

Adaptive Cognitive Rehabilitation Interventions based on Serious Games for Children with ADHD using Biofeedback Techniques: Assessment and Evaluation

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ABSTRACT

Attention deficit with hyperactivity disorder (ADHD) is one of the most prevalent disorders within the child population today. The number of developments in the area of Serious Games and Biofeedback targeting these children has increased recently. Nevertheless there is no specific methodology for evaluating these interventions. The object of this article is to establish a common core of minimum criteria for carrying out validation experiments of this kind. These protocol guidelines are aimed at the evaluation of cognitive rehabilitation activities for children with ADHD. The key point in this methodology is that it takes into account the inclusion of biofeedback and Serious Games techniques within the intervention program. The proposed methodology was specifically designed for researchers in computer science, who need to evaluate each study setting specifically, so as to determine the most suitable validation protocol for each case.

Categories and Subject Descriptors

H.5 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces—*Evaluation/methodology*

General Terms

Design, Experimentation, Standardization, Verification

Keywords

Methodology, ADHD, Serious Games, Biofeedback

1. INTRODUCTION

Attention deficit with hyperactivity disorder (ADHD) is one of the most prevalent disorders within the child population today, affecting an estimated 5.29% of children worldwide [1]. At present the diagnosis and treatment of ADHD should

be performed in a multi-modal environment in which information is provided to parents, teachers and patients with ADHD. In addition, the latter must have psycho-educational support at school, as well as psychological support in cases where it is strictly necessary (for the individual, the family and the community) and pharmacological treatment, if required by the specific symptoms [2]. Over-diagnosis must be minimized and a strict control of the administration of medication must be ensured [3].

ADHD usually manifests itself before the child is 7 years of age and is characterized by a certain degree of impulsiveness, inattention and excess of activity which does not match the child's developmental age and is not appropriate in all situations that may arise [4]. Succeeding in motivating a child affected by ADHD to undertake academic activities is a key element in their development. There is a need to encourage their learning process and memory, concentration and time management skills using structured activities, clear rules and striking materials. The possible solutions or improvements include developing the interest of the group towards these activities, which, together with an early and continuous intervention [5], can achieve a behavioral reduction in these problems and the negative consequences that arise in the mid- to long-term.

The use of techniques employed in the design of video-games, combined with the establishment of certain goals, guidelines and rules which not only encourage the use of these type of technologies, but also serve to reinforce the training of such skills as working memory, stimulation of attention, concentration and the aforementioned management skills, represent a new type of effective therapy in their application to ADHD [6, 7]. Although methodologies for validating psycho-pedagogical and medical interventions are available in the literature [8, 9, 10], there is no specific criteria for cognitive rehabilitation intervention based in Serious Games for Health. However, in recent years the studies undertaken in this area have multiplied.

The object of this article is to establish a common core of minimum criteria for carrying out these types of validation experiments, once the tool has been totally developed. These protocol guidelines are aimed at the evaluation of cog-

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nitive rehabilitation activities for children with ADHD. The key point in this methodology is that it takes into account the inclusion of biofeedback and Serious Games techniques within the intervention program.

In the *Materials and Methods* section, all the criteria needed for defining these interventions will be stated and the patterns for carrying out the testing protocol will be established. Finally, the conclusions and discussion regarding the outlined validation model will be provided.

2. MATERIALS AND METHODS

The *Materials and Methods* section presents the criteria needed for the definition of cognitive rehabilitation testing protocols aimed at children with ADHD.

2.1 Participants

Children taking part in the evaluation of interventions using *Serious Games* and *biofeedback techniques* may need to meet certain specific criteria.

2.1.1 Inclusion criteria:

Inclusion criteria to be considered:

- All participants in the study should be diagnosed with ADHD in any of its types (Inattentive, Hyperactive of Combined) [4][11, 12].
- The age range of the sample should be appropriate to the final needs of the cognitive rehabilitation intervention using ICTs. For specific interventions in which users may need to interact autonomously with the system, the main age ranges are between 6 and 13 years old [13, 14]. However, when there is no need of performing complex intervention procedures or they are supervised, this age limit could be reduced to 4-5 years old. [15].
- $IQ \geq 80$ may be important for those interventions that need an specific ICT response [6, 16]. Intelligence could be measured individually by the territorial adaptation of an adequate validated intelligence scale. As example of these scales is the *Wechsler Intelligence Scale for Children (WISC-III)* [17]

2.1.2 Exclusion criteria:

Exclusion criteria to be considered are:

- Subjects with comorbidities (tics or conduct disorders) or any neurological disorder, sensory (color blindness and sight) or motor impairment [18, 6] that may interfere with the study or evaluation techniques.
- Users taking additional and continued medication, apart from Metilfenidate, that may affect their response [18, 6].

2.1.3 Other criteria:

Although gender is not an inclusion or exclusion criteria by itself, experimental groups should be balanced as regards this feature. This will avoid any possible interference by

gender in the experiment [19]. There will not be any difference based on participants socioeconomic data.

Sample size should be big enough to provide the element of data representativeness [20].

In order to ensure the creation of balanced experimental groups, participants should be paired according to sex, age, severity level, intervention performance and therapy location and procedure (school center, association or place of intervention).

One of the experimental groups will undergo an extended intervention using *Serious Games for Health*, ICTs and *biofeedback* techniques, and the other will only receive standard intervention.

The study should be approved by the Research Ethics Board of the research center conducting the study. Participants in these studies are minors so assent must be obtained from all participants. Mature minors, or parents of younger children, must sign an informed consent.

2.2 Validation Model

This section describes the instruments and variables used for the validation of cognitive rehabilitation interventions.

2.2.1 Devices

It is interesting to implement systems that record intervention related parameters by themselves, such as time-performance, achievements and mistakes, among others. These parameters are of great use in the evolution assessment and follow-up [21, 22].

The use of specific sensors and biofeedback data during interventions may represent a key point in some specific cognitive rehabilitation activities. In these studies it is important to effectively determine which devices are reliable and valid for the intervention. Gaze interaction measurements may be an interesting feature for exercises that imply visual interaction and attention procedures [23, 24]. Variables measured during intervention should be defined, identified and registered exhaustively.

2.2.2 Questionnaires and scales

In order to assess the validity of the intervention, validated questionnaires and scales should be used. These measurement techniques must be available in the language of the participants and they need to measure the key aspects of cognitive rehabilitation. For example, for assessing attention improvements in longitudinal studies, the following scales and questionnaires could be used: *Integrated Visual and Auditory Continuous Performance Test (IVA)* [25], *Test of Variable Attention (TOVA)* [26], among others.

2.2.3 Observation techniques

An observation protocol must be defined and put into operation before performing the intervention. Professionals should always stick to the predefined observation protocol, registering the behavioral data that may be relevant to the conducted study.

Underlined features in section 2.2 provide the information needed for the statistical analysis of users evolution.

2.3 Design and Validation Protocol

This section introduces the standards to be followed in the definition of the experiment. The instruments and validation procedure employed will also be outlined.

In order to avoid an increase in the number of signs related to ADHD or behavioral disturbances, it is recommended that experimental setting in children's standard intervention environment be performed. This procedure should be carried out by therapists in charge of standard intervention who should be trained to perform the new study. Figure 1 shows the proposed protocol guidelines to perform longitudinal studies in the area described in the paper.

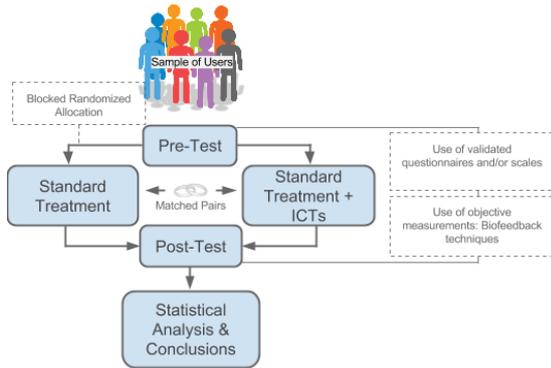


Figure 1: Design and validation protocol

Validated questionnaires, scales and biofeedback measurements are used in pre and post test stages (please refer to section 2.2.2 and 2.2.1 for more information).

Repeated activities must be avoided between the test and intervention stages. During the cognitive rehabilitation learning stage, motivation and fatigue must be carefully monitored.

After the pretest stage, participants should be randomly divided into the available experimental groups. One group will perform the standard intervention, and the other will conduct the extended intervention. Once the intervention stage is over, post-test measurements must be recorded. These indicators should be the same at those that were taken during the pretest stage to statistically quantify changes during the intervention.

3. CONCLUSION AND DISCUSSION

This article describes the design and development of a methodology for the evaluation of cognitive rehabilitation interventions using serious games and biofeedback techniques aimed at children with ADHD.

Although this methodology was specifically designed for researchers in computer science, it can be adopted by other professionals working in this kind of study validation.

The target collective for this intervention are children with

ADHD. Nevertheless, by applying the correct adjustments, it can be extended to other collectives, maintaining the age range required for the study. For example, although participants in the clinical group must be diagnosed with ADHD, exceptionally, users not specifically diagnosed but with evident learning difficulties may also take part in the study intervention group. Researchers need to evaluate the implications of this inclusion. These users should perform a screening pre-evaluation test (for example, *The Vanderbilt Assessment Scale* [27], *ACTeRS* [28], *Copeland Symptom Checklist for Attention Deficit Disorder* [29], *Brown Attention Deficit Disorder Scales*[30], among others)

The use of multiple matching variables will imply the use of greater sample size, which will lead to a more restrictive study. Researchers should determine the number and definition of matching variables to use in their models, so as to ensure analysis effectiveness.

The validation protocol exposed is quasi-experimental and it can be applied to reduced sample sizes, thus boosting validation accessibility. Since it is a protocol aimed at children, professionals must be previously trained in the intervention patterns.

To conclude, authors recommend evaluating each study setting specifically, so as to determine the most suitable validation protocol for each case.

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