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ClinicaVR: Classroom-CPT: A virtual reality tool for assessing attention and inhibition in children and adolescents

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ABSTRACT

Having garnered interest both in clinic and research areas, the Virtual Classroom (Rizzo et al., 2000) assesses children's attention in a virtual context. The Digital MediaWorks team (www.dmw.ca) has evolved the original basic classroom concept over a number of iterations to form the ClinicaVR Suite containing the Classroom-CPT as one of its components. The present study has three aims: investigate certain validity and reliability aspects of the tool; examine the relationship between performance in the virtual test and the attendant sense of presence and cybersickness experienced by participants; assess potential effects of gender and age on performance in the test. The study was conducted with 102 children and adolescents from Grade 2 to Grade 10. All participants were enrolled in a regular school program. Results support both concurrent and construct validity as well as temporal stability of ClinicaVR: Classroom-Continuous Performance Test (CPT). Gender exerted no effect on performance, while age did. The test did not cause much cybersickness. We recommend ClinicaVR: Classroom-CPT as an assessment tool for selective and sustained attention, and inhibition, in clinic and research domains.
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1. Introduction

Through traditional neuropsychological assessment (Lezak, Howieson, Loring, Hannay, & Fischer, 2004), it is possible to better understand people's neurocognitive abilities and problems. It provides clinicians with a basis for developing diagnoses and rehabilitation strategies for a variety of populations. However, its ecological validity has been questioned (Bowman, 1996; Marcotte & Grant, 2010; Sbordone & Long, 1996; van der Linden, 2008a, 2008b). Critics claim that neuropsychological tests do not predict people's daily functioning very well, and that this effect is especially important when results fall within the normal range or when they indicate mild deficits (Sbordone, 2008). Then, limited ecological validity of traditional neuropsychological testing represents one of its main drawback.

The ecological approach to neuropsychological testing was first developed in the late 1980s as an attempt by researchers and clinicians to improve the quality of traditional testing. In this approach, emphasis is placed on the test's ability to be representative of people's functioning in everyday situations (Chaytor & Schmitter-Edgecombe, 2003). From this perspective, virtual reality techniques hold promise for researchers and clinicians (Allain et al., 2011; Jovanovski et al., 2012; Parsons, Carlew, & Sullivan, 2015; Rizzo, Buckwalter, & Zaag, 2002; Rizzo, Schultheis, Kerns, & Mateer, 2004; Schultheis, Himelstein, & Rizzo, 2002). Through this technology, users navigate and interact within three-dimensional environments. The term "ecological" applies to virtual reality because virtual environments can simulate everyday environments (e.g. a classroom) and require the user to display behaviours that are necessary in real life. By nature, tests conducted through virtual reality are better than traditional tests at detecting problems experienced by users in daily situations; they do not suffer from some methodological flaws that would exist in uncontrolled assessments conducted in real-life environments (e.g.

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people's homes). The ability to observe people's behaviour in virtual environments makes it possible to detect cognitive deficits that would go unnoticed in traditional neuropsychological testing (Nolin, Martin, & Bouchard, 2009; Rizzo et al., 2000, 2004; Schultheis et al., 2002; Tarr & Warren, 2002; Trepagnier, 1999).

Virtual reality has already been applied to testing procedures for a number of cognitive domains including attention (e.g. Larson et al., 2011; Parsons, Rizzo, van der Zaag, McGee, & Buckwalter, 2005; Rizzo et al., 2006), memory (e.g. Knight & Titov, 2009; Matheis et al., 2007; Parsons & Rizzo, 2008a, 2008b) and executive functions (e.g. Albani et al., 2010; Baumgartner, Valko, Esslen, & Jäncke, 2006; Elkind, Rubin, Rosenthal, Skoff, & Prather, 2001; Klinger, Cao, Douguet, & Fuchs, 2009; Pugnetti et al., 1998; Raspelli et al., 2009). The advantages of virtual reality have also been demonstrated in the field of neuropsychological rehabilitation (Penn, Rose, & Johnson, 2009; Rose, Brooks, & Rizzo, 2005; Wang & Reid, 2011).

However, the overwhelming majority of neuropsychological studies using virtual reality have dealt with adults while studies with children and adolescents are relatively scarce (Penn et al., 2009; Yen Hwee-Ling, 2007). Of the few studies which have been conducted with children, data were mostly generated using the Virtual Classroom, which was developed by Rizzo et al. (2000) with the aim of adapting virtual reality techniques to a setting that children and adolescents are familiar with: school. The Virtual Classroom features a continuous performance test (CPT). A number of studies have shown the utility of the Virtual Classroom in assessing children with ADHD (Adams, Finn, Moes, Flannery, & Rizzo, 2009; Gutiérrez-Maldonado, Letosa-Porta, Rus-Calafell, & Peñaloza-Salazar, 2009; Moreau, Guay, Achim, Rizzo, & Lageix, 2006; Parsons, Bowerly, Buckwalter, & Rizzo, 2007; Parsons, Rizzo, Rogers, & York, 2009; Pollak, Shomaly, Weiss, Rizzo, & Gross-Tsur, 2010; Pollak et al., 2009; Rizzo et al., 2006) and those with traumatic brain injury (TBI) (Nolin et al., 2009). Consequently, Digital MediaWorks (www.dmw.ca) has evolved the original basic classroom concept over a number of iterations to form the ClinicaVR Suite containing the Classroom-CPT as one of its components. The revision of the Virtual Classroom is one sign that it is currently arousing interest both in clinic and in research. Nevertheless, few studies have investigated its validity, and no range of normal results has yet been established.

Our first aim in the present study is to present *ClinicaVR: Classroom-CPT* and to assess its concurrent and construct validity as well as temporal stability. To achieve this, we used the traditional (Cegalis, 1991), and virtual version of VIGIL-CPT (*ClinicaVR: Classroom-CPT*). As a second aim, we endeavour to gauge the quality of the immersion in the *ClinicaVR: Classroom-CPT*. This question dealt with two key factors that must be considered in any study involving virtual reality: sense of presence and cybersickness. Sense of presence refers to the subjective sensation or mental manifestation in which someone has the sense of being 'physically present with visual, auditory, or force displays generated by a computer' (Sheridan, 1992). Cybersickness denotes symptoms that may be felt during or after the participant's experience in virtual reality, such as nausea or eye strain. Based on previous studies (Betts, Mckay, Maruff, & Anderson, 2006) that support that attention grows during childhood, our third aim is to determine the effect of participants' age and gender on test performance.

2. Material and methods

2.1. Participants

Participants were recruited from schools in Trois-Rivières, a medium-sized city in Quebec, Canada with a population of about 150,000. A total of 102 French speaking students from Grade 2 to Grade 10 (aged from 7 to 16) agreed to participate in the study by signing a consent form along with their parents. The group was made up of 53 girls and 49 boys. All the children were in a regular school program. Based on the developmental and general information questionnaire that was completed by the parents, no child had received special education services or presented difficulties which would have required interventions. The distribution of participants by age and gender can be seen in Table 5. In order to have a sufficient number of participants per group, participants in Grade 4 to Grade 6 were combined into one group, after checking that there were no significant differences between these three groups to all variables on ClinicaVR: Classroom-CPT.

2.2. Instruments

2.2.1. Development and general information questionnaire

Our team developed and administered a questionnaire to collect information on sociodemographic status, education, and physical and mental health of participants from the perinatal period to the time of the assessment. The questionnaire was used to verify that all participants had a normal developmental and educational history.

2.2.2. Traditional neuropsychological test: VIGIL-CPT

The VIGIL-CPT (Vigil Continuous Performance Test; Cegalis, 1991), a traditional test of attention and inhibition, was administered to all participants. In this computerized test, letters appear one at a time in the centre of a screen, changing at an interval that is kept constant throughout the test. The participant is required to click the mouse each time the letter K appears after being immediately preceded by the letter A. The six-minute test presents a total of 300 stimuli, 60 of which require a response. In both clinic and research activities, the VIGIL-CPT is a recognized measure of selective and sustained attention, vigilance, impulsivity and reaction time (Egeland & Kovalik-Gran, 2010). The three variables measured were (1) the number of correct responses (i.e. to respond to the letter K when immediately preceded by the letter A), (2) the number of commissions (i.e. responding to the letter K when not preceded by the letter A or responding to another letter) and (3) the mean reaction time in ms.

2.2.3. Virtual neuropsychological test: ClinicaVR: Classroom-CPT

The virtual test of attention and inhibition used in this study was a CPT presented in a virtual classroom. The first Virtual Classroom was developed by Rizzo et al. (2000). It was revised by the Digital MediaWorks team (http://www.dmw.ca/) under the name *ClinicaVR: Classroom-CPT*. They tried to achieve a better balance of left/centre/right distractors including those that were purely auditory, purely visual, and audio/visual in nature. Many of the original elements were the same but with improvements in the quality of the visuals aided by improvements in 3D Engine technology. The test was also broken down into fixed size blocks that were repeated at various intervals depending on the desired length of the test. The test is identical to the traditional VIGIL-CPT except for the environment in which it is administered: instead of being presented on a computer screen, the stimuli appear on a whiteboard situated in a virtual classroom. The virtual classroom features objects and people commonly found in real classrooms, such as a whiteboard, desks, a teacher and students (see Fig. 1). Participants were immersed in the virtual environment by wearing an Emagin Z800 Head mounted display (HMD) with the ability to monitor the wearer's head movements. The zero reference for the yaw, pitch, and roll (tilt) axes is an imaginary line from the seated position to the center of the active display area (where the letters are

Table 1
Intercorrelations between scores from ClinicaVR: Classroom-CPT and from the traditional VIGIL-CPT.

	ClinicaVR: Classroom-CPT	Correct response	Commission	Reaction time	Right and left head mvt.	Up and down head mvt.	Tilt head mvt.
Vigil-CPT Traditional	Correct response	.63***	−.23*	−.42***	−.27**	−.45***	−.30**
	Commission	−.14	.50***	−.13	.19*	.15	.08
	Reaction Time	−.60***	.11	.82***	.37***	.47***	.35***

*p < .05 **p < .01 ***p < .001.

displayed). In the early versions the highest excursions ± for each axis was recorded as well as the average (average gaze vector). This was done for each block and the overall (all blocks). This indicates the range of gaze the user went thru. Participants were able to look 360° around themselves as well as up and down in the virtual environment. Typical classroom sounds were played to the participant through headphones integrated into the HMD. Throughout the virtual version of the VIGIL-CPT, the wearer experienced auditory and visual distractions typical of a real classroom, such as a knock at the door, a bell announcing the end of class, children laughing outside and a visit from the principal. The six variables measured in the *ClinicaVR: Classroom-CPT* were (1) the number of correct responses, (2) the number of commissions, (3) the mean reaction time in ms, (4) the number of left-right (horizontal) head movements, (5) the number of up–down (vertical) head movements and (6) the number of tilt head movements.

2.2.4. Sense of presence and cybersickness questionnaires

After completion of the *ClinicaVR: Classroom-CPT*, participants filled two questionnaires describing their VR experience. The realistic subscale of the Presence Questionnaire (Witmer & Signer, 1998; French adapted version of UQO Cyberpsychology Laboratory: Robillard, Bouchard, Renaud, & Cournoyer, 2002) evaluated the realism of the VR task with 7 questions to be rated on a scale from 1 to 7 (examples of questions included in the questionnaire: “How natural did your interactions with the environment seem?” “How much did the visual aspects of the environment involve you?”). The Simulator Sickness Questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993; French adapted version of UQO Cyberpsychology Laboratory; Bouchard, Robillard, & Renaud, 2007) assessed the occurrence, nature and severity of sickness symptoms induced by VR environments with 16 items to be rated on a scale from 0 to 3 (examples of symptoms included in the questionnaire: “General discomfort”, “Fatigue”, “Headache”).

2.3. Procedure

Students participated individually in testing sessions during regular class hours. The order of the traditional and virtual versions of the CPT was counterbalanced across participants to prevent skewing of the results due to practice or fatigue effects. All participants and their parents gave written informed consent before participation in this study. The study procedure was approved by the Human Research Ethics Committee of the University of Québec at Trois-Rivières.

Table 2
Factor weights by variable for ClinicaVR: Classroom-CPT and the traditional VIGIL-CPT according to the three factors derived from the factorial analysis.

Variable	Factor		
	1	2	3
Up and down head movements	**.80**	.33	.20
Tilt head movements	**.78**	.14	.16
Right and Left head movements	**.72**	.19	.18
Reaction time in virtual test	.23	**.81**	−.28
Reaction time in Traditional test	.23	**.81**	−.02
Correct responses in virtual test	−.25	−.57	**−.48**
Commissions in traditional test	.14	−.19	**.76**
Commissions in virtual test	.18	−.04	**.75**
Correct responses in traditional test	−.20	−.40	**−.51**

Note: The numbers in bold represent scores that were used to identify the different factors.

3. Results

3.1. Concurrent validity of ClinicaVR: Classroom-CPT

The concurrent validity of ClinicaVR: Classroom-CPT was verified by analysing intercorrelations between the scores from the ClinicaVR: Classroom-CPT and those from the traditional VIGIL-CPT (see Table 1). The three variables common to both tests (correct responses, commissions and reaction time) have obtained high significant intercorrelations (.50–.82). Furthermore, head movements, evaluated only by ClinicaVR: Classroom-CPT, have generally shown good correlations with the traditional variables of the CPT (correct responses, commissions, and reaction time). These results suggest a good concurrent validity of ClinicaVR: Classroom-CPT.

3.2. Construct validity of ClinicaVR: Classroom-CPT

Construct validity of *ClinicaVR: Classroom-CPT* was verified by means of a principal axis exploratory factorial analysis with Varimax rotation, which was performed on the virtual and traditional test scores. The criteria for a valid correlation matrix (which is necessary for interpretation of the factorial analysis) were satisfied: the correlation determinant was greater than .00001; Bartlett's test of sphericity was lower than .05; and the Kaiser-Meyer-Olkin index was .77, which fell within the range of .50–.90, suggesting that the sample was adequate. Factors with eigenvalues greater than 1.00 were flagged (see Table 2). Three such factors were found, accounting for 76.12% of the total variance. The first factor is made up of all three types of head movements in the virtual test (left-right, up–down and tilt), and accounts for 41.68% of the variance. The second factor is made up of reaction times in both the virtual and traditional tests and accounts for 22.33% of the variance. The third factor is made up of the number of correct responses in both the virtual and traditional tests and the number of commissions in both the virtual and traditional tests and accounts for 12.11% of the variance.

3.3. Temporal stability of ClinicaVR: Classroom-CPT

The temporal stability of *ClinicaVR: Classroom-CPT* was analysed by examining the scores from 21 participants in the original sample (Time 1) who were reassessed one month after the initial assessment (Time 2). This subsample was made up of 11 girls and 10 boys with a mean age of 13.62 years (SD = 1.28 years).

Table 3 shows intercorrelations between scores from *ClinicaVR: Classroom-CPT* at Time 1 and Time 2.

Analysis of this table shows good intercorrelations between the scores of *ClinicaVR: Classroom-CPT* obtained at Time 1 and Time 2 (correct responses, commissions, right–left, up–down and tilt

Table 3
Intercorrelations between scores from ClinicaVR: Classroom-CPT at Time 1 and Time 2.

	ClinicaVR: Classroom-CPT Time 1	Correct response	Commission	Reaction Time	Right and Left head mvt.	Up and down head mvt.	Tilt Head mvt.
ClinicaVR: Classroom-CPT Time 2	Correct response	**.61*****	−.41**	−.10	−.34*	−.09	−.42**
	Commission	−.35*	**.34***	.04	.28	.06	.25
	Reaction Time	−.70***	.48**	**.13**	.10	−.10	−.07
	Right and left Head mvt.	−.28	.03	−.03	**.49****	.37*	.49***
	Up and down Head mvt.	−.15	−.09	−.17	.49**	**.54*****	.54***
	Tilt head mvt.	−.16	.03	−.16	.39*	.46**	**.46****

Note: The numbers in bold indicate the correlations between variables that are similar in both tests (traditional and virtual).
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 4
Frequency of cybersickness experienced during the ClinicaVR: Classroom-CPT.

Cybersickness	Frequency	
	Present (%)	Absent (%)
General discomfort	26.1	73.9
Fatigue	57.7	42.3
Headache	29.7	70.3
Eye strain	67.6	32.4
Difficulty focussing	29.7	69.4
Increased salivation	13.5	86.5
Sweating	13.5	86.5
Nausea	4.5	95.5
Difficulty concentrating	30.6	69.4
“Fullness of the head”	39.6	60.4
Blurred vision	35.1	64.9
Dizziness with eyes open	15.3	84.7
Dizziness with eyes closed	13.2	86.5
Vertigo	12.6	87.4
“Stomach awareness”	12.6	87.4
Burping	.0	100.0

head movements). Only reaction times showed no intercorrelation between the two measurement times. Therefore, the *ClinicaVR: Classroom-CPT* seems stable over time.

3.4. Cybersickness

Table 4 presents the frequency of cybersickness for the total sample. Analysis of this table shows that most common cybersickness experienced were “eye strain” and “fatigue”. Least frequent cybersickness were “nausea” and “burping”. In addition, participants reported little cybersickness in general in *ClinicaVR: Classroom-CPT* (mean = 3.99 SD = 2.59).

3.5. Sense of presence

Table 5 presents data for sense of presence; the ANOVA showed that the groups did not differ with respect to Grade [$F(6,101) = .77$, $p = .60$], gender [$F(1,101) = .01$, $p = .96$] or the interaction between these two factors [$F(6,101) = .87$, $p = .52$]. All participants felt “moderately” present while performing the virtual test. Since there was no correlation between sense of presence and the scores from the *ClinicaVR: Classroom-CPT* test (omissions $r = .06$, $p > .05$; commissions $r = .02$; $p > .05$; reaction time $r = .06$, $p > .05$; left–right head movements, $r = .11$; $p > .05$; up–down head movements, $r = -.05$. $p > .05$; tilt head movements, $r = .04$, $p > .05$), we were able to conduct group comparisons on performance in the virtual test.

3.6. Effect of gender and age on ClinicaVR: Classroom-CPT scores

This section concerns the differences observed between participant groups after a 7 × 2 ANOVA (grade × gender) was applied to each of the scores from *ClinicaVR: Classroom-CPT*.

With respect to gender, analyses conducted on the data (see Table 5) showed that girls made fewer right and left head movements [$F(1,101) = 10.99$, $p = .001$] and fewer tilt head movements than boys [$F(1,101) = 5.07$, $p = .03$]. However, when the Bonferroni correction was applied to avoid Type I errors, this gender difference disappeared for tilt head movements.

As for age group, significant differences were observed, even after the Bonferroni correction, on all variables measured in *ClinicaVR: Classroom-CPT*. Those are total of correct response [$F(1,101) = 29.40$, $p = .000$], total of commission [$F(1,101) = 9.05$, $p = .000$], reaction time [$F(1,101) = 13.64$, $p = .000$], total of right and left head movements [$F(1,101) = 7.42$, $p = .000$], total of up and down head movements [$F(1,101) = 8.63$, $p = .000$], and total of tilt head movements [$F(1,101) = 3.30$, $p = .006$]. In general, post-hoc Fisher's least significant difference (LSD) tests showed that, for all the variables of the *ClinicaVR: Classroom-CPT*, children from Grade 2 scored significantly lower than those from Grade 3 to 10; those from Grade 3 and 4 scored lower than those from Grade 7 to10.

Finally, no significant interaction effect was found between grade group and gender for any of the variables.

4. Discussion

The first aim of the present study was to present *ClinicaVR: Classroom-CPT* and to examine some aspects related to its validity and reliability.

Our results support the concurrent validity of *ClinicaVR: Classroom-CPT* since all scores relating to concurrent validity were significantly correlated with the corresponding scores in the traditional version of the test. Specifically, significant and strong correlations were found between the virtual and traditional test scores for three variables: number of correct responses, number of commissions, and reaction times. Finally, the types of head movement were significantly correlated with most variables in the traditional VIGIL-CPT, which shows a resemblance between the constructs measured by the two tests: both the *ClinicaVR: Classroom-CPT* and the VIGIL-CPT are measures of sustained and selective attention, and impulsivity (inhibition).

In regard to construct validity, results show consistency between the variables in the VIGIL-CPT and those in *ClinicaVR: Classroom-CPT*. Three factors emerge from the tests, each composed of a different grouping of variables. The first factor is made up of all three types of head movements in the virtual test (left-right, up–down and tilt); this factor represents the participants' capacity to resist to distractors (inhibition). The second factor is made up of reaction times in both virtual and traditional tests; this factor represents the participants' speed of execution. The third factor is made up of the number of correct responses in both virtual and traditional tests and the number of commissions in virtual and

Table 5
Means and standard deviations for sense of presence, and variables in ClinicaVR: Classroom-CPT by gender and by Grade level, and results of the posteriori analysis.

Variable	Grade 2		Grade 3		Grade 4–5–6		Grade 7		Grade 8		Grade 9		Grade 10		LSD posteriori
	7–8 years		8–9 years		9–12 years		12–13 years		13–14 years		14–15 years		15–16 years		
	♀ (n = 5)	♂ (n = 5)	♀ (n = 5)	♂ (n = 7)	♀ (n = 6)	♂ (n = 9)	♀ (n = 8)	♂ (n = 2)	♀ (n = 10)	♂ (n = 9)	♀ (n = 8)	♂ (n = 8)	♀ (n = 11)	♂ (n = 9)	
	X (SD)		X (SD)		X (SD)		X (SD)		X (SD)		X (SD)		X (SD)		
Sense of presence	4.49 (1.62)	4.66 (1.62)	4.35 (1.03)	5.51 (1.53)	4.81 (1.06)	4.33 (1.54)	4.79 (1.92)	3.89 (1.35)	4.10 (.95)	4.05 (1.26)	4.23 (.80)	4.59 (.66)	4.60 (.84)	4.39 (1.01)	____
Correct response	41.60 (9.24)	48.80 (2.78)	46.29 (4.07)	48.40 (6.19)	52.89 (4.89)	53.17 (5.78)	56.50 (2.12)	57.75 (1.91)	57.78 (2.39)	58.20 (1.62)	58.87 (1.46)	59.00 (.76)	59.44 (.73)	58.27 (2.49)	2, 3 < 4 to 10 4 < 7 to 10
Commission	12.40 (6.11)	11.40 (7.02)	6.86 (7.40)	11.00 (5.61)	5.44 (4.69)	9.50 (6.16)	11.50 (6.36)	6.50 (3.51)	4.22 (2.28)	4.20 (2.20)	2.63 (1.60)	4.75 (2.25)	1.11 (.78)	3.18 (2.48)	2 < 4 to 10 3, 4, 7 < 8 to 10
Reaction time	.490 (.135)	.581 (.051)	.524 (.081)	.470 (.075)	.452 (.084)	.467 (.098)	.343 (.022)	.376 (.028)	.401 (.056)	.382 (.036)	.396 (.031)	.358 (.025)	.390 (.048)	.367 (.044)	2 < 4 to 10 3, 4 < 7 to 10
Right and left Head movement	86.80 (47.67)	87.00 (37.61)	66.00 (30.65)	108.80 (43.22)	46.11 (19.51)	65.00 (37.00)	27.00 (12.73)	57.88 (37.44)	23.67 (10.67)	50.60 (32.99)	27.87 (14.85)	50.25 (53.14)	23.67 (21.71)	34.18 (22.74)	2, 3 < 4 to 10 4 < 10
Up and down Head movement	74.60 (30.08)	71.00 (26.35)	75.14 (47.30)	56.20 (16.87)	38.89 (20.64)	50.67 (34.67)	39.50 (21.92)	50.38 (39.24)	21.56 (10.58)	37.00 (14.24)	31.50 (21.86)	23.63 (12.82)	16.22 (10.37)	19.91 (16.69)	2, 3 < 4 to 10 4, 7 < 10
Tilt Head movement	41.40 (31.10)	68.20 (15.91)	42.43 (19.03)	54.20 (14.86)	28.22 (11.03)	37.17 (30.25)	18.50 (12.02)	35.75 (22.36)	33.78 (44.49)	27.30 (14.80)	25.63 (16.61)	34.13 (22.18)	14.67 (13.30)	24.55 (24.48)	2 < 4 to 10 3 < 8 to 10

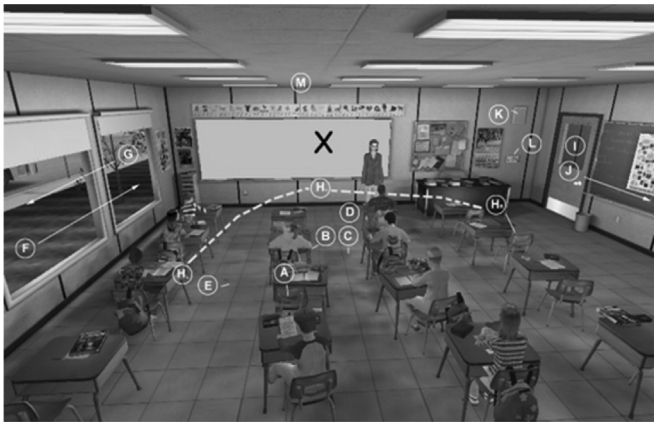

Fig. 1. An overall view of ClinivaVR: Classroom and location of distractors.

Legend

Reference	Distractor	Location	Type
F	School Bus	Left	Audio/Visual
G	SUV Vehicle	Left	Audio/Visual
-	Crumple Paper	Left	Auditory
E	Drop Pencil	Left	Auditory
H	Paper Airplane	Left -> Right	Visual
D	Drop Book	Centre	Audio/Visual
B	Raise Hand	Centre	Audio/Visual
C	Note Pass	Centre	Audio/Visual
-	Cough	Centre	Auditory
M	Jet Noise	Centre	Auditory
I	Answer Door	Right	Audio/Visual
J	Principal	Right	Audio/Visual
L	Intercom	Right	Auditory
K	Bell	Right	Auditory
-	Sneeze	Right	Auditory

traditional tests; this factor represents the participants' capacity of attention. *ClinicaVR: Classroom-CPT*, therefore, can be said to cover three distinct attentional processes.

With respect to the intercorrelations between the variables of the *ClinicaVR: Classroom-CPT* and those of the traditional CPT, results support temporal stability of the *ClinicaVR: Classroom-CPT* in performance over a period of one month (although they will have to be corroborated by future studies with greater sample sizes). Participants' results were consistent between both times of measurement, which points to the utility of *ClinicaVR: Classroom-CPT* in longitudinal studies.

The second objective of this study was to gauge cybersickness and the sense of presence brought about by *ClinicaVR: Classroom-CPT*. Generally, participants did not report much cybersickness. Perhaps this is because they were seated in the virtual classroom and not required to navigate throughout the environment. It appears that *ClinicaVR: Classroom-CPT* is not likely to cause cybersickness in participants. With respect to sense of presence, results show that the virtual test is generally associated with a "moderate" level of presence. Neither age nor gender had an effect on sense of presence. This suggests a homogenous effect for the virtual test among the population aged 7–16 years, which can be seen as a strength of the measure. Still, unlike other studies that use virtual reality to investigate emotional and affective components (e.g. Aymerich-Franch, 2010; Riva et al., 2007), results show no relationship between sense of presence and performance in the virtual test. A more thorough investigation of the dynamic between sense of presence and cognitive performance in virtual reality would be relevant in future studies.

The third objective of the study was to observe how gender and age affected performance in virtual CPT scores. We found that test scores are indistinguishable with respect to gender, except for right and left head movements. This may support the notion that gender exerts a minimal influence on the attention and inhibition abilities measured by this tool. The case is rather different, however, when it comes to the effect of age. Significant differences were found among age groups for all the variables measured in *ClinicaVR: Classroom-CPT*. Specifically, attention and inhibition appear to improve a great deal between the ages of 7 and 12 years before reaching a plateau. Recent work by Anderson (2008) supports a model of development of attention and inhibition wherein these

functions increase and reach a plateau as children grow. Continued research in this area would allow to determine more precisely how these functions develop from childhood to adulthood, and *ClinicaVR: Classroom-CPT* could prove a useful tool in this endeavour. Despite the interest of the differences that were observed in this study for different age levels, it appears essential to urge caution in the use of these data. Indeed, given the relatively small number of participants compared to the number of variables included in our analysis of variance, our design appears quite under-powered.

5. Conclusion

From a clinical point of view, the study nevertheless has positive elements. Indeed, it supports the validity of the VIGIL-CPT in a virtual version. Emphasize here that virtual reality is seen as a way of improving neuropsychological tests. This allows to make them more representative of the child's functioning in real life. In *ClinicaVR: Classroom*, the child must perform VIGIL-CPT, which is presented on a whiteboard in the virtual classroom, while resisting visual and auditory distractors that occur throughout the task. This, we believe, lies the richness of this task. Thus, *ClinicaVR: Classroom* could help provide links between neuropsychological assessment in the office of neuropsychologist, in a controlled environment and where the child is met alone, and what happens in a context where the child has to manage many types of stimuli, such as at school. It appears interesting to add this type of clinical analysis to the traditional neuropsychological evaluation process.

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