AULA: An ecological virtual reality test with distractors for evaluating attention in children and adolescents

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Abstract

Attention-deficit/hyperactivity disorder (ADHD) is a chronic mental health disorder with distinct behavioral manifestations in childhood, adolescence, and adulthood. Neuropsychological evaluation has increasingly become part of the protocol to the understanding and appropriate diagnosis of this pathology, but lack of ecological validity of ordinary psycho-educational batteries has open the door to other type of tools, such as computerized and Virtual Reality tests. With the aim to overcome the absence of ecological validity of many computerized tests of attention, AULA test (a VR environment which simulates a real classroom environment and demands the patient to complete different tasks presented on both a visual and auditory basis) was developed. The current study describes the main features of the AULA test, and analyzes the performance of the Spanish normative sample of 1272 children from 6 to 16 years old from the perspective of the influence of ecological distractors present in the test. Results show influence of distractors in both increasing reaction time for providing both correct answers and commission errors, and increasing the time the patients deviate their attention focus. Some of the anecdotes happened in different
evaluation settings with relation to children’s reactions to distractors appearing in AULA are also presented.

**Keywords:** ADHD, attention, ecological assessment, virtual reality, distractors

**Introduction**

Attention-deficit/hyperactivity disorder (ADHD) is a chronic mental health disorder with distinct behavioral manifestations in childhood, adolescence, and adulthood (Barkley, 1994; Barkley, Fischer, Smallish, & Fletcher, 2002). It may be characterized by attentional lability, impulsive behavioral style, sterile hyperactivity and fragility of the mechanisms of adaptation to the environment, all of those without any other psychopathological problems that justify the presence of these symptoms (Narbona, 2001; Narbona, & Schulumberger, 2007). Different sources place the ADHD prevalence in 3% to 7.5% of school-aged children (Fischer, Barkley, Smallish, & Fletcher, 2005), while a recent meta-analysis of 300 studies, most of them from 1995 to 2006, estimated a world-wide prevalence of 5%, similar in all studied countries (Polanczyk, Lima, Horta et al., 2007).

Neuropsychological evaluation has increasingly become part of the protocol in an efficient approach to the understanding and appropriate diagnosis of this pathology (Barkley, 1997; Crespo-Eguilaz, Sánchez-Carpintero, Narbona et al., 2010; Holmes, Gathercole, & Place, 2010). However, a revision by Gualtieri & Johnson (2005) complains about the lack of ecological validity of ordinary psycho-educational batteries, which can at most be only an indirect measure of ADHD. These authors state that attention deficits, locomotor hyperactivity, and cognitive impulsivity may or may not be evidenced when a child is in a small room, one-on-one with a single adult; at this point, Gualtieri & Johnson (2005) open the door to other type of tools for the assessment of ADHD, such as computerized tests. This is the case of Conners’ Continuous Performance Test (Conners, 1994a, 1994b), the Children Sustained Attention Task (CSAT) by Servera and Llabrés (2004), Integrated Visual and Auditory
Continuous Performance Test (IVA) (Tinius, 2002), or Test Of Variables of Attention
Continuous Performance Test (TOVA) (Leark, Greenberg, Kindschi, & Dupuy, 2007). However, these tests may also suffer to a different extent from a lack of ecological validity in the testing environment, and, as a common feature, do not provide two highly relevant measures for the support in the diagnosis of ADHD: (1) resistance to interference from distractors (a problem relative to this disorder, documented by Xu, Zhou and Wang, 2004), and (2) head motor activity (i.e. both irrelevant and relevant movements of the head – i.e. relevant to the performance of attending the task). Interestingly, lately Virtual Reality has been considered a reliable method to test ADHD children ability to sustain performances over time, specially by the research team of Rizzo (Bioulac, Lallemand, Rizzo, et al., 2012; Rizzo, Buckwalter, Bowerly, et al., 2000; Rizzo, Bowerly, Buckwalter, et al., 2006).

With the aim to take advantage from Virtual Reality (VR) as an increasingly useful resource for multiple health-related applications, and also to overcome the absence of ecological validity and other problems related to computerized tests of attention, AULA test was developed (authors blinded, year blinded). The current study describes the main features of the AULA test, analyzes the performance of the Spanish normative sample from the perspective of the influence of ecological distractors included in AULA, and documents some of the anecdotes happened in different evaluation settings with relation to children’s reactions to distractors appearing in AULA.

**Method**

**Participants**

The Spanish normative sample was composed of 1272 participants (48.2% female) with an age range from 6 to 16 years old (x=10.25, sd = 2.83). All of them had Spanish as their mother tongue. Figure 1 shows the distribution by age and sex.
The recruitment was performed in four different schools from the regions of Basque Country and Navarra in northern Spain. The sample was incidental and, depending on their willingness to participate in the experiment, schools were selected and individual potential participants were contacted. At the same time, all the school children from 6 to 16 years old had full freedom to participate or not in the study, and every student fulfilling the age range inclusion criteria had the same chance to be included in the study. No specific evaluations were previously performed in order to exclude children with potential psychiatric disorders or other neurodevelopmental disorders. Only children with visual or auditory disorders as to make them unable to take the AULA test were excluded from the normative sample.

**Measure**

AULA is based on the paradigm of other Continuous Performance Tests (CPT) but performed in a Virtual Reality (VR) environment, and it is visualized by means of a especial set of VR glasses with movement sensors. The scenario is similar to either a
primary or a high school classroom, and the perspective (i.e. what the participant sees) is placed in one of the classroom desks, looking to the blackboard. Stimuli are presented both on a visual and auditory basis, and, at the same time, previously randomized distractors of ecological nature appear progressively.

The core of AULA is composed by 2 main exercises: (1) a NO-X paradigm based exercise (i.e. Press the button when you DO NOT perceive the target stimulus) and (2) an X paradigm based exercise (i.e. Press the button whenever you DO perceive the target stimulus). The reason for this sequence of presentation (i.e. first NO-X, then X) is that NO-X tasks generate an overstimulation that derives in fast, inaccurate and inadequate responses, while X-tasks lead to a hypoactivation and thus to slow, variable and inefficient answers (Artigas-Pallarés, 2009). It is assumed that this sequence of presentation reproduces more accurately the problem faced by a child with self-regulation problems (as it happens in children with attentional problems) to adapt to new environmental requirements once they have performed an overstimulating activity, as it is stated by the model of state regulation by Sergeant, Oosterlaan, and Van der Meere (1999). Figure 2 provides a fast overview of the appearance of AULA.

Figure 2: NO-X task. Press the button when you do NOT hear or see an apple.
Distractors and related measures obtained in AULA

In addition, some of the items from the tests are accompanied by distractors, equal to those that may appear in a classroom. Below, we present a list of distractors with their respective description:

- Paper ball: a kid throws a paper ball from his desk. The length of the flight is about 3 seconds, it hits in the floor and it rolls (Figure 3).

![Figure 3: Distractor of the boy throwing the paper ball.](image)

- Teacher's walk: the teacher walks smoothly across the classroom. While he walks by, his steps are heard by the patient. From time to time, he observes the work performed by the children (Figure 4).
- Whispers at the right side: it is heard at the right of the patient: “pss, pss, hey, you, pss, pss, hey…”.

- The teacher’s ballpen drops: A ballpen drops from teacher’s desk. The ballpen rolls across the teacher’s table and falls to the floor making a dry and localized noise. The teacher goes for it and takes it back to the table.

- A kid passes a note to another: students in front of the patient pass each other a little note while they look straight to the blackboard, stretching one arm each. The boy on the left stretches his hand with the paper and the girl on the right approaches her hand to the paper in order to take it.

- Cough on the left: the patient can hear a loud cough on the left.

- One kid gives a paper to the teacher: one kid stands up from one desk behind, approaches teacher’s desk, leaves a paper and goes back and sits down in his desk again. When standing up and down, his chair makes considerable noise (Figure 5).
Figure 5:. Distractor of the kid giving the paper to the teacher.

- An ambulance passes by: on the right side of the classroom there is a great window. In a certain moment, from the back side of the patient to the front, an ambulance passes very fast across the street, very close to this window, and the sound of its siren is heard clearly (Figure 6).

Figure 6:. Distractor of the ambulance passing by on the street.
- The bell rings: the bell indicating the change to the next lesson rings.

- A car passes by: from the front part of the child to the back, as can be seen through the window on the right, a red car passes by. When it passes by the windows, its horn sounds as to greet somebody, decreases its speed a little bit and then continues its way.

- Voice at the left: it is heard at the left of the patient: “pss, pss, hey, you, pss, pss, hey...”.

- Cough at the right: someone suffers a cough attack on the right side of the patient.

- Step noise at the corridor: in the corridor to the left of the classroom, steps approaching the classroom door from the back are heard. A turmoil of children speaking is heard, noise and steps are progressively going in the opposite direction and a door closing is heard.

- A kid on the left raises his hand: a kid on a desk on the left raises his hand as if he were to ask something (Figure 7).

![Figure 7:. Distractor of a kid raising his hand.](image)
- Laughs: on the right side of the patient someone laughs, immediately after the laugh somebody demands silence: "sssht!"

- Somebody knocks at the door: the sound of someone knocking at the door is heard; the professor approaches the door, opens it, pops his head out of the room (it looks like he is talking to the person outside), closes the door again and goes back to his place (Figure 8).

![Figure 8: Distractor of the teacher talking to somebody at the corridor.](image)

- A kid on the right raises his hand: the kid in a desk on the right raises his hand as if he were to ask something.

In order to compare children’s performance under the influence and in absence of distractors, main measures obtained when distractors are present were taken and compared with their analogous ones in absence of distractors. The main measures studied were the following:

1. Reaction time for correct answers and commission errors: time required to answer a stimulus (measured in milliseconds). It tends to be longer in people
with attention deficit since they tend to process the information slower (Parsons, Bowerly, Buckwalter, & Rizzo, 2007; Rizzo, Bowerly, Buckwalter, et al., 2006). In AULA, among others, reaction times are measured when correct answers are provided but also when commission errors take place (i.e. the child is told not to press when X stimulus appears, but he finally presses it, and the lapse between the presentation of the stimulus and the presentation of the answer -commission error- is registered).

2. Deviation from the focus: Amount of time (in milliseconds) that the child is not attending the blackboard (usually, because he or she is distracted by something else).

Thus, three couples of variables were compared:

- Reaction time for correct answers with distractors vs. reaction time for correct answers without distractors.
- Reaction time for commission errors with distractors vs. reaction time for commission errors without distractors.
- Deviation from the focus with distractors vs. deviation from the focus without distractors.

Results

Quantitative results: performance with and without distractors compared.

A Kruskal-Wallis test was performed in order to analyze differences of performance in AULA between the sequences in which distractors were presented and those in which they were absent.

As it can be seen, reaction times were lengthened by the presence of distractors both when providing correct answers and commission errors (though this one did not
reach statistical significance). Additionally, distractors increased the time that the child was deviating his/her attentional focus from the blackboard. Table 1 shows the results calculated for the whole normative sample.

Table 1. Performance with and without distractors for the whole sample.

<table>
<thead>
<tr>
<th></th>
<th>N = 1272</th>
<th>Mean</th>
<th>sd</th>
<th>Z</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>RT_correct answers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>with distractors</td>
<td>893.02</td>
<td>172.25</td>
<td>-12.737</td>
<td>.000</td>
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<tr>
<td>without distractors</td>
<td>866.25</td>
<td>151.05</td>
<td>-1.926</td>
<td>.054</td>
<td></td>
</tr>
<tr>
<td>RT_commissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with distractors</td>
<td>792.24</td>
<td>381.91</td>
<td>-1.926</td>
<td>.054</td>
<td></td>
</tr>
<tr>
<td>without distractors</td>
<td>777.38</td>
<td>300.99</td>
<td>0.283</td>
<td></td>
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<tr>
<td>Deviation from the focus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with distractors</td>
<td>14051.94</td>
<td>46887.38</td>
<td>-2.483</td>
<td>.013</td>
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<tr>
<td>without distractors</td>
<td>12865.27</td>
<td>45130.94</td>
<td>0.076</td>
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</table>

Subsequently, these same differences were analyzed separately for the sample of boys and girls separately. The same trend of performance was seen in boys separately as in the general sample, as can be seen in table 2.

Table 2. Performance comparison with and without distractors for boys.

<table>
<thead>
<tr>
<th></th>
<th>N = 659</th>
<th>Mean</th>
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<td>RT_correct answers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>with distractors</td>
<td>883.54</td>
<td>174.88</td>
<td>-7.517</td>
<td>.000</td>
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<tr>
<td>without distractors</td>
<td>862.07</td>
<td>154.08</td>
<td>0.183</td>
<td></td>
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<tr>
<td>RT_commissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with distractors</td>
<td>786.22</td>
<td>346.17</td>
<td>-1.031</td>
<td>.302</td>
<td></td>
</tr>
<tr>
<td>without distractors</td>
<td>779.49</td>
<td>278.17</td>
<td>0.192</td>
<td></td>
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<tr>
<td>Deviation from the focus</td>
<td></td>
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</tr>
<tr>
<td>with distractors</td>
<td>15635.49</td>
<td>40682.53</td>
<td>-1.564</td>
<td>.118</td>
<td></td>
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<tr>
<td>without distractors</td>
<td>14828.98</td>
<td>38521.35</td>
<td>0.818</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In presence of distractors, performance was worse with a higher reaction time for correct answers. Difference on reaction time for commission errors and deviation from the focus did not reach statistical significance.

Finally, when examining the performance results for girls, a similar pattern of performance as in boys appeared, as can be seen in table 3. In this case, girls showed additionally a significantly longer deviation of the focus when distractors were present.

### Table 3. Performance comparison with and without distractors for girls.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>sd</th>
<th>Z</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>RT_correct answers_with distractors</td>
<td>903.22</td>
<td>168.94</td>
<td>-10.531</td>
<td>.000</td>
</tr>
<tr>
<td>RT_correct answers_without distractors</td>
<td>870.74</td>
<td>147.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT_commissions_with distractors</td>
<td>798.71</td>
<td>417.12</td>
<td>-1.70</td>
<td>.089</td>
</tr>
<tr>
<td>RT_commissions_without distractors</td>
<td>775.12</td>
<td>323.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviation from the focus with distractors</td>
<td>12349.57</td>
<td>52731.53</td>
<td>-2.089</td>
<td>.037</td>
</tr>
<tr>
<td>Deviation from the focus without distractors</td>
<td>10754.21</td>
<td>51244.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualitative results: how children react to distractors**

In terms of influence of distractors form the qualitative point of view, the most memorable anecdotes were collected from the performance of younger children, aged from 6 to 8 year old. Many of them behaved as if AULA’s characters were real persons, that is, as if they were their real classmates. They strikingly interacted with the distractors: they raised their hands, followed the teacher, they asked him where he was going… With the auditory distractor of the boy saying “pss, hey, you… pssss”, one girl completely turn her body back –wearing the VR glasses- and looking behind...
she recriminated her virtual classmate telling him "ssssh, shut up, they will catch us!!". Even in the sensitivity study, a child stood up, wearing the glasses, and said that he was going to take a walk to see the rest of the school.

In subsequent applications of AULA in clinical populations, collected experiences reflect that the child or adolescent reacts in the virtual environment in a very similar way to reality. For example, a 10 year-old kid with ADHD disorder, hyperactive-impulsive subtype, repeated some of the words said by the teacher and continuously raised his hand because he wanted to interrupt him and/or ask him a question. The same child, when the auditory distractor of the boy saying "pss, hey, you... pssss" appeared, he raised his hand and stated “teacher, there is a problem, someone is annoying me!”. Another 9 year old kid with ADHD and behavioral disorders, started to say “hello classmates... why are you all looking to the blackboard? Don't you wanna go outside? Are you deaf... or what? I want to see the playground!!”. He started insulting one of the classmates while he was trying to touch and beat him. Then he turned around and talked to the teacher, saying “teacher, come here, why cannot we go to the playground?”. At that specific moment, the virtual teacher was walking to the door and the child reacted “Wow, you don't even listen to me and now you go away!”. On the other hand, there were some situations in which the reactions from the children were very natural and spontaneous to different distractors, which indicated they were completely immersed in the classroom situation. For example, one adolescent who was 12-years old, when the classmate said "pss, pss", he answered “shut up" in a low voice answering to where the voice came from. And a 9 years-old child answered “ok” to some of the instructions provided by the teacher.

**Conclusion**

The current study presents the AULA test as a VR Test emulating faithfully the context of a real classroom and enhances one of the main features that differentiate it from other CPT-paradigm based tests, which is the inclusion of ecological
distractors similar to the ones a child might find in a real classroom. This provides a high added value to the evaluation of the attentional problems in the context of a classroom, and determines how much the child must be interfered by the presence of these distractors. Results show that there is some delay in the response for correct answers and a higher deviation from the attentional focus (i.e. amount of time that kids are not looking at the blackboard), which implies that to some extent distractors fulfill their interfering role. Further studies will determine to what extent AULA VR test has the discriminative ability to differentiate between ADHD and other attentional problems specifically related to childhood and adolescence.

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References


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