorder. This will allow us to identify the tool, the areas of applications and potential developments in the future. To achieve this, we have done a search for bibliography using the ISI Web of Knowledge platform, covering the period from 1990 to 2012. The following descriptors were used: virtual reality, children, ADDH, treatment, assessment, Continuous-Performance Test-*CPT*.

Virtual Reality Applications in ADHD

At a time when there was already a certain tradition of developing virtual environments in the clinical context (North, North and Coble, 1997; Botella, Baños, Perpiñá and Ballester, 1998; Botella, Villa, Baños, Perpiñá and García-Palacios, 1999), a software was designed specifically for ADHD. Known as the "Virtual Classroom" (Rizzo et al., 2000), the software was developed as part of an investigation aimed at developing VR applications for the study, assessment and rehabilitation of cognitive and functional processes among clinical populations that have some type of involvement in the SNC.

The Virtual Classroom simulated a classroom in which the child has to do different Continuous-Performance Tests (CPTs) and respond to the stimuli that appear on the blackboard (ten minutes). The children were asked to complete the tasks both with and without visual, auditory and mixed distractions. The study by Doyle, Biederman and Seidman (2000) showed that when this virtual tool was used, the combination of visual and auditory tasks yielded more diagnostic information than the unimodal Continuous-Performance Test, which was the test most commonly used. Later, Rizzo et al. (2001) developed a specific application based on the original tool in order to evaluate the attention deficits associated with hyperactivity disorder. The performances of a control group (minors without a diagnosis) were compared with those of children diagnosed with ADHD. The performances of both groups were compared while they carried out visual and auditory attention tasks; as they worked on these tasks, different distractive stimuli were systematically manipulated within the virtual environment. The results obtained from this study revealed the advantages of VR in neuropsychological assessment and cognitive rehabilitation.

In Spain, Gutiérrez-Maldonado et al. (2007) did an adaptation of the Virtual CPT based on the studies by Rizzo et al., (2000) in order to assess the validity of these tests as a way to detect ADHD. There are visual and auditory tasks presented in four modes: auditory without distractions, auditory with distractions, visual without distractions and visual with distractions. The authors worked with a sample of 20 children (ages 6-11); half of the sample (10 children) had a diagnosis of ADHD and the remaining half were children of the same age with no diagnosis. The results allowed them to conclude that the Virtual CPT is an effective tool for distinguishing between ADHD children and child controls without a diagnosis. There were differences between both groups in the errors of omission and commission respectively, with poorer performances by the group with ADHD as the tasks progressed and in the overall test results. The performance patterns of the hyperactive minors were similar independently of the nature of the different tasks (visual or auditory, with or without distractions), although the auditory task with distractions tended to be the most effective at distinguishing children with the disorder. Based on the results of the study, the authors concluded that the Virtual CPT allowed for the detection of ADHD cases, providing greater ecological validity than other tools by simulating one of the situations (school) in which children carried out most of their day-to-day activities.

Recently, another Continuous-Performance Test was developed in Spain. Similar to the Virtual CPT, the *AULA Nesplora* (AULA) (Climent Banterla and Iriarte, 2011) has proven effective in the assessment of ADHD (Fernández-Fernández, Morillo-Rojas and Alonso-Romero, 2012; Díaz-Orueta, Iriarte, Climent and Banterla, 2012).

Virtual Reality as an ADHD Assessment Tool

As a tool for assessment, VR is an alternative to the standard tests for sustained attention (CPTs) that have been used for decades in this field because of their efficacy (Schultheis and Rizzo, 2001). Continuous-Performance Tests (CPTs) are objective tools for assessing sustained attention, response time and/or resistance to distractions and ability to inhibit responses and they are used very widely today (Harper, Aylward and Brager, 2002).

According to the stimuli mode and the way stimuli are presented, there are visual, auditory and simple CPTs (the pa-

tient responds to a specific stimulus) or contiguous presentation (the tasks requires that the patient respond to a stimulus whenever it is preceded by another specific stimulus), respectively. These tests, which evaluate the hyperactive-impulsive symptomatology and lack of attention at the visual and auditory level, have proven very useful in detecting potential cases of ADHD because of their high sensitivity to inattention behaviors, distraction, agitation and impulsivity (Satterfield, Cantwell, Lesser and Posodin, 1972). At the same time, they have proven efficient as assessment tools and as tests to monitor treatment effects (Epstein, Johnson, Varia and Conners, 2001; Monastra, Monastra and George, 2002; Madaan et al., 2008). TOVA (the Test of Variables of Attention) (Greenberg, 1996) and IVA (the Integrated Visual and Auditory Continuous Performance Test, IVA/CPT) (Sandford and Turner, 1995) are two of the CPTs most commonly used to assess the efficacy of clinical interventions and both are mainly based on neurofeedback (Yan et al., 2008; Moreno, Lora, Aires and Meneres, 2011) and/or virtual reality (Pollak et al., 2009).

As lab tests, CPTs are believed to retain control over extraneous variables and therefore, show higher internal validity. However, this has a negative effect on the tests' external or ecological validity; in the diagnosis of ADHD, VR applications attempt to compensate for this limitation. Thus, by mimicking natural situations, the external validity can be increased without negatively affecting the internal validity of the test (Gutierrez-Maldonado et al., 2007). The investigations published to date show that the use of VR in the assessment and diagnosis of ADHD is based on several courses of action: *a)* comparing the results obtained from standard CPTs and VR in terms of detecting attentional deficit among ADHD children, *b)* using VR to evaluate children with ADHD as well as other problems and psychological disorders, and *c)* using VR as a measure of therapeutic efficacy to determine the results of the administered treatments. The assessment of the therapeutic results is commonly done by contrasting the different groups of minors who have received treatment using standard CPTs in some cases and EEGs in others (Lansbergen, van Dongen-Boomsma, Buitelaar and Slaats-Willemse, 2011).

Pollak et al. (2009) have contrasted the efficacy of three assessment tools used in ADHD: the CPT, the VR/CPT (*Aula Virtual)* and the TOVA/CPT. A total of 37 boys ages 9-17 participated in the study; 20 of the minors had been diagnosed with ADHD and 17 were controls. All participants were evaluated in three different ways: with the VR/CPT tool, with the same CPT but without virtual reality (a standard computer screen was used and speakers were turned off so the participant would only see the numbers that appeared in the middle of the screen) and with the TOVA/CPT. According to the data obtained from the study, children with ADHD had poorer performances on all of the assessments. At the same time, although the VR/CPT yielded results similar to those obtained with the TOVA, it was the most appealing of the assessments according to the participants. Ultimately, the authors concluded that the VR/CPT was a sensible and easy-to-use assessment tool that could assist in the diagnosis of ADHD.

Gutiérrez-Maldonado et al. (2009) utilized their own virtual tool based on the Virtual Classroom (Rizzo et al., 2000) to evaluate children with ADHD. They compared the performances of 20 minors (ages 6-11), 10 with a diagnosis of ADHD and 10 without the disorder. Based on the findings of the authors, VR applications allowed them to present distracting stimuli similar to those found in a natural context, a fact which increased the ecological validity of this tool in comparison with the standard CPTs commonly used in these cases. The results obtained in the study provide support for the validity of this type of tool in evaluating attentions difficulties and proved similar to the findings of the Virtual Classroom. Other studies have emphasized that VR applications help to reduce the errors of omission more effectively than a standard CPT, while also noting that VR is more widely accepted and appealing to the minors who participated in the study (Pollak, Shomaly, Weiss, Rizzo and Gross-Tsur, 2010; Shriki et al., 2010).

On the other hand, Bioulac et al. (2012) analyzed the evolution over time of the performances of hyperactive minors and those of peers not diagnosed with ADHD. According to these results, the performances of hyperactive minors worsened significantly over time in this type of tasks, unlike what was observed for the control group, which sustained their performances over time. In short, children with ADHD were clearly more vulnerable to the effect of time passing in terms of their performances on the assigned tasks.

ADHD Treatment through Virtual Reality

In the studies published on the use of VR technology as an intervention procedure in ADHD treatment, two courses of action appear: *a)* specifying the efficacy of VR as a therapeutic procedure by contrasting different groups and *b)* including VR in multimodal treatment programs. As can be seen (Table 1), VR is compared with cognitive-behavioral procedures and neurofeedback.

Considering that VR is a technology that has only recently been applied in the area of mental health, the first studies to examine the therapeutic usefulness of VR for ADHD refer to a study by Othmer and Kaiser (2000) in order to analyze the efficacy of neurofeedback administered in conjunction with VR technology. This study evaluated 120 children with different diagnoses: epilepsy, mood disorders and ADHD. The results showed that the treatment improved the cognitive performance of the patients, noting that VR's more realistic representative of physiological activity made patients more committed to treatment. It also had a positive effect on their understanding and involvement in the biofeedback tasks.

Table 1. Virtual Reality Application in ADHD Treatment.

Reference	Participants	Description of the Study	Results
Othmer and Kaiser (2000)	120 children Children diagnosed with: - Epilepsy - Mood disorders - ADHD	Test the efficacy of the implementation of neurofeedback with VR technology Twenty thirty-minute sessions or more	The multimodal neurofeedback treatment that includes RV generally increases the patient's commitment to treatment
Lee, Cho, Ku, Kim, Lee, Kim and Kim (2001)	20 adolescents: All displayed impulsivity and were clinically suspected of ADHD Two groups were created: - VR group (10 subjects) - Control group: without VR (10 subjects)	The participants were evaluated using an EEG evaluation through the CPT, twice in the case of the VR group (before and after the intervention) and once in the control group The VR group received 10 sessions (10 minutes each) with the VR tool	Improvement in the attentional symptoms of the VR group. In the control group, there were fewer shifts in behavior..
Cho, Ku,Jang, Kim, Lee, Kim, Lee and Kim (2002)	26 adolescents with learning disabilities, attention deficits and impulsive tendencies, clinically suspected of ADHD. - VR Group: Cognitive training and VR with an HMD device (n= 8) - Non-VR group: Cognitive training (n= 9) - Control (did not receive treatment) (n=9)	8 sessions (20 minutes each) for 2 weeks The VR and Non-VR groups were assessed with a CPT before and after receiving the training. The control group was assessed only once	The combined use of VR and cognitive training proved most effective for improving the attentional abilities of the minors who participated in the study. The immersive VR increased the motivation for treatment.
Cho, Kim, Shin, Lee, Lee, Kim and Kim (2004)	28 adolescents (ages 14-18) with social problems and clinically suspected of ADHD. - VR Group(n=10) - Non-VR (n=9) - Control group (n=9)	Both groups, VR and non-VR, received training in neurofeedback VR Group (with a full HMD immersion system) Non-RV (use of a computer monitor) Control group (did not receive treatment) 8 sessions (20 minutes each) for 2 weeks Assessment of results with a CPT.	The VR and non-VR groups obtained better results after the training in comparison to the control group. The VR group tended to achieve the best results. This suggests that immersion VR combined with neurofeedback is applicable for the treatment of impulsivity and lack of attention.
Yan, Wan, Liu, Zong, Jiao, Yue, Lv, Yang, Lan and Liu (2008)	12 minors, 10 boys and 2 girls (ages 8 -12) diagnosed with ADHD	20 neurofeedback sessions with VR. The participants were assessed with a CPT.	The results showed significant improvements in terms of both the patient's ability to control his/her behaviors as well as attention.
Anton, Opris, Dobrean, David and Rizzo (2009)		VR integrated in the cognitive-behavioral treatment program for ADHD treatment. 2 weekly sessions of 25-35 minutes each for 10 weeks.	The created tool did not represent a new therapeutic mode; instead, it is a supplement to therapy that increases the efficacy of treatment.

The pioneering work of Othmer and Kaiser was followed by other studies with similar objectives. Cho et al. (2004), for example, confirmed the efficacy of combining training in neurofeedback and VR to reduce poor attention and impulsivity among a group of 28 adolescents (ages 14-18). All of the participants had social issues and were suspected to suffer from ADHD though none had yet received a clinical diagnosis. They were assigned to three groups: VR, alternative treatment to VR and the control group. The VR and alternative treatment groups received eight neurofeedback training sessions that lasted a little over two weeks, while the control group merely waited and did not receive any treatment during this period. The difference among the experimental groups resided in the type of immersion utilized; the HMD (head-mounted display), a full-immersion system, was used for the VR group, while a computer monitor with a fixed view point was used for the alternative treatment to VR. Participants were evaluated with a continuous-performance test (CPT) before and after the full training session while the control group was evaluated only once. The results revealed that both experimental groups (VR and alternative treatment to VR) got higher scores on the CPT than controls after the neurofeedback training session. In addition, the VR group tended to have better results, thus suggesting that the immersive VR could be administered in conjunction with neurofeedback in order to improve the results of patients with attention difficulties and impulsivity.

On the other hand, Yan et al., (2008) emphasized that as a method for positive feedback and when used alone, neurofeedback can prove monotonous, negatively affecting the motivation and the attention demanded of minors with ADHD. Based on this limitation, a decision was made to use neurofeedback and VR together. Participants were evaluated with a Continuous-Performance Test (IVA/CPT) commonly used in studies on neurofeedback (Moreno et al., 2011) and the authors found that the attention of the minors improved after receiving 20 training sessions. In the authors' opinion, a system combining neurofeedback and VR is useful in the treatment of children with ADHD.

Years earlier, Lee et al. (2001) had noted the novel nature of VR when used as a therapeutic tool as well as the results obtained with it. In this study, the authors compared the results obtained from two groups of ten adolescents, all clinically suspected of ADHD. The adolescents were evaluated using an EEG and VR was administered to only ten of them. These adolescents attended ten sessions, each ten minutes long. The VR group was evaluated with a Continuous-Performance Test (CPT) before and after exposure to the VR technique. The control group was only evaluated once with the CPT. The results showed an improvement in the attention of the minors treated, highlighting the following advantages: *a)* the VR tool allowed different environments to be developed for treating children with ADHD, *b)* fewer people had to be involved in the treatment, *c)* the tool facilitated constant progress in the performance of the minors during treatment, avoiding the secondary effects derived from exhaustion, fatigue, etc. and *d)* it provided the possibility for administering multimodal treatments that integrated VR and the cognitive training techniques in order to increase the attention and concentration of those affected. This was the objective of the study by Cho et al. (2002), who applied VR techniques as part of a cognitive training program to improve the attention of three groups of minors. All the participants had some type of learning disability, attention difficulties and impulsive tendencies although none had been diagnosed with ADHD. The participants were divided into three groups based on the type of treatment administered: cognitive training and VR with an HMD (head-mounted display), cognitive treatment alone and a control group that received no treatment. The training lasted for two weeks and all of the minors were evaluated with a CPT before and after the sessions. The results showed that the combined application of VR and cognitive training was more effective in terms of improving the attentional capacity of the minors participating in the study.

A similar line of study was adopted in the research conducted by Anton, Opris, Dobrean, David and Rizzo (2009) to implement VR in a treatment program based on cognitive-behavioral techniques for children with ADHD. The program consisted of applying cognitive-behavioral techniques in a virtual school environment. The treatment involved 16 weekly sessions of cognitive and behavioral techniques for both the child and his/her family. Based on the results of the study, the authors concluded that this alternative did not represent a new therapeutic mode on its own; instead, it showed how to take advantage of the tools available to increase the ability of therapists and provide them with the support required to obtain the best results from the therapeutic process.

In addition to the use of VR as a tool for assessment and intervention in ADHD, there have been new developments aimed at applying virtual reality to other psychological problems and alterations. These compare both the therapeutic modes as well as the effects, which vary depending on the disorder in question. For example, Rizzo, Bowerly and Buckwalter (2002) suggested that this technology could be useful in the pathologies that come into play in attentional difficulties, i.e. acquired brain damage injuries and neodegenerative disorders (Alzheimer's, vascular dementia, etc.) This approach has been followed in other studies such as that by Gutiérrez-Maldonado et al. (2007), who applied VR in the school setting, comparing three groups of students with different alterations: ADHD, school phobia and test anxiety.

Based on the results, the authors concluded that VR is a valid technique for the assessment and treatment of different problems observed in the school setting. The authors added that the intrinsically motivating nature of virtual reality could prove decisive in raising the validity of the assessment procedures and treatment adherence among a clinical population of children and adolescents.

Conclusions:

After analyzing the studies published on the period in question, it is possible to reach certain conclusions on VR technology applied to attention deficit-hyperactivity disorder (ADHD):

The results obtained so far support the use of VR as a practical, sensible assessment tool for the detection and assessment of ADHD.

In addition to increasing the ecological validity of the procedure, the studies done to date highlight how this tool is able to increase the attention and concentration of minors with attentional deficits and reveal that the more immersive the technique, the more effective it proves.

The VR application allows for increased control over environmental situations, an aspect that is desirable in both the assessment of the disorder and in the treatment programs.

VR allows for environments (virtual settings) that are similar to reality, mainly school classrooms, thus exposing minors to the natural situation "live". This contributes to reducing the cost and time of therapy treatments administered to ADHD patients.

VR encourages self-training and overlearning. After several practice sessions, the patient learns the ability he/she needs to confront the situations that mainly appear in the classroom.

The virtual settings that have already been developed recreate the school setting, with the main target of reducing the attentional deficits that characterize children with ADHD and improving their academic performance.

The therapeutic applications of VR in ADHD are associated with neurofeedback treatment and behavioral-cognitive therapies.

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