A new Virtual Reality tool (Nesplora Aquarium) for assessing attention and working memory in adults: a normative study

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A new Virtual Reality tool (Nesplora Aquarium) for assessing attention and working memory in adults: a normative study

Attentional and working memory processes undergo significant changes during different stages of development. However, currently there are not many Continuous Performance tools based on Virtual Reality (VR) for measuring attentional capacity in adults. The present study aimed to obtain normative data for the Nesplora Aquarium VR test in a Spanish population, looking at sex and age variables. In addition, this study also aimed to analyze the psychometric properties of the tool such as scale, internal consistency and item difficulty and discrimination indices. A total of 1469 participants from different regions of Spain (57.6% female) with ages ranging from 16 to 90 years old took part in this normative study. Nesplora Aquarium was developed in order to support clinicians in the assessment of attentional processes and WM in adults over 16 years old. It is an 18-minute individual test performed through a virtual reality (VR) system. The system provides better visual and auditory immersion in the task than computerized CPTs. This study revealed that the new VR tool, designed to measure adult attention and working memory levels, exhibited good psychometric properties related to reliability and internal consistency. In addition, item difficulty and discrimination values were also acceptable.

Keywords: adults; diagnosis; virtual reality; continuous performance test; attention.

Introduction

Age-specific phases concerning development of attentional processes

Attention is one of the most basic cognitive functions and its proper working is essential for the performance of other more complex functions. It is impossible to study processes such as perception and memory without considering attentional processes (Amador, Forns & Kirchner, 2006). In the normal ageing process, a large number of neuropsychological and cognitive variables are negatively related to increased age (Craik & Salthouse, 2008; Salthouse, 2009) and performance in attention-requiring tasks is substantially lower (Salthouse, 2012), which often has an impact on quality of life. Sustained attention appears to be significantly poorer at later ages than in young people (McAvinue, 2012). Several authors have identified an age-related reduction of attentional processes (and processing speed) as one aspect of the impairments of old age, although the vast majority of cognitive functions also suffer a general slowdown affecting the capacity to simultaneously process information from different sources (Salthouse, 2009). Furthermore, cognitive inhibition also seems to be damaged at more advanced ages (Villar, 2003). Working Memory (WM) is a memory system that has direct links to attentional control (Baddeley & Hitch, 1974) which can also be affected by aging, such as the difficulty blocking interference by irrelevant information in certain tests that has been observed in older groups. This lack of inhibitory control can in turn lead to incorrect or inappropriate responses in particular contexts or tasks. Attention switching is a cognitive mechanism for switching the focus of attention, it enables flexibility in the selection of information. This is another cognitive aspect which affects WM development over a lifetime (Smid, Martens, de Witte, & Bruggeman, 2013).

Various findings have been published about the importance of adolescence as a critical stage in the development of attentional processes. It has been reported that variables relating to visual attentional capacity and to the efficiency of top-down attentional selection all show a developmental peak during adolescence, thus implying an inevitable decline thereafter (McAvinue et al., 2012). The variables related to sustained attention seem to follow inverted U-shaped, with poor performance in childhood (age 12) and adolescence, a plateau during young and middle adulthood, and a performance deterioration in older adulthood in accordance with a curvilinear relationship with age. Nevertheless, the largest declines have been observed in the variables related to visual processing capacity and visual short-term memory capacity.

Both variables also peak during teenage years, followed by a linear decline through succeeding decades. In a recent study with an unprecedented sample of 10,430 participants between 10-70 years old (Fortenbaugh et al., 2016), it was concluded that there is a rapid development in sustained attention ability and reaction time variability (decrease in response variability) between the ages of 10 - 16, then a period of relative stability until ~43 years of age, when the performance starts to decline. According to the reaction time mean, the breakpoints appear at around 15 and 58.5 years old.

Therefore, it can be concluded that attentional processes undergo significant changes during different stages of development, some of which could result in an impairment. Hence the importance of the early diagnosis of attentional deficiencies, as the problem can then be tackled before the impairment becomes greater and impacts the individual's welfare in more detrimental ways.

Clinical conditions affecting attentional processes

There are several different clinical conditions in which attentional processes are particularly affected. First of all, there is ADHD (Attention Deficit Hyperactivity Disorder), which (as the name indicates) is a neuro-developmental disorder that is primarily characterized by attention disability, an impulsive behavioral lifestyle, hyperactivity and fragility of adaptive mechanisms for the environment (APA, 2013). This disorder persists during adulthood in two thirds of the diagnosed cases in childhood, with a prevalence rate of between 2-4% (Asherson, Manor, & Huss, 2014). ADHD symptoms, if not tackled in time, have the potential to result in social disadvantage and exclusion, limited employment opportunities and the adoption of high-risk behaviors, which may end up being the perfect scenario for subsequent legal problems (Rodríguez et al., 2016) as well as for problems at work, in personal relationships or in the family. While hyperactivity and impulsivity levels tend to diminish considerably, inattention symptoms remain over the years and these are what have more negative impacts on those affected (Hassiotis et al., 2011; McCarthy et al, 2016; Young et al., 2011). Moreover, between 70 and 75% of the adults with ADHD symptoms present at least one psychiatric comorbid diagnosis (Miranda, Berenguer, Colomer, & Roselló, 2014), with the most common being behavioral disorders, depression, anxiety and borderline personality disorder, although high levels of ADHD in adulthood are also related to psychotic disorders (Marwaha et al., 2015). These associations between attentional impairment and psychiatric disorders call for attention to the joint effect that both –comorbid- conditions may have on the individual with ADHD. It has been demonstrated that the presence of an associated disorder is related to a worse progression of ADHD symptoms. This association can also predict long-term outcomes in school-age children (Cherkasova, Sulla, Dalena, Pondé, & Hechtman, 2013; Levy, Traicu, Iyer, Malla, & Joober, 2015). Thus, the need for an accurate, valid, reliable diagnosis of ADHD.

However, it is important to highlight that ADHD is not the only disorder related to low attentional levels. In depressive disorders attention plays a particular role because its impairment is associated with inhibitory deficits (Disner, Beevers, Haigh, & Beck, 2011). There is evidence that people with depression show increased attention for negative stimuli and reduced attention for positive stimuli (Kellough, Beevers, Ellis, & Wells, 2008). Moreover, according to other authors who observed selective attention related disturbance, subjects also demonstrated worse test execution in CPTs (Continuous Performance Tests) (Bredemeier et al., 2012) where the stimuli were neutral instead of emotional. Sustained attention is another attentional subtype impaired in depression, along with executive function attention (Talarowska, Zajączkowska, & Galecki, 2015). Anxiety disorders are also related to attentional deficits. Recent studies

(Ajilchi & Nejati, 2017) reaffirm that people suffering from anxiety exhibit worse performance in comparison with healthy subjects. According to the Processing Efficiency theory from Eysenck and Calvo (1992), supported by various studies, this collective presents higher distractibility in tasks which require a load on the WM (Najmi, Amir, Frosio, & Ayers, 2015).

Furthermore, psychotic disorders tend to present a general neuropsychological impairment in which the most robust findings belong to attention deficits (Shen et al., 2014). In fact, WM and processing speed are other functions where major impairment can be seen, even before the disease develops (Mirzakhanian, Singh, Seeber, Shafer, & Cadenhead, 2013), so the possibility of discriminating between healthy individuals and people at risk could be considered. Sustained attention is already significantly affected in the prodromal stage (Mirzakhanian et al., 2013), especially visual attention (Verleger, Talamo, Simmer, Smigasiewicz, & Lence, 2013). Selective attention, together with divided attention, are not immune from developing a disorder. It is noted that omission errors seem to be associated with people with schizophrenia and subjects at risk of suffering from a psychotic disorder (Shen et al., 2014). Moreover, this group demonstrates worse performance in tasks which require the involvement of WM (Tan et al., 2000; Subramaniam et al., 2014).

In addition to ADHD and psychiatric disorders, attentional process deficits are also commonly associated with other clinical conditions that should be considered. Patients with autism syndrome show more attention deficit symptoms (Di Martino et al., 2013). Moreover, when gender differences in adult patients with autism were analysed, girls were rated as having more social problems, attention problems and thought problems (Hartley & Sikora, 2009). Similarly, learning difficulties (particularly Reading, Writing and Mathematical Learning Disabilities) are also commonly associated with attentional problems. Patients who were diagnosed with learning disabilities frequently referred to inattention symptoms (Solan, Larson, Shelley-Tremblay, Ficarra, & Silverman, 2001). There are a huge variety of clinical conditions which show an attentional deficit that do not improve in adulthood. For this reason, it is very important to have objective assessment tools for detecting attentional problems in adult patients in order to prevent further deterioration.

Continuous Performance Test and attention assessment

Among the most widely known methods and techniques for the assessment of inattention problems it is worth noting the influence of questionnaires which allow the assessment of different components related to attention and impulsiveness according to information provided by individual and external informants (García, González-Castro, Areces, Cueli, & Rodríguez, 2014). These questionnaires are based on the identification of a series of behaviors that may be indicative of deficits in those components. While there are many questionnaires for measuring inattention problems in child populations, there are far fewer for adults. The Wender Utah Rating Scale (WURS) (Ward, Wender, & Reimherr, 1993), and the Adult ADHD Self-Report Scale (ASRS) (Kessler et al., 2005) are the most widely used questionnaires (Ramos-Quiroga et al., 2012). However, the use of these instruments as the only measure of evaluation has certain limitations, such as the possible subjectivity of the informant (García et al., 2014). This makes them a good complement to the assessment process, but not the only instrument that should be used.

Another type of widely used test for the assessment of attentional problems and inhibitory control are the instruments based on an individual's execution, with the Continuous Performance Test (CPT) being the most researched. CPTs are objective tools for assessing attention, response speed, inhibition capacity and distractibility

(Meneres, Delgado, Aires, & Moreno, 2015). CPTs consist of a test paradigm where visual and/or auditory stimuli are presented and the participant is required to respond to certain stimuli. The first CPTs were developed by Rosvold, Mirsky, Sarason, Bransome, & Beck (1956) to study vigilance in adults with acquired brain damage (Díaz-Orueta, 2017) and parts of CPTs have been applied in clinical and research settings in studies related to attention (Raz, Bar-Haim, Sadeh, & Dan, 2014), sleep restriction (Van Enkhuizen et al., 2014) and clinical conditions such as schizophrenia (Young et al., 2011) and bipolar disorder (Robinson, 2013). CPTs have commonly been used in ADHD (Huang-Pollock, Karalunas, Tam y Moore, 2012; Moreno, Delgado, Aires, & Meneres, 2013; Zulueta, Iriarte, Orueta, & Climent, 2013). Nowadays, CPTs are the most widely used measures for assessing attention and processing speed and they can be considered a group of different paradigms for evaluating inhibition control as well (Díaz-Orueta, 2017). Currently these tests are also used to evaluate the efficacy of diverse interventions and are very sensitive for the monitoring of treatment effects such as the pharmacological treatment of ADHD (Mejías, Redondo, Fernández, & Díaz-Orueta, 2016).

Different presentations of CPTs have been developed over time, changing stimulus presentation (auditory/visual), stimuli type (numbers, letters, geometrical figures, spoken words, sinusoidal sounds, etc.), frequencies and duration of presentation, as well as instructions provided to the subject (Albrecht, Sandersleben, Wiedmann, & Rotherberger, 2015).

Virtual Reality (VR) provides new, interesting possibilities for neuropsychological assessment (Díaz-Orueta, 2017). Research by Rizzo, Bowerly, Buckwalter, Klimchuk, Mitura, & Parsons (2006) created the Virtual Classroom, a head-mounted display (HMD) VR system for the assessment and possible rehabilitation of attention processes. VR is a reliable measure for assessing ADHD children's attentional processes. Climent & Banterla (2011) developed a Virtual Reality classroom environment called Nesplora AULA (which means "classroom" in Spanish), it offers two different CPT paradigms (no_go and go) mixing auditory and visual stimuli and integrating natural distractors in the environment. AULA is now a normative reference tool for assessing attention in children aged between 6 and 16. This test provides more detailed and accurate information than the traditional continuous performance tests. In a recent study, Díaz-Orueta et al. (2014) found that the test was able to discriminate between children with ADHD – even if they were receiving medication- and those without, thanks to the different indicators offered by the test. More recent studies also support the utility of this tool in the diagnosis of ADHD in a Spanish sample of children and adolescents (Areces, Rodríguez, García, Cueli, & González-Castro, 2016).

The integration of neuropsychological measures based on solid paradigms in VR environments on the one hand provides better internal validity using total environment control during the testing process, and on the other hand gives better ecological validity, emulating situations similar to real life, and using three dimensional stimuli as part of the task. VR also helps to improve immersion in the task, collecting information about performance even if the patient is not looking at the attentional focus. However, currently there are no similar tools for assessing attentional problems in the adult population. It is important to design and analyze the effectiveness of a new VR test for measuring attentional capacity in adults.

The main objective of this study was to obtain normative data for the Nesplora Aquarium VR test in a Spanish population, looking at sex and age variables. In addition, this study also aims to analyze the psychometric properties of the tool, such as scale, internal consistency and item difficulty and discrimination indices. Nesplora Aquarium is a VR test designed to assess attentional processes and WM ability in adults over 16 years old. This tool aims to characterize the attentional profile in adults without cognitive impairment, as well as in different conditions such as ADHD, depression, anxiety, psychotic disorders etc. Although cognitive performance is not part of the diagnostic criteria, this type of measure may be an interesting complement for the understanding of the disease (Iriarte, Díaz-Orueta, Cueto, Irazustabarrena, Banterla & Climent, 2012).

Materials and Methods

Participants

The normative sample was composed of 1469 participants from different regions of Spain (57.6% female) with ages ranging from 16 to 90 years old (M = 44.81, SD= ±20.89). The test was administered in Spanish, the subjects' native language. All cases in the study were native Spanish speakers.

In order to collect a representative sample of the population, recruitment was performed by different institutions such as professional training centers, companies, elderly communities, cultural centers and universities (such as the University of Oviedo, Autonomous University of Barcelona), as well as different collaborators. The sample was collected in various regions, the Basque Country, Catalonia, Galicia, Asturias, and Castile and León in order to minimize cultural bias. Participants' levels of educational attainment were also recorded in the study in order to get a proportional sample of each group.

Prior to the study, in order to comply with ethical guidelines, signed informed consent forms were obtained from participants or from their parents or guardians (if they were under 18). The Ethical Committee approved the study and the data collection protocol for Research with Human Beings - CEISH, from the University of the Basque Country. The study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Procedure

The administration of Nesplora Aquarium, and therefore the collection of normative data, was carried out by expert evaluators, psychologists from Nesplora and undergraduate students in their final years of Psychology degrees at local universities. They were properly trained on the standardized procedures for the administration of the test.

Assessment Tool

Nesplora Aquarium was developed by Nesplora-Technology and Behavior in order to support clinicians in the assessment of attentional processes and WM in adults over 16 years old. It is an individual, computerized test which lasts for around 18 minutes and is performed through a virtual reality (VR) system composed of a pair of goggles, a mobile phone, headphones and a button. The system provides better visual and auditory immersion in the task than computerized CPTs.

The tasks are based on CPT paradigms, but performed, as the name suggests, in a virtual aquarium where the person has to press a button whenever they see or hear certain fish or words, depending on the instruction. Several distracting elements in the environment are presented during the tasks in order to measure their effect on subjects' motor activity and distractibility.

Rather than following a single model or theory, the test incorporates several scientific concepts. As a result, Nesplora Aquarium is an integration of diverse models which make it a broad tool. The theoretical model from Sohlberg and Mateer (Mateer &

Sohlberg, 2001; Sohlberg and Mateer, 1987) was a significant reference for the construction of this test due to its contribution to the understanding of attentional processes. In addition, the model from Baddeley and Hitch (1974) was useful for designing the dual execution tasks included in Nesplora Aquarium.

The test is based on two CPT paradigms, which are considered reliable measures of sustained attention (Meneres, Delgado, Aires, & Moreno, 2015). Before the test tasks, the users perform a usability task and a learning task. This so that: (a) the participants can familiarize themselves with the type of tasks they will have to do later, and (b) the participants do not become overexcited or anxious by using this type of technology. The tasks are explained below.

(1) Usability task: So that the participant can get used to the virtual environment and have an opportunity to explore it and understand how the button works. The subject has to find and turn on four displays in the main room of the aquarium by putting a white dot seen in the centre of the frame over each display and pressing the button.

(2) Learning task training/Learning task: This task consists of an AX or 1-back type text. The button must be pressed whenever the person sees the Clownfish or hears the word "clownfish", if the previous fish or word had been Sturgeon. The learning task training has 20 items and the Learning task has 140 items. No neuropsychological evaluation data is produced from this task. The purpose of this first test is to train the participant and ensure they learn the stimuli.

(3) Dual execution - Xno training/Dual execution - Xno task: This is a Dual X_no or Dual No_go task. The person must press the button whenever a fish appears or a word is heard except when seeing the Clownfish or hearing the word "sturgeon", establishing a different target for visual and auditory channels.

Training for Task 2 is made up of 20 items and Task 2, 140 items. The execution of this task is geared towards measuring selective attention, sustained attention, inhibitory control and the Central Executive System due to its dual component. Nevertheless, Reaction Time (RT), and Variability of RT are also assessed.

(4) Dual execution + i - Xno training/Dual execution + i - Xno task: This is a Dual X_no or Dual No_go task with interference of the previous task due the inversion of the target stimuli. The participant must press the button whenever they see a fish or they hear a word except when seeing the Sturgeon or hearing the word "clownfish", establishing a different target for visual and auditory channels. Training for Task 3 comprises 20 items and Task 3, 140 items. The execution of this task is geared towards measuring selective attention, sustained attention, inhibitory control and the Central Executive System due to its dual components. Nevertheless, Reaction Time (RT), and Variability of RT are assessed as well. In addition, through the inversion of the target stimuli it is possible to evaluate the control of interference both by switching capacity (cost of task change) and perseveration errors.

The tests provide the following measures:

- Omission errors: These errors occur when the participant does not press the button on the target stimulus. These types of errors are interpreted as a measure of the level of alertness, as well as the ability to selectively pay attention to the target stimulus. A standardized score above 60 points indicates inattention problems.
- Commission errors: These occur when the participant presses the button on a non-target stimulus. These errors represent an index of impulsivity or ability to

inhibit the response involved in selective attention processes. A standardized score above 60 points indicates impulsive behaviour.

- Reaction time (RT): This measure indicates the average time elapsed from the presentation of the target stimulus until the button is pressed to respond. This measure reflects the participant's response time. A standardized score above 60 is related to a low processing speed.
- Variability of RT: Indicates the consistency of reaction time in correct answers. This measure is indicative of changes in sustained attention or fatigability during the task. A standardized score above 60 points indicates fluctuation of attention during the test.
- Motor activity: This variable indicates the amount of head movement during the test, measured using the virtual reality glasses. This measure could be indicative of motor hyperactivity during the test. A standardized score above 60 points indicates hyperactive problems.
- Discrepancy of correct answers between blocks: This score is obtained by comparing the hits in the first half of the task with those from the second half of the task. This gives additional information about the consistency of performance through each task. A standardized score above 60 points indicates little consistency in the performance of each task or fatigability during the tasks.
- Mean RT (reaction time)-commissions: This indicates the average time from the stimulus appearing until the button is pressed in incorrect presses (commissions). This measure gives us complementary information on commission errors. In this variable, a high score (low reaction time) is related to greater impulsivity and / or hyperactivity; while a low score (high reaction time) is considered a secondary measure of inattention (Halperin, Wolf, Greenblatt, &

Young, 1991). Therefore, this variable gives us explanatory information about the cause of commission errors.

- Switching: The score shows the difference between the number of hits in the last part of a task and the number of hits in the beginning of the next task. This variable provides information on the participant's ability to adapt to the paradigm shift without their execution suffering. A standardized score above 60 points is a sign of difficulties changing tasks or switching.
- Switching RT- correct answers: This variable shows the difference between the reaction time of the hits in the last part of a task with the reaction time of the hits in the beginning of the next task. It provides information about the participant's ability to adapt to the paradigm change without their reaction speed suffering. A standardized score above 60 points is a sign of switching difficulties tasks.
- Working Memory: This variable is calculated from the correct items of the dual execution task and the dual execution task + i. These tasks involve different target stimuli for the visual and auditory channels. The parallel processing of both sensory modalities defines these exercises as dual execution tasks. These types of tasks are used for the evaluation of working memory. This index is interpreted inversely to the previous variables mentioned; in this sense, a standardized score of more than 60 points indicates a good performance in the variable because it is based on the number of successes.
- Perseverance: This type of error occurs in the dual execution task with interference when responding to the task following the instructions of the previous task, in other words. This variable provides a measure of control of the participant's retroactive. A standardized score above 60 points is interpreted as a deficit in cognitive flexibility.

Statistical analyses

The following analyses were carried out using a sample of 1469 subjects aged from 16 to 90 years old. However, the identification of the different age ranges seen in the execution of the test and the differences by sex were carried out with an initial sample of 903 subjects using analysis of variance. Since the variables were not normally distributed, the results of nonparametric analyses are presented below.

Differences in means by age were analysed using the Kruskall-Wallis test. Differences according to sex were analysed using the Mann-Whitney U Test. Scale reliability was examined using Cronbach's Alpha coefficient in multiple scales in order to show the main results of the dual tasks which make up the Nesplora Aquarium Test. Finally, difficulty and discrimination indexes from the two main test tasks were produced.

Results

Differences according to sex and age

The analysis of variance showed that there were three differentiated age groups in the sample according to the differences found in the scores. There were no statistically significant "intragroup" differences in the different variables based on the age but there were differences between the three groups. The first group ranged from 16 to 40 years old and is made up of 667 subjects (51.7% female; age M=25.5, SD=7.6), the second, aged from 41 to 60 consisted of 415 subjects (51.3% female; age M=49.4, SD=5.6). The third comprised 387 subjects aged from 61 to 90 (74.4% female; age mean=73.1, SD=7.4). Table 1 shows statistically significant differences based on age in all variables, except in the variable "head movements" which represents the motor activity of the participants.

The sample was also divided into two groups based on gender. In general terms, men had more correct answers in all tasks making up Aqua Nesplora. Women had fewer commission errors, while men had fewer omission errors.

[Table 1]

Table 2 shows statistically significant differences between men and women's performance in some of the variables analyzed.

[Table 2]

Reliability analysis of the scales

In general, the value of the alpha coefficient indicates high scale reliability and excellent internal consistency. The Alpha coefficient ranges from 0.83 to 0.99, and the main values for both dual tasks are 0,975 and 0,968 (Dual execution - Xno task; and Dual execution+i - Xno task, respectively).

Difficulty and Discrimination Index of Aqua Nesplora items

Table 3 shows the Difficulty and Discrimination Index of the items that make up the 2 evaluation tasks in the test. In general, these indices have acceptable values.

[Table 3]

Discussion

This study presented the first data obtained using the Nesplora Aquarium. In terms of the main objective of this research, the results show that the new VR tool, designed to measure adult attention and working memory levels, exhibited good psychometric properties related to reliability and internal consistency. In addition, item difficulty and discrimination values were also acceptable.

As indicated in previous studies (Gershon & Gershon, 2002; Yen, Yen, Chen, Tang, & Ko, 2009), the analysis of the scores in the different variables showed that there was a general pattern of gender differences. Men had more correct answers and fewer omission errors while women had fewer commission errors and less motor activity during the tasks. The findings from this sample showed that men performed better and presented more symptoms of impulsivity and hyperactivity (related to the number of commission errors and more head movements; while women showed more symptoms of inattention (related to the number of omission errors). If we look at age-related differences, the youngest group (16-40 years of age) demonstrated better performance in most variables (more correct answers, fewer omission and commission errors and less motor activity). These results are similar to those from previous neuroimaging studies which indicated that older adults manifested an extensive, complex pattern of age-related change in brain structure and function, including attentional processes (Cabeza, Nyberg, & Park, 2016) and the normal decline of cognitive abilities (Salthouse, 2009).

According to the findings from this normative study, Nesplora Aquarium could be included in the assessment protocols for the evaluation of attentional and working memory ability in adults. Currently, clinicians make the assessment using the data provided by unstructured interviews and observation scales, and more objective measures are needed which would complement the information collected by those subjective methods (Barkley, Murphy, & Fischer, 2010). The variables offered by Nesplora Aquarium also provide data with better ecological validity thanks to the nature of VR technology. The use of scales and information from interviews as the sole variables for the detection of attentional or working memory deficits has significant limitations which must be overcome. The most important limitation is the possible subjectivity of the informant (García et al., 2014). This means that the diagnostic process depends on professional experience, so it would be very useful to be able to make comparisons with objective variables to carry out a tighter assessment (Hoffman, Patterson, & Carrougher, 2000). This tool also makes it possible to carry out longitudinal studies in an adult population. The data could be used to check whether the differences between men and women are similar or not, depending on the age range.

Nesplora Aquarium has been shown to be effective for measuring different types of variables related to attention and working memory in an adult population. It could be used to complement data provided by scales and retrospective data based on a subject's childhood.

The results must be interpreted with the following limitations in mind, which may be addressed in future work. Firstly, it would be advisable to improve the evidence of validity of the instrument (Lane, 2014; Padilla & Benítez, 2014), and to apply the instrument in other countries to check whether the normative studies carried out in other countries exhibit similar data to this study. Similarly, it would also be interesting to gather longitudinal data which would allow us to check whether this tool could be used as an intervention tool.

Disclosure

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Gema Climent, Miguel Mejías, Amaia Aierbe, Marta Moreno, and Mari Feli González are employees of

the company Nesplora, Technology & Behavior, where the Nesplora Aquarium test was developed.

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Table 1. Differences in Nesplora Aquarium variables based on the age of the sample (Kruskall Wallis)

Variables	Group 16-40 M(SD)	Group 41-60 M(SD)	Group 61-90 M(SD)	$\chi^2_{(13)}$
Total correct Items	240.70 (33.89)	221.30 (46.34)	161.60 (37.34)	620.848***
Total omission Errors	23.18 (32.35)	43.70 (46.35)	99.37 (41.55)	545.414***
Total commission errors	11.34 (15.62)	14.95 (17.07)	19.64 (32.79)	281.281***
RT_correct answers	888.30 (72.92)	916.20 (82.25)	964.80 (134.00)	158.737***
RT_ commission errors	682.80 (131.10)	727.30 (185.50)	764.50 (198.70)	156.176***
SUM_head movements	0.23 (0.17)	0.24 (0.15)	0.27 (0.27)	0.110
Total omissions errors in visual channel	7.07 (12.29)	16.07 (21.47)	53.42 (28.37)	632.304***
Total omission errors in auditory channel	16.10 (22.67)	27.63 (32.14)	45.95 (31.13)	337.570***
Total commissions errors in visual channel	10.45 (6.21)	9.31 (7.07)	11.28 (9.10)	197.874***
Total commissions errors in auditory channel	5.70 (4.41)	5.64 (5.77)	7.71 (7.64)	115.298***
X-NOTask_ total correct items	122.8 (17.59)	111.8 (24.51)	80.89 (21.18)	563.376***
X-NOTask_ total omission errors	10.83 (16.93)	22.15 (24.38)	50.65 (22.61)	543.539***
X-NOTask_ total commission errors	6.33 (4.31)	6.08 (5.35)	8.46 (7.31)	58.299***
X-NOTask_RT_ correct answers	884.20 (80.95)	911.80 (94.99)	951.10 (157.90)	134.921***
X-NOTask_ RT_ commissions errors	641.70 (209.70)	657.50 (259.50)	686.70 (280.30)	42.158***
X-NOTask_ Errors when participants are looking at the target stimulus	7.32 (6.94)	12.20 (11.51)	31.34 (12.99)	629.684***
X-NOTask_SUM_ head movements	0.22	0.23	0.26	11384

	(0.19)	(0.15)	(0.28)	
X-NOTask _total omissions errors in visual channel	3.05 (6.47)	8.17 (10.97)	26.20 (14.66)	649.845***
X-NOTask _total omissions errors in auditory channel	7.77 (12.09)	13.98 (17.38)	24.45 (17.10)	347.007***
X-NOTask _total commissions errors in visual channel	4.28 (2.96)	4.02 (4.04)	5.165 (5.22)	41.431***
X-NOTask _total commissions errors in auditory channel	2.05 (2.35)	2.05 (3.04)	3.30 (4.16)	39.895***
I-X-NOTask_ total correct items	117.80 (18.04)	109.60 (24.01)	80.75 (18.93)	527.714***
I-X-NOTask_ total omission errors	12.35 (16.82)	21.54 (23.41)	48.73 (21.30)	509.871***
I-X-NOTask_ total commission errors	9.82 (6.05)	8.877 (6.87)	10.52 (8.14)	67.432***
I-X-NOTask_ RT_correct answers	888.80 (93.50)	918.7 (87.83)	977.60 (144.00)	212.642***
I-X-NOTask_ RT_commision errors	690.3 (172.40)	721.7 (225.80)	759.00 (267.30)	66.903***
I-X-NOTask_Errors when participants are looking at the target stimulus	10.18 (8.242)	13.16 (12.29)	33.31 (13.29)	568.977***
I-X-NOTask_SUM_ head movements	0.2612 (0.22)	0.26 (0.19)	0.26 (0.25)	15541
I-X-NOTask _ total omissions errors in visual channel	4.021 (6.98)	7.89 (11.51)	27.22 (15.49)	566.789***
I-X-NOTask _ total omissions errors in auditory channel	8.328 (11.37)	13.65 (15.75)	21.50 (15.61)	344.198***
I-X-NOTask _ total commissions errors in visual channel	6.169 (4.03)	5.29 (4.57)	6.11 (5.67)	88.177***
I-X-NOTask _ total commissions errors in auditory channel	3.652 (2.98)	3.58 (3.80)	4.41 (4.90)	31.660*
RT_correct answers in visual channel	748.9 (72.67)	806.50 (88.65)	799.40 (196.70)	158.606***
RT_correct answers in auditory channel	1009.00 (222.00)	956.60 (311.50)	1011.00 (286.50)	42.137***
XNOTask_Discrepancy in the number of hits between the two halves	0.54 (4.89)	0.53 (6.34)	0.32 (7.13)	82.624***
I-XNOTask_Discrepancy in the number of hits between the two halves	-0.99 (5.05)	-0.26 (5.47)	-0.16 (6.34)	33.648**
Total_discrepancy of correct answers	-0.22	-0.10	0.80	85.571***

	(3.22)	(3.67)	(4.04)	
Switching_correct answer	1.576 (4.50)	1.489 (5.14)	-0.66 (6.02)	87.557***
RT_switching_correct answer	278.00 (46.37)	555.9 (5.14)	-1254.00 (5998.00)	39.281***
Perseveration errors	14.89 (8.06)	17.05 (9.70)	26.17 (7.16)	426.965***

Note. N = Number; *M* = Mean; *SD* = Standard Deviation; SUM = Summation; RT = Response Time; X-NOTask = Dual execution - Xno task; I-X-NOTask = Inversion of the target stimuli in Dual execution – X-NOTask.

*p<.05. **p< .005. ***p< .001.

Table 2. Differences in Nesplora Aquarium variables based on the sex of the sample (Mann Whitney U Test)

Variables	Female M (SD)	Male M (SD)	Mann Whitney U
Total correct Items	210.2 (51.44)	220.2 (48.36)	145404.000 ***
Total omission Errors	53.78 (51.29)	42.26 (47.38)	139556.000 ***
Total commission errors	15.51 (22.87)	17.49 (21.40)	172.677.000
RT_correct answers	929.40 (99.16)	898.40 (98.02)	141194.000 ***
RT_ commission errors	723.30 (177.70)	708.20 (158.50)	154074.500 **
SUM_head movements	0.24 (0.20)	0.26 (0.19)	149275.500 ***
Total omissions errors in visual channel	25.22 (29.92)	16.99 (23.97)	135996.500 ***
Total omission errors in auditory channel	28.55 (30.16)	25.27 (30.59)	146417.500 ***
Total commissions errors in visual channel	9.79 (7.19)	11.17 (7.50)	170.547.500
Total commissions errors in auditory channel	6.18 (5.62)	6.32 (6.20)	166.808.500
X-NOTask_ total correct items	106.50 (27.53)	111.80 (25.57)	149184.500 ***
X-NOTask_ total omission errors	26.90 (27.15)	21.04 (24.83)	144640.000 ***
X-NOTask_ total commission errors	6.63 (5.67)	7.13 (5.55)	153894.500 **
X-NOTask_RT_ correct answers	921.80 (113.70)	892.70 (109.60)	143518.000 ***
X-NOTask_ RT_ commissions errors	664.00 (250.00)	650.10 (235.40)	173.659.500
X-NOTask_ Errors when participants are looking at the target stimulus	16.38 (15.02)	13.08 (12.75)	150688.500 ***
X-NOTask_SUM_ head movements	0.23 (0.21)	0.25 (0.21)	150985.000 ***

X-NOTask _total omissions errors in visual channel	12.12 (15.09)	8.36 (12.40)	143144.500 ***
X-NOTask _total omissions errors in auditory channel	14.78 (16.65)	12.67 (16.29)	148442.500 ***
X-NOTask _total commissions errors in visual channel	4.26 (3.99)	4.72 (4.00)	151771.500 ***
X-NOTask _total commissions errors in auditory channel	2.37 (3.01)	2.41 (3.32)	170.061.500
I-X-NOTask_ total correct items	103.80 (25.56)	108.40 (24.51)	151800.500 ***
I-X-NOTask_ total omission errors	26.88 (25.49)	21.22 (23.83)	142402.500 ***
I-X-NOTask_ total commission errors	9.34 (6.77)	10.36 (7.08)	151755.500 ***
I-X-NOTask_ RT_correct answers	933.00 (117.20)	903.60 (105.60)	144911.000 ***
I-X-NOTask_ RT_commision errors	720.10 (229.70)	714.30 (199.30)	165.391.500
I-X-NOTask_ Errors when participants are looking at the target stimulus	18.62 (15.53)	15.04 (13.04)	153521.500 **
I-X-NOTask_SUM_ head movements	0.24 (0.22)	0.28 (0.22)	143618.000 ***
I-X-NOTask _total omissions errors in visual channel	13.11 (15.79)	8.62 (12.54)	141469.500 ***
I-X-NOTask _total omissions errors in auditory channel	13.77 (14.66)	12.60 (15.08)	147192.000 ***
I-X-NOTask _total commissions errors in visual channel	5.52 (4.57)	6.44 (4.76)	147260.000 ***
I-X-NOTask _total commissions errors in auditory channel	3.81 (3.81)	3.91 (3.85)	164.378.500
RT_correct answers in visual channel	788.90 (136.20)	764.00 (104.00)	134407.500 ***
RT_correct answers in auditory channel	1003.00 (258.10)	984.60 (280.90)	164.611.500
XNOTask_Discrepancy in the number of hits between the two halves	1.55 (6.20)	0.83 (5.85)	154411.000 **
I-XNOTask_Discrepancy in the number of hits between the two halves	-1.84 (5.57)	1.40 (5.59)	157912.000 *
Total_discrepancy of correct answers	-0.14 (3.80)	-0.28 (3.43)	173.123.500

Switching_correct answer	0.84 (5.40)	1.15 (4.56)	167.421.000
Switching_correct answer	-117.20 (54.83)	58.94 (48.22)	173.350.000
Perseveration errors	19.04 (9.48)	17.75 (9.63)	157162.500 **

Note. N = Number; *M* = Mean; *SD* = Standard Deviation; SUM = Summation.

RT = Response Time; X-NOTask = Dual execution – X-NOTask; I-X-NOTask = Inversion of the target stimuli in Dual execution – X-NOTask.

*p<.05. **p< .005. ***p< .001

Table 3. Difficulty and Discrimination Index in X-NO Task and I-X-NO Task.

Items	**Difficulty Index**		**Discrimination Index**	
	X-NO Task	I-X- NO Task	X- NO Task	I-X- NO Task
1	.98	.94	.03	.09
2	.95	.94	.09	.11
3	.93	.93	.20	.19
4	.95	.88	.09	.32
5	.92	.68	.22	.32
6	.97	.70	.04	.5
7	.92	.90	.27	.27
8	.90	.91	.24	.26
9	.96	.93	.07	.23
10	.93	.97	.22	.07
11	.96	.98	.02	.07
12	.95	.87	.11	.36
13	.44	.89	.09	.18
14	.79	.75	.47	.33
15	.85	.61	.22	.49
16	.52	.94	.53	.15
17	.93	.87	.16	.34
18	.89	.96	.20	.09
19	.85	.86	.40	.38
20	.90	.92	.29	.26
21	.89	.63	.35	.34
22	.96	.85	.11	.34
23	.91	.83	.15	.42
24	.63	.66	.20	.25
25	.82	.88	.50	.32
26	.93	.91	.14	.28
27	.98	.81	.08	.38
28	.66	.79	.30	.29
29	.84	.81	.15	.43
30	.77	.89	.52	.26

31	.84	.96	.48	.11
32	.90	.82	.19	.39
33	.96	.93	.08	.21
34	.94	.95	.17	.15
35	.92	.98	.18	.08
36	.76	.58	.19	.4
37	.94	.83	.10	.44
38	.95	.89	.07	.34
39	.91	.75	.10	.28
40	.88	.84	.30	.41
41	.60	.84	.66	.36
42	.76	.68	.25	.31
43	.96	.86	.06	.23
44	.93	.89	.12	.26
45	.85	.61	.42	.54
46	.94	.84	.19	.31
47	.96	.91	.14	.23
48	.84	.80	.42	.18
49	.88	.89	.20	.26
50	.89	.83	.34	.39
51	.92	.50	.17	.56
52	.88	.62	.33	.18
53	.95	.85	.13	.38
54	.83	.92	.24	.27
55	.97	.65	.09	.26
56	.90	.82	.16	.45
57	.97	.71	.10	.3
58	.85	.84	.39	.34
59	.90	.87	.30	.14
60	.89	.83	.30	.46
61	.96	.91	.10	.29
62	.89	.59	.33	.28
63	.89	.82	.17	.4

64	.82	.89	.44	.32
65	.81	.86	.45	.34
66	.75	.92	.27	.25
67	.82	.95	.38	.14
68	.92	.97	.18	.08
69	.98	.67	.07	.37
70	.94	.80	.14	.22
71	.85	.95	.42	.11
72	.94	.97	.16	.09
73	.86	.77	.39	.5
74	.95	.88	.10	.35
75	.97	.97	.09	.11
76	.84	.89	.42	.36
77	.83	.96	.23	.12
78	.93	.97	.21	.09
79	.92	.98	.22	.08
80	.92	.57	.20	.41
81	.83	.95	.43	.11
82	.83	.67	.19	.29
83	.90	.82	.23	.13
84	.80	.90	.47	.27
85	.68	.65	.37	.5
86	.92	.87	.07	.37
87	.85	.74	.42	.29
88	.87	.71	.21	.13
89	.91	.88	.06	.34
90	.88	.77	.32	.28
91	.95	.91	.14	.28
92	.86	.85	.38	.31
93	.77	.83	.50	.45
94	.88	.96	.34	.1
95	.97	.97	.11	.11
96	.90	.76	.31	.34

97	.83	.84	.29	.1
98	.79	.88	.60	.32
99	.87	.73	.15	.28
100	.90	.86	.24	.4
101	.91	.65	.21	.59
102	.63	.77	.70	.23
103	.71	.88	.34	.37
104	.90	.94	.27	.18
105	.78	.86	.50	.4
106	.86	.87	.37	.38
107	.84	.95	.47	.14
108	.86	.85	.21	.2
109	.81	.90	.07	.3
110	.89	.92	.31	.26
111	.92	.61	.23	.34
112	.95	.83	.15	.19
113	.85	.85	.40	.42
114	.86	.83	.36	.3
115	.96	.91	.11	.28
116	.93	.85	.19	.42
117	.95	.96	.16	.12
118	.98	.57	.08	.56
119	.84	.91	.41	.32
120	.90	.88	.30	.39
121	.90	.93	.31	.26
122	.88	.82	.32	.32
123	.96	.90	.10	.23
124	.78	.90	.49	.31
125	.88	.93	.33	.08
126	.90	.88	.29	.38
127	.91	.91	.26	.28
128	.91	.65	.27	.34
129	.97	.88	.10	.21

130	.89	.88	.12	.03
131	.72	.87	.13	.37
132	.92	.89	.22	.16
133	.79	.87	.19	.23
134	.72	.92	.59	.24
135	.93	.81	.16	.53
136	.97	.64	.08	.54
137	.62	.67	.15	.38
138	.85	.89	.39	.26
139	.95	.80	.12	.52
140	.80	.83	.44	.3

Note. X-NOTask = Dual execution – X-NOTask; I-X-NOTask = Inversion of the target stimuli in Dual execution – X-NOTask.