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Assessing attention in a 3D environment: Preliminary evidence from a pilot study using the Computerized Battery for the Assessment of Attention Disorders (CBAAD)

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Abstract

Neuropsychological assessment is traditionally performed with the use of either paper-pencil administered tests or 2D computerized tests. Both testing procedures have been associated with limitations in reflecting real world situations. While 3D environments have been used increasingly in the field of neuropsychological rehabilitation with promising results, neuropsychological assessment has largely retained traditional tools. Thus, in order to provide a reality-based attention assessment, we developed the Computerized Battery for the Assessment of Attention Disorders (CBAAD). In the current study, we present preliminary data from the administration of the CBAAD to 50 healthy ($N = 26$ females) adult participants, as well as their feedback regarding their experience taking the test and its usefulness. Preliminary findings suggest that participants generally performed well and rated their experience with the CBAAD as pleasant, motivating, real-life resembling, and time-preserving. Results are discussed with respect to the aims of the battery development. In conclusion, this is the first 3D attention assessment battery to our knowledge, and the present study provides strong preliminary evidence that it is user-friendly.

Key-words: attention, neuropsychological battery, computerized-assessment, 3D

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1. Introduction

Attention is a complex system with highly interactive subprocesses. Although theoretical models vary with respect to the number and type of attention subcomponents, they propose the existence of four main functions [1, 2]: selective attention (identifying target stimuli while simultaneously ignoring distracting information), sustained attention (maintenance of effortful attention during monotonous tasks), divided attention (sharing attentional focus between two tasks that are of equal importance), and shifting attention (the ability to switch between two tasks that are performed alternatingly). Attentional functions are involved in nearly every aspect of everyday living (i.e., driving, working), therefore, the detection of attention failures is of utmost importance. In a more severe form, attentional deficits are present in many neurological (e.g., dementia, stroke, traumatic brain injury) and psychiatric diseases (Attention Deficit/Hyperactivity Disorder) [3]. Therefore, clinical assessment of attention is an integral part of the diagnostic procedure.

The neuropsychological assessment of attentional processes traditionally involved the use of well-known paper-and-pencil tests (i.e., Trail Making Test) [4] (Stroop Color-Word Test) [5] and batteries (for an exhaustive measurement of attentional functions), such as the Test of Everyday Attention [6]. Paper-and-pencil tests have the advantage of their relatively easy administration and face to face interaction with the examinee [7] but the results obtained depend significantly on the examiner's experience in administration and scoring [8, 9]. To surpass these difficulties, computerized batteries, such as the Test of Variables of Attention [10] and other computer-based tests (Sustained Attention to Response Test) [11, 12] haven been developed. An important advantage of computerized assessment over standard paper-and-pencil testing is that they provide millisecond level accuracy. Moreover, computerized reports are quickly and easily obtained, including statistically complex performance parameters (median and standard deviation of performance) [13]; this in contrast to paper-and-pencil examination, in which calculating performance scores and reporting might take hours for the examiner. Moreover, administration and scoring demands are minimized for the examiner and no special training is needed. Last, some computerized batteries are flexible in terms of the presentation of testing material, as the items or their difficulty level can be adapted to the participant's performance level in order to avoid floor or ceiling effects [9]. On the other hand, most well-known computerized batteries [i.e., the *Test of Attentional Performance-Revised* **(**TAP-R)] [14] and even some newly developed (i.e., Dalhousie Computerized Attention Battery) [15] have the main disadvantage of presenting testing material in 2D form. Such laboratory-type material has been regarded by other researchers as less motivating for the examinees [16]. Finally, most attention tests are based on complicated instructions, either presented in visual form or requiring written responses from the examinee. The latter makes attention assessment arduous for clinical populations experiencing reading or writing difficulties.

As regards Greece, there is scarcity in computerized tests or batteries assessing attentional abilities. Despite the fact that there have been made attempts to standardize comprehensive attention tests, such as the Test of Everyday Attention for Children (TEA-Ch) [17, 2] or specific tests such as the Color Trails Tests [18], these attempts concern traditional paper-and-pencil tests and not computerized batteries for adults.

Therefore, our aim was to develop a battery in a 3D environment for the assessment of attention in adults, in order to make the testing material as realistic as possible. Even though 3D environments are used in neuropsychological rehabilitation [19], to our knowledge it is the first time that such material is being used for assessment purposes.

2. Methods

2.1 Participants

Fifty healthy adults (N = 26 females) aged from 18 to 62 years old (mean age = 36.9 years, SD = 11.93 years) volunteered to participate. Prior to the assessment, participants were interviewed regarding their medical history. Those reporting a history of a neurological or psychiatric disorder, or other medical condition that affects the central nervous system, were excluded from the study.

2.2 Material

The test battery comprises four subtests assessing selective attention, sustained attention, divided attention and shift of attention, all using 3D scenes and objects. A brief description of the subtests follows.

2.2.1 Selective attention: The Supermarket subtest

This subtest assesses the participant's ability to actively scan the presented visual field and search for a specific target-object. A 3D supermarket aisle stacked with items of daily use such as plates, toothbrushes, handbags and televisions are presented on the right and left sides of the screen. The participant uses the computer mouse to move through the aisle, while detecting with a mouse click the target stimulus (i.e., a particular television among others). If the participant chooses the correct product, it is removed from the aisle and the answer is recorded as correct, otherwise the item becomes lighter in color and remains in the aisle (and is recorded as an error). If the participant fails to select a target-product, this is recorded as an omission error. In order to not tap the examinee's working memory, the target stimulus remains on the upper side of the screen during the task. The aim of the test is for the examinee to detect all target items as quickly as possible, while avoiding errors.

The test has 6 levels and the participants proceed to the next level when they think that they have found all the objects of the particular level. The total number of objects is 351 and the targets are 83. Performance parameters obtained from the test are: correct hits, commission errors, and omissions, mean, median, and standard deviation of completion time for each level and for all the levels combined.

2.2.2 Sustained attention: The Car Driving subtest

The second test is a sustained attention task designed to assess ability to maintain attention to visually presented stimuli during a driving task. The examinee must stay alert in order to respond to sudden car brakes, as happens commonly in everyday life. More specifically, the computer navigates a car for the examinee, which is following a second car in front on the first one. The examinee must respond to the brakes (red lights) of the car ahead by pressing a key (the Spacebar) as quickly as possible. If the individual fails to press the spacebar within the time frame given (5 seconds), the car will crash into the car in front of it and the event will be registered as an omission error. In the event of a crash, the test continues and further crashes should be avoided. If the participant presses the Spacebar button although the car ahead has not braked, then the warning message: "Do not press the brake" appears on the monitor screen, and the response is recorded as an error (false alarm).

The aim of the test is to avoid the crashes by braking as soon as possible. The total test duration is approximately 3 minutes, so the examinee must remain focused. Performance parame-

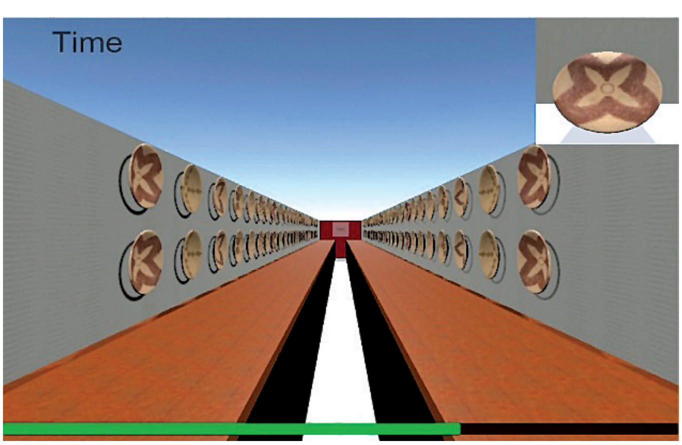

Figure1. Scene from the Supermaket subtest

Figure2. Scene from the Car driving subtest

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ters measured are: correct hits, errors, omissions, mean, and median and standard deviation of brake reaction time (RT).

2.2.3 Divided attention: The Car Driving While Listening to Music subtest

In this subtest the examinee is required to focus simultaneously on two different tasks, one visual and one auditory, and react, by key presses. The visual part consists of the driving task that was performed in the previously described subtest, where the examinee must notice the brake lights of the car ahead and brake in order to avoid a crash. The acoustic task includes listening to different songs on the radio, with the requirement of detecting the songs performed by female singers and respond by pressing the indicated key. Thus, examinees must listen carefully to the songs and react as quickly as possible with a key press (correct responses). Responding to male singers, sounds of radio frequencies or instrumental pieces is considered incorrect (false alarm errors). The total duration of the task is 10 minutes. Performance parameters in this task are calculated for both the auditory (press a particular key for detection of female singer) and the visual (press another key to brake) responses. Performance parameters are: correct audio presses, erroneous audio presses, omissions, and mean, median and standard deviation of audio reaction time on the audio stimuli, correct presses within the breaktime, erroneous brake presses (when not needed to brake), missed presses (delayed responses), mean, median and standard deviation brake reaction times.

2.2.4 Shift of attention: The Sports Watching subtest

This shifting attention subtest assesses one's ability to switch attentional focus by alternating between two different tasks. The subtest depicts a café in which the examinee is apparently watching sports on a TV screen. He/she is instructed to press as quickly as possible two distinct keys, the right key in response to long jump scenes and the left key in response to high jump scenes. Thus, the examinee must focus on the athlete when he/she makes the jump and to press the proper key as quickly as possible. If the participant presses the key before the athlete initiates the jump, or after completing it, this

Figure3. Scene from the Sports Watching subtest

is considered an error. An error of omission would be if the examinee fails to press the proper key and a false alarm error would be if he/she presses the opposite key. Performance parameters obtained from this subtest include: correct hits, commission errors, false alarm errors, omissions, mean, and median and standard deviation of reaction times.

2.2.5 The Usability Questionnaire

The Usability Questionnaire was developed by the authors in order to assess the usability of CBAAD. More specifically, our pilot sample was asked to report on 13 questions describing their experience with CBBAD. Assessing the usability of a newly developed computerized tool constitutes a formal and obligatory part of the development procedure. The latter was assumed to help the developers to adjust or modify the battery if needed according to the participants' reporting. Instructions of the questionnaire were as follows: *"Please fill out this questionnaire regarding the usability of the battery you were assessed previously. You are kindly requested to carefully read the questions and circle the response that suits better your own opinion. Your answers will be very helpful to us in order to improve the battery. It will take you a few minutes to complete the questionnaire. Responses are anonymous and confidential".*

2.3 Procedure

Participants were tested individually at a place that was convenient to them. We obtained their written consent to participate in the study and filled out a demographic questionnaire recording age, gender, education, profession and health problems. Distance between the lap top and the examinee was kept for all cases at 40 inches to reduce eyestrain and to ensure that the environment met the prerequisite for obtaining best performance. After the administration of CBAAD, individuals were asked to complete the questionnaire reporting on the usability of the battery.

3. Results

3.1 Descriptive Statistics

As can be seen from the descriptive statistics displayed on Tables 1-4, sample's performance on CBAAD subtest parameters was within the expected range. More specifically, CBAAD was primarily developed for assessing neurological or psychiatric patients of a wide age range exhibiting severe attention disorders. Thus, it can be easily understood that subtests will not cause any difficulty in healthy adults to perform. This assumption was confirmed by the descriptive statistics displayed by our sample. More specifically, observed error rates were in all

Table 1. Descriptive statistics (mean, standard deviation, minimum and maximum) of the sample's performance on the Supermarket subtest

The Supermarket subtest (selective attention)							
	Correct	Errors	Omissions	Mean tot dur (sec)	Median tot dur (sec)	Std tot dur (sec)	Tot dur (sec)
Mean	81.24	2.96	1.76	48.96	46.49	13.31	293.74
Std.	2.87	3.71	2.87	14.36	12.87	8.99	86.17
Min	67	0	0	21.58	22.16	3.99	129.50
Max	83	16	16	85.25	82.89	49.08	511.53
Note: Std = standard deviation, Min =minimum, Max = maximum, tot dur = total duration of the test, sec = seconds, RT =response time							

Table 2. Descriptive statistics (mean, standard deviation, minimum and maximum) of the sample's performance on the Car Driving subtest

The Car Driving subtest (sustained attention)						
	Correct	Errors	Omissions	Mean RT (msec)	Median RT (msec)	Std RT (mesc)
Mean	5.98	.18	.02	587.70	523.74	.21
Std	.14	.53	.14	139.12	111.11	.17
Min	5	0	0	414.36	366.18	.06
Max	6	3	1	1103.25	958.91	.70
Note: Std = standard deviation, Min =minimum, Max = maximum, msec = milliseconds, RT = response time						

Table 3. Descriptive statistics (mean, standard deviation, minimum and maximum) of the sample's performance on the Car Driving while Listening to Music subtest

The Car Driving While Listening to Music subtest (divided attention)						
VISUAL TASK	Correct	Errors	Omissions	Mean RT (msec)	Median RT (msec)	Std RT (mesc)
Mean	14.94	.86	.08	577.32	546.32	.15
Std	.24	1.14	.27	73.51	65.31	.06
Min	14	0	0	442.67	416.87	.06
Max	15	5	1	738.91	733.80	.31
AUDIO TASK	Corrects	Errors	Omissions	Mean RT (msec)	Median RT (msec)	Std RT (mesc)
Mean	8.64	.66	.26	1689.61	1203.76	1.45
Std	.60	.82	.49	1041.08	491.11	1.91
Min	7	0	0	700.48	650.39	.12
Max	9	4	2	5671.65	3199.28	10.11
Note: Std = standard deviation, Min =minimum, Max = maximum, msec = milliseconds, RT = response time						

Table 4. Descriptive statistics (mean, standard deviation, minimum and maximum) of the sample's performance on the Car Driving while Listening to Music subtest

The Sports Watching subtest (shift of attention)							
	Corrects	Errors	False Alarm Errors	Omissions	Mean RT (msec)	Median RT (msec)	Std RT (mesc)
Mean	28.76	.74	.48	.02	1153.03	1066.88	.27
Std	1.41	1.01	.95	.14	12.42	1.72	.02
Min	25	0	0	0	1091.31	1064.10	.16
Max	30	4	5	1	1174.95	1074.95	.29
Note: Std = standard deviation, Min =minimum, Max = maximum, msec = milliseconds, RT = response time							

subtests low, with no significant variation. However, the sample tends to make more errors at the Supermarket subtest. In contrast to the accuracy indices (corrects, errors, false alarms, omissions), speed of performance indices (mean RT, median RT, std RT, total duration) showed a higher range in the millisecond/second level.

3.2. Reports on the Usability Questionnaire

Results showed that nearly all participants understood perfectly the CBAAD instructions on each subtest (86%) and considered it as a pure attention task (84% answered very much). As regards the level of task difficulty, the Supermarket was the less easiest of all subtests (*mean* = 3.54), then follows the double task of Car Driving while Listening to music (*mean* = 3.80), the Sports Watching Subtest (*mean* = 4.24) and finally the Car Driving Subtest was the easiest of all (4.82 and 84% of the sample found it very easy). It seems that participants' subjective experience is line with their actual performance, as they rated as less easy the selective attention subtest on which they made more errors, as mentioned above. Generally, it seemed that individuals' experience with CBAAD was rated as very pleasant (*mean* = 4.58). Thus, they would easily recommend their friends to take part at an assessment with CBAAD (*mean* = 4.12). Moreover, participants did not believe that the level of prior computer knowledge (74% reported not at all to a little) or driving experience (80%) affected their performance on the respective CBAAD subtests. Finally, the whole assessment procedure seemed not to have tired or discomforted the sample (66% referred no to only a little) and they would agree to undertake the examination after a while (82% much to very much).

4. Discussion

In the present study we described the performance and reactions of a Greek pilot sample, and recorded their opinions regarding the utility of the CBAAD, a newly developed tool for the comprehensive assessment of attention in a 3D environment. As it is the first time that a neuropsychological assess-

Table 5. Frequency percentages, mean and standard deviation of the sample's responses on the Usability Questionnaire

	Questions	not at all	a little	rather	much	very much	mean	std
		1	2	3	4	5		
1.	Was the assessment a pleasant experience to you?	-	-	8%	26%	66%	4.58	0.64
2.	How much do you think that this battery assess attention?	-	-	-	16%	84%	4.84	0.37
3.	How easy was the supermarket subtest?	-	8%	44%	34%	14%	3.54	0.83
4.	How easy was the driving subtest?	-	-	2%	14%	84%	4.82	0.44
5.	How easy was the driving while listening to music subtest?	-	14%	26%	26%	34%	3.80	1.07
6.	How easy was the sports watching subtest?	-	-	10%	56%	34%	4.24	0.63
7.	Do you think it took very long to complete the whole battery?	6%	60%	30%	4%	-	2.32	0.65
8.	To which degree do you think that performance on the battery relates to your level of computer knowledge?	34%	40%	24%	2%	-	1.94	0.82
9.	Were the instructions of the subtests easy to understand?	86%	14%	-	-	-	1.14	0.35
10.	How much willing would you be to repeat in advance the whole assessment with this battery if needed?	-	-	18%	72%	10%	3.92	0.53
11.	How strongly would you recommend to a friend to participate in an assessment with thus battery?	-	-	20%	48%	32%	4.12	0.72
12	How well would a plus 70-year old participant respond to this battery?	2%	28%	44%	22%	4%	2.98	0.87
13.	To what degree do you believe that your performance on the two car driving subtests is influenced by your car driving ability?	80%	16%	4%	-	-	1.24	0.52

ment tool is implemented in 3D environment, results of this pilot study are essential for the CBAAD developers in order to optimize the battery to meet the assessment goals.

It has to be mentioned that the CBAAD was developed with the intention of measuring attention deficits in clinical (neurological or psychiatric) populations. Thus, it is expected to be completed easily by healthy adults. The results from the descriptive statistics regarding the accuracy indices (errors, omissions or false alarm errors) showed that our sample scored relatively high in nearly all the subtests. Speed of performance indices, in contrast, present more variability and could, therefore, be considered as more indicative of healthy adult performance. Reaction time (mean, median, standard deviation) has also been considered in previous research as a more informative index in computerized attention tests than the accuracy scores [12, 20]. An alternative index proposed instead of the above is the calculation of the speed-accuracy tradeoff. The latter is suggested to correct the examinee's performance according to his/her preferred test strategy (favoring accuracy over speed or the opposite) [21]. The speed-accuracy tradeoff is intended to be included as an extra performance parameter as soon as the CBAAD is upgraded and optimized. Nevertheless, most errors occurred in the Supermarket subtest. This selective attention test resembles in its logic the Trail Making Test [4], as it assesses visual search speed, scanning, speed of processing and mental flexibility. Besides that, it is more demanding for the participants, because it requires scrolling the mouse to move on the corridor of the supermarket and a motor reaction (clicking the computer mouse) in order to select the target-products. It is the only CBAAD subtest for which a computer mouse is used, since responding on the rest of the subtests requires only key-button presses. In a prospective psychometric study, it would be interesting to measure the convergent validity between the CBAAD Supermarket subtest and the Trail Making Test.

As concerns its utility, CBAAD appears to be a user-friendly computer environment and testing material appears also very pleasant and appealing to our sample. Tools implemented in 3D environments have the ability to motivate the participants to perform, as they resemble real-life situations more than do traditional 2D experimental tests [16, 19]. Because of this pleasant experience, they stated that they would recommend to their friends to participate in a test session with the CBAAD or would agree to being reassessed themselves with the CBAAD. Moreover, we noted that our sample was quite aware of their performance on the CBAAD. More specifically, even though they rated all the subtests as relatively easy, they referred to the Supermarket subtest as being the least easy task. This result is in line with their actual performance on the specific subtest, which was lower (they made more errors) than in the other subtests. Finally, another advantage of the battery is that participants considered it as a pure attention measure. The latter gives us a preliminary sense that the CBAAD would demonstrate a high face validity in future studies. However, the participants' claim that the CBAAD is associated with minimized requirements regarding computer or driving skills remains to be confirmed in a study examining whether the level of (computer or driving) experience affects performance on CBAAD subtests.

5. Conclusions

The preliminary findings of this pilot study suggest that we met our goals regarding the implementation of the CBAAD. This test was perceived as a motivating, pleasant, and time-preserving attention battery resembling real-life situations. Moreover, the testing material is presented in audiovisual form, thus, presumably bypassing potential assessment difficulties due to written comprehension or production impairment with clinical population. However, those findings remain to be confirmed by a larger scale study with a larger sample. Obtaining normative data would also be important so as to enable interpretation of performance of both healthy and clinical samples. Finally, the evaluation of the validity, reliability and diagnostic utility of the CBAAD is our next step for future plans concerning our new assessment tool.

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