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VIRTUAL REALITY IN THE REHABILITATION OF ATTENTION DEFICIT / HYPERACTIVITY DISORDER. INSTRUMENT CONSTRUCTION PRINCIPLES

*Raluca ANTON[1], David OPRIS[*1], Anca DOBREAN[1], Daniel DAVID[1], Albert "Skip" RIZZO[2]*

[1]Babes-Bolyai University, Cluj-Napoca, Romania
[2]USC Institute for Creative Technologies, San Diego, California, USA

Abstract
Attention-deficit/hyperactivity disorder (ADHD) is one of the most prevalent psychiatric childhood disorders. Good clinical practices are therefore needed regarding both assessment and therapy. In which assessment is concerned, valid instruments are available, one of the last developments in the field being the virtual reality guided assessment (VirtualClassroom). Regarding intervention, the multimodal, cognitive behavioral therapy (CBT) oriented approach is the most frequently employed. However, this approach has some limitations, one of them concerning ecological validity. Our VR-based intervention addresses this issue, by providing a high ecological validity therapeutic tool. We do not propose a new therapeutic paradigm. We instead move the intervention from the clinician's office into the virtual classroom, where we still use cognitive restructuring and the behavioral techniques of the classic intervention. This paper highlights the implementation of the psychotherapeutic principles of ADHD therapy in the VR environment. The different features of this instrument are designed to address specific cognitive-behavioral modifications involved in the therapeutic process.

Keywords: VR, ADHD, CBT, psychotherapy

Virtual reality (VR) is being increasingly used in a number of psychotherapy and rehabilitation contexts (Glanz, Rizzo, & Graap, 2003). An important feature of VR is its capacity to deliver environments that allow precise

[*] Correspondence concerning this article should be addressed to:
Email: davidopris@psychology.ro

control of complex, immersive, and dynamic three-dimensional stimulus presentations, where sophisticated interaction, behavioral tracking and performance recording is possible (Rizzo, 2006). These environments can be used for assessment, training or treatment purposes, and can address situations that are not easily deliverable or controllable in the "real-world", leading to enhanced ecological validity.

Treatment in ADHD

Attention-deficit/hyperactivity disorder (ADHD) is among the most prevalent psychiatric childhood disorders, affecting 8% to 10% of children (Baren, 2002) and persisting into adolescence in approximately 80% of cases (Baren, 1998; Schubiner, Robin, & Neustern, 1996). However, ADHD is largely considered a childhood disorder, so most patients are diagnosed during childhood. The DSM-IV (Diagnostic and Statistical Manual of Mental Disorders Fourth Edition) definition of ADHD requires symptoms to be present before the age of 7 years (DSM-IV-TR, 2000). Accurate ADHD diagnosis in this age group is particularly important because of the impact of untreated ADHD on adolescents, their immediate family, and society as a whole. If the condition remains untreated, the adolescent is likely to underachieve in school, leading to poor employment prospects (Baren, 2002). Relationships with family, peers, teachers, and employers are likely to be fraught with difficulties, further impacting on educational and employment prospects and leading to poor social relationships (Baren, 2002). Adolescents with ADHD are more likely to become involved in risk-taking behaviors such as reckless driving, risky sexual activities, substance abuse, and criminality (Barkley, Fischer, Edelbrock, & Smallish, 1990) which may negatively affect their life into adulthood.

Clinical research and consensus guidelines on the treatment of ADHD over the past few years have increasingly clarified the most effective treatment approaches. A recent review of evidence based psychosocial treatments for children and adolescents with ADHD indicates that there is adequate evidence for behavioral parent training and behavioral school interventions that has resulted in such treatments being classified as empirically validated interventions (Chronis, Jones, & Raggi, 2006). Both behavioral parent training and classroom behavior management involve teaching parents and teachers to use behavior modification strategies based on social learning principles, such as praise, positive attention and rewards to increase positive behavior, and ignoring, timeout and non – physical disciplining strategies to decrease unwanted behavior. Some of the limitations of behavioral approaches overlap with the limitations of medication treatment, and include the following: a) effects appear to be short-term and limited to the period of the intervention, b) not all children respond positively to treatment (which may partly be influenced by the delivery of treatment, willingness of parents, knowledge and skills of the therapist), and c) the lack of

demonstrated effectiveness on the long term (Waschbusch and Hill, 2003). Overall, both medication and behavioral approaches have been shown to be effective, but limitations exist suggesting the need to consider additional strategies and approaches.

Multimodal programs, like the one proposed by Dopfner (Dopfner, Shurmann, & Frolich, 2006) are considered to be the most efficient ones. A multilevel program means that the therapist works on the cognitive and behavioral levels of the child using a combination of parent training and child-focused cognitive behavioral intervention. The cognitive behavioral therapy (CBT) component of multimodal programs includes: a) reinforcement techniques, b) techniques for eliminating maladaptive behavior and c) cognitive restructuring techniques.

Reinforcement techniques (Catania & Brigham, 1978; David, 2006)

- Positive reinforcements – when effective, they control our responses, increasing the probability of their occurrence. Generally speaking, stimuli that reduce physiological needs and stimuli that control high probability responses are typically reinforcing.

- Negative reinforcements – increase the probability of a response because they terminate/remove an aversive stimulus. A major difference between negative and positive reinforcement is in the relation of the response to the reinforcing event. In the case of positive reinforcements, the stimulus is absent before and during the response, and occurs after the response. In negative reinforcement, however, the stimulus is present before and during the response, and unconditioned responses to it can interfere with the behavior of interest.

- Instructions – with humans it is often possible to produce a response by telling the person what to do or by asking her to do it. Once the response is emitted it can then be reinforced. Children diagnosed with ADHD have that readiness of responding to instructions, so this technique can be successfully used in their case.

- Guidance – describes the situation where the parent guides his/her child in doing a behavior that does not exist in the child's repertoire. A more useful procedure is the combination of guidance, reinforcement and the gradual withdrawal of support. In many cases an entire behavioral sequence can be guided and then assistance can be gradually withdrawn starting with the final response of the chain (i.e., backward shaping)

- Successive approximations (i.e., forward shaping) – is the classic procedure of developing new responses. It involves carefully observing ongoing behavior and reinforcing the response closest to the one desired.

Techniques for eliminating maladaptive behavior (David, 2006)

- Extinction – discontinues the relationship between a response and its reinforcing stimulus and reduces the rate of a previously established response. Research shows that previous experience with extinction is important. A series of transitions from reinforcement to extinction make the response decline more rapidly with each successive exposure to extinction.

Cognitive restructuring techniques (David, 2006; Ellis & Bernard, 2007)

- Empirical disputing – looking for the evidence supporting the inferences and the evaluations of the client;
- Logical disputing – looking for the evidence that the client's conclusions and expectations are rationally and logically derived from reality;
- Semantic disputing – offering objective definitions of words and phrases that children use when describing/evaluating the world;
- Functional disputing – stresses the personal usefulness of irrational thoughts.

VR assessment in ADHD

Traditional assessment commonly uses paper and pencil-based psychometric tests, which were criticized as limited in the area of ecological validity (i.e., the relevance or similarity that a test or training system has relative to the real world, and it's value for predicting and improving daily functioning) (Neisser, 1978; Wilson, 1998). A well designed VR environment could have greater predictive validity and clinical relevance for the challenges that patients face in everyday life.

VirtualClassroom was built as a virtual reality environment designed for the study, assessment and possible rehabilitation of ADHD (Rizzo, Buckwalter, Bowerly et al., 2000). Children can be assessed in terms of attention performance while a series of typical classroom distracters are systematically controlled and manipulated within the virtual environment. A detailed description of the environment can be found in Rizzo et. al., 2000 and Rizzo, 2006.

The initial testing, involving a clinical trial that compared eight physician-referred boys diagnosed with ADHD (6-12 years of age) with 10 non-diagnosed boys, and controlling for a number of potentially confounded variables, suggested that the Virtual Classroom had good potential as an efficient, cost-effective and scalable tool for conducting attention performance measurements beyond what exists using traditional methodologies (Rizzo, 2006).

VR treatment in ADHD

Rationale

Virtual Reality is seen to offer many advantages in assessing children with ADHD, but there are no applications concerning intervention in this disorder. Our objective with this new program was to create an instrument for clinicians working in the field of ADHD. We know from the literature that multimodal interventions seem to be the most effective. Therefore we decided to keep the multimodal intervention approach but to replace the classic intervention procedure with one closer to the area most problematic in ADHD, namely school behavior.

Considering that the virtual classroom is a highly ecological environment, that it offers very accurate data in the assessment of ADHD, and that the procedure takes a significantly shorter time than the traditional assessment procedures, we are confident regarding its utility as a virtual reality application in ADHD intervention. Specifically, we hope that the skills acquired in the therapeutic process will have a higher transferability and will be more relevant to everyday life. In the therapeutic process, children learn techniques that they are then expected to apply in family, school, and everyday life. Many of these techniques are difficult to transfer into real life, especially into the school environment. Whereas in the family environment, parents usually support their children in practicing the therapeutic procedures, this is not always the case at school. We believe that this new intervention program will help children exercise the techniques in the virtual classroom, learn to master these techniques and then apply them in the real school environment. We are confident that because of the high similarities of the two environments (i.e., the virtual classroom and the real classroom) the transfer process will be easier than when using the traditional approach.

Furthermore, the transformation of the assessment instrument into an intervention procedure can be done with relatively low costs considering that we use the assessment component of VirtualClassroom and add to it new control features for the intervention process.

To be more specific, we do not propose a new therapeutic paradigm. We instead move the intervention from the clinician's office into the virtual classroom, where we still use cognitive restructuring and the behavioral techniques of the classic intervention. As far as we know, this virtual reality program is the first program that allows the clinician to use all the relevant CBT techniques.

Psychological aspects

Given ADHD characteristics and the cognitive behavioral intervention principles used in the clinical management of the disorder, we are considering modifying the VirtualClassroom virtual reality environment from an assessment

oriented tool to an intervention oriented one. CBT techniques will be implemented into the virtual environment with the following features:

- Graphic display of child performance (e.g. time indicator, response bar, distracters), online for the last responses and offline for the entire session. This element of the program gives the therapist an overview of the child's performance, thus enabling him/her to use CBT techniques according to the requirements of the therapeutic process.

- Pause button - this button pauses stimulus presentation. Children need instructions from the therapist from time to time. We know that these children are able to follow instructions so we considered this an important part of the virtual treatment program based on CBT principles. More than that, the therapist can use this pause button to apply cognitive restructuring techniques.

- Self talk event recording – this feature allows monitoring the extent to which the child internalizes the cognitive restructuring techniques employed by the therapist.

- Control of distracters / environment – the clinician can select the different types of distracters that are suited for a particular situation, or he/she can control specific aspects of the virtual classroom (e.g. student location, noise level and source). This feature can be used for guidance and successive approximations techniques.

- Reward / punishment system - contains different types of rewards: images, sounds, short videos/animations. These features tap on positive and negative reinforcement techniques.

- Option for giving feedback to the child about how correct his/her last response was (green light / red light). This feature can be used by the therapist taking as part of the behavioral principles of CBT (e.g., positive reinforcement)

- Ability to deliver different tasks regarding both content and difficulty. We employ the successive approximations technique by changing/grading the difficulty of the task as the child manages to answer current task levels.

- Head movement tracking – along with the graphic display of the child's performance, this tool gives the therapist feed-back about the client's behavior in the virtual environment.

Intervention protocol

The intervention program we use for ADHD is the one proposed by Dopfner, Shurmann and Frolich (2006). This program does not involve a standard procedure because it is a family-based program, so the techniques vary from family to family and from child to child. This flexibility does not refer to modifying the cognitive or behavioral techniques, but, for example, to skipping

some phases if they are not considered useful for the client.

A number of studies have proven that family based intervention is very efficient for children with defiant behavior (McMahon & Forehand, 1984); this intervention is also efficient when using contingency management techniques (Dubey, O'Leary, & Kaufman, 1983). Moreover, combining family intervention with self–education techniques significantly improves the child's behavior. But what seems to be the problem is the fact that during therapy, it is often impossible to expose the family and the child to a real environment where they can practice the techniques they learn. Thus, we propose a virtual reality based intervention as an adjacent technique for the ADHD clinical program we use. The virtual reality environment that we created includes the classic techniques that we employ in the therapeutic milieu. We expect that this will make it much easier for the children to understand and apply what they are thought.

More specifically, the intervention involves 16 weekly sessions. In each session the family and the child are thought cognitive and behavioral techniques and principles that they are then required to practice daily. One part/component of the intervention is addressed to the parents (they are taught various techniques to apply on a daily basis with the child) and the other one, to the child (the therapist reads a story of Peter – a child with ADHD – every session; each story is based on what the parents have to do with the child until the next session). The child-based intervention is reduced during each session, which is why we propose the VR program. During each VR session the child learns new principles in an environment that is similar to the one where he encounters problems. The VR intervention is not planned to be used in each session, but only in those in which CBT principles can be applied in such an environment.

Assessment:

Initial and a final assessment are focused on: behavioral assessment, cognitive abilities (i.e., intelligence) evaluation and a family diagnostic. The behavioral assessment involves the clinical evaluation using the KID-SCID (Structured Clinical Interview for DSM-IV disorders), based on the DSM-IV diagnostic criteria, and also a psychiatric evaluation (Hien et al., 2007). A virtual reality-based assessment is also employed, using VirtualClassroom. In addition, we use a parent rating scale (CBCL – Child Behavior Check List) and a teacher rating scale (TRF – Teacher's Report Form) (Achenbach & Rescorla, 2001). Intelligence is evaluated using Raven's Progressive Matrices. The Parenting Scale is used for family assessment (DuPaul et al., 1998). The Parent's ADHD Scale, an instrument measuring the costs of the therapy for the parents (in terms of time and money) is also used in each session.

The intervention is planned to take place as follows:

Session 1: Defining behavioral problems

This component establishes the individual problems of the child and

family. We then establish the objectives of our intervention in terms of behavioral changes in the family context and we then work on the list of defined problems. The VR assessment program for ADHD is also used during the first session.

Session 2: Case Conceptualization (I)

Starting from the parents' conceptualization we propose a common one that includes both perspectives. Different conceptualizations are, frequently, the cause of failure. The therapist needs to devote particular attention to this stage of the intervention.

Session 3: Case Conceptualization (II)

The third session is a continuation of the second one: we create a common explanatory model of the causes of the child's behavior, from a "macro" perspective (e.g., child characteristics, parent characteristics, family problems, etc.) and from a "micro" perspective (the way family interactions become immediate causes for the development and the maintenance of the disorder).

Session 4: Establishing the Objectives of the Intervention

After the first three sessions we can establish specific objectives. These have to be realistic and they have to be formulated in a way that suggests partial solutions. A VR assessment is conducted in this session again, to have a periodical evaluation

Session 5: Focusing on Positive Interactions with the Child

In this session we make a survey of positive and negative experiences that the parent has with the child. The purpose of this session is to focus the parents on the positive behavioral pattern of the child. One of the problems of parents of children diagnosed with ADHD is that they are so focused on the negative characteristics of the child that they overlook positive ones.

In this session the child plays a game in the VR environment (Penguin Race). We train the parents to identify and underline the positive behaviors of the child.

Session 6: Building Positive Interactions through Games

Moments of amusement and play are introduced in the sessions to increase the number of positive interactions between the parent and the child. Our goal is to improve and strengthen their relationship, and this is the first step in changing the parents' behavior.

Session 7: Family Rules

One of the problems of families with children suffering from ADHD is that they don't have specific family rules, or they don't have clear or transparent rules.

Session 8: Efficient Requirements

This session is recommended in the cases when the child does not follow the parents' requests or in the case when the parents' requests are stated inefficiently (e.g., not clearly formulated due to the high number of requests in brief periods of time, for instance). Parents are taught to formulate fewer requests and formulate them in a way that catches the child's attention.

Session 9: Social Reinforcement if requests are followed

If the child does not follow requests, parents are taught to use social reinforcements for every situation when the child behaves according to what he/she is asked to do.

In this session we start using the VR system for treatment. The child performs different tasks, their content and difficulty being controlled by the therapist. The simplest task is to identify a certain target (e.g., image, letter, number) from e sequence of non-target elements. Difficulty can be varied by increasing the speed of the presentation and by transforming the target from an element to a sequence of elements. Reinforcements consist of verbal reinforcements from the therapist and visual and auditory reinforcements from a cartoon character in the virtual environment. We expect positive effects both for the parent and for the child. The parent will learn vicariously how to apply social reinforcements and the child will get used to receiving them.

Session 10: Social Reinforcement if the child does not interrupt adults from their activity

An ADHD child often interrupts his/her parents from their daily activities, such as cooking, reading the paper, talking on the phone, etc. This component of the program first requires the parents to make sure that they give the child enough attention (see session 6). If this condition is met, when parents have something to do, they are thought to involve the child in an autonomous activity. The therapist discusses with the parent the importance of giving attention and reinforcing the child if he/she did not interrupt the parent.

Session 11: How to Efficiently Monitor the child

This session is implemented only if the parents report problematic behaviors when the child is alone. In this case, we discuss rules for the time the child spends on his/her own, the fact that these rules have to be reminded to the child, and, most important, ways to monitor the child (e.g., to get involved for a short period of time in what the child does) and to use positive or negative reinforcements as needed.

Session 12: "Natural" Negative Consequences

This session deals with situations where the requests or the rules established by the parents, and the strategies implemented during sessions 8, 9 and 10 do not work. The "natural" negative consequences are directly related to the rule the child breaks, as an obvious consequence emerging from the child's behavior (e.g., putting together the toy the child broke).

The VR intervention is the same as the one described in session 9, except for the content of reinforcements - negative reinforcement is used in this case.

Session 13: The “Points” Plan

We use this system when social reinforcements don't work. A list of rewards is established in collaboration with the child, each reward worth a certain number of points. Every time the child respects a rule he/she earns a point. After gathering enough points, he/she can exchange them for the desired reward.

In the VR intervention the child is in the virtual classroom environment and his task is similar to the one in Session 9, only that this time it is more difficult. The main difference compared to the previous sessions is that the child earns a point for every correct answer. This also gives him/her immediate feedback regarding his/her performance. The points are visible to the child, which gives him/her the possibility of monitoring his/her performance. Points earned in the virtual reality environment are cumulative and can be transformed into objective rewards.

Session 14: How to give points

This session establishes a reward system that is attractive for the child and functional from the parents' perspective. We also teach parents to adapt the points system to different contexts and how to give it up when it is no longer needed.

In the virtual reality environment, we have a transition scenario between Session 13 and Session 15. If in Session 13 points are awarded after each correct answer without a feedback concerning incorrect answers, in Session 14 the child gets a red point for every correct answer and a black one for each incorrect answer. This time, points earned in virtual reality are not cumulative and are not transformed into a reward. The child learns how to cope with a negative feedback.

Session 15: Reinforcement / benefits withdrawal systems

So far, the intervention in mainly based on positive reinforcement. In this session we teach parents the use of negative reinforcement. A contest between parent and child is introduced from now on in that the child wins a point every time he/she follows a rule, and the parent wins a point every time the child does not follow an established rule.

This session also involves a VR component. In this case, we expand the points system in Session 13, adding the concept of loosing points. To be more specific: the child earns a point every time he/she gives a correct answer, and loses a point in favor of an "opponent" (i.e., a cartoon character) with every incorrect answer. At the end, points can be turned into a reward but only if the child has earned more points that the cartoon character.

Session 16: Time-out

The time-out technique is employed to manage behaviors resistant to all the strategies above. When such a behavior occurs, the child is isolated for a certain period of time, depending on the child's age.

Session 17: Stabilizing the gains

In this session, parents are reminded everything that was learned during therapy sessions, and we make sure that they know how to apply the techniques by themselves (e.g., we describe a problematic situation and the parent is asked to find the optimal solution for solving it).

Technical aspects

The intervention system consists of two computers - the client's system (running the VirtualClassroom) and the therapist's remote control system (SchoolMaster). The two systems are connected through a wired or wireless

network interface. The testing system requires high graphical capabilities; the virtual environment is presented to the patient on an eMagin Z800 head mounted display and the subject's response is given through a standard mouse. The therapist controls the environment of the VirtualClassroom in real-time, through a visual interface on the remote system. The feed-back about the child's performance is also presented in real-time and on the same visual interface on the remote system. This way the therapist has the information regarding the child's performance and the intervention tools in one place (i.e., the SchoolMaster visual interface).

Conclusions

Our VR based intervention in ADHD is a completely novel approach, and a therapeutic instrument with high ecological validity. We know that assessment using this procedure is highly accurate and requires a significantly shorter time than traditional assessment. Thus, we are confident that implementing a VR intervention application will be a great success. One of the main advantages of this new program is that the transfer process will be better than using the traditional approach. The ability to control the therapeutic process in real time, combined with the possibility of applying CBT techniques required in the treatment of ADHD in real time makes this application a very innovative one.

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