# EXPLORING THE ATTENTIONAL PROFILE OF GIFTED CHILDREN USING A VR-BASED ASSESSMENT TOOL

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**ABSTRACT**

An accurate global assessment of gifted children is essential to provide them with educational and counseling programs tailored to their strengths and vulnerabilities. Without neglecting the fundamental role of social-emotional skills on individual well-being and academic success, it is essential to shedding light on the attentional profile of intellectually gifted children. In this regard, findings from empirical studies are not always consistent. The purpose of this exploratory study was to investigate the relationship between the cognitive profile of fifteen gifted children (mean age 9.6 years; SD 2.3), as described through the main WISC-IV indexes (IVE, IRP, IML, IVE, FSIQ), and their attentional profile assessed through AULA, an innovative VR-based ecological assessment tool that evaluates attention and inhibitory control. These first findings highlighted the correlation between intelligence and attention and provided indications for educational interventions. Therefore it is crucial to use innovative and highly ecological assessment tools to engage the IGen gifted learners. In this regard, researchers have recently developed and tested new tools that employ virtual reality (VR) to assess EFs (Climent et al. , 2010; Rizzo et al., 2006). VR-based assessment tools allow children to interact dynamically with realistic scenarios and situations that reproduce aspects of their everyday life.
The present study aimed to explore the correlation between the cognitive profile of gifted students, as measured by the WISC-IV paper-and-pencil test, and their attentional profile assessed through AULA, an innovative virtual reality-based attention assessment tool. A previous study by Diaz-Orueta et al. (2014) explored the correlation between WISC-IV indices in a sample of averaged cognitive ability learners diagnosed with ADHD, demonstrating the reliability of the VR-based attention assessment tool in discriminating clinical subjects. To our knowledge, no studies have yet been conducted analysing the attentional profile of gifted children using a VR-based attention assessment tool. Therefore, we expect to provide valuable new information on the peculiar attentional functioning of gifted children.

**KEYWORDS**

Gifted Children, Assessment, Attention, Virtual Reality, Executive Functions, School Intervention

## 1. INTRODUCTION

A high cognitive potential stems from a complex dynamic interaction between genetic, behavioural, and environmental factors. Biological aspects, also linked to epigenetic processes, are a prerequisite but not a sufficient condition for developing and expressing an individual's potential (Plomin and Deary, 2015; Sastre-Riba, 2020).

Recent neurocomputational simulations of gifted children's developmental trajectories (Thomas, 2018) clearly illustrate the interplay of multiple exogenous and endogenous factors that contribute to the expression of gifted children's cognitive potential. Among endogenous modulators, executive functions (EFs) play a central role in effectively managing intellectual resources. EFs are a set of top-down cognitive processes responsible for executing and regulating actions and are crucial for concentration and attention (Espy *et al.*, 2004). EFs have been linked to academic performance (Benedek *et al.*, 2014; Visu-Petra *et al.*, 2011) and are critical elements in promoting meaningful self-regulated and reflective learning (Kontostavlou *et al.*, 2022). Students need EFs to focus and sustain attention, plan and organise behaviour, prioritise information to initiate work, monitor task performance, and manage emotions related to the learning experience. EFs are one of the critical factors explaining individual differences in the developmental trajectory and expression of high cognitive potential, contributing to account for the gap observed in gifted students' cognitive performance.

Some researchers have suggested that the relation between executive functions' domains is related with intelligence in various ways (Arffa, 2007; Friedman *et al.*, 2006). Several studies have shown the correlation between attention and intelligence (Aubry and Bourdin, 2021; Cowan *et al.*, 2006), highlighting sustained attention as a variable capable of predicting individuals' performance on intelligence tests (Schweizer and Moosbrugger, 2004). Furthermore, executive control processes are found to be significantly correlated with intellectual ability (Tourva, Spanoudis and Demetriou, 2015). In particular, sustained attention refers to the ability to remain engaged in an activity for a specific time. Furthermore, it requires individuals to focus on the activity they are performing at that moment and simultaneously resist disturbances in the context by inhibiting unneeded responses (Trautmann and Zepf, 2012). With regard to gifted children's performance on attentional and executive control tasks, the empirical results are inconsistent. Some studies show that gifted individuals perform better than their intellectually non-gifted peers on most attentional tasks (Shi *et al.*, 2013). Particularly, Aubry, Gonthier and Bourdin (2021) stated that gifted children are characterized by their processing accuracy, showing a better ability to deliberately focus on solving a simple perceptual conflict than children with typical development. Therefore, accuracy appears to be a key element of gifted high performance on attentional tasks. Other studies have shown that individual differences in fluid intelligence can predict the ability to remove outdated information from the mind (Engle, 2018; Shipstead, Harrison and Engle, 2016).

Studies have compared the performance in attentional tasks of intellectually gifted children with those of their typically developing peers. Results showed that the gifted group performs better in processing relevant information (Zhang *et al.*, 2006), and seems to have a more remarkable ability to inhibit irrelevant information or inappropriate responses (Johnson, Im-Bolter and Pasqual-Leone, 2003). However, other studies suggest that the quality of attention of gifted children may be a vulnerability (Rommelse *et al.*, 2016). In this regard, Webb and Latimer (1993) pointed out that some gifted children could have problems controlling impulses, exhibiting hyperactivity and poor sustained attention. Westberg *et al.* (1993) have suggested that gifted children fail to focus attention on content in the classroom because they find the proposed activities uninspiring and, therefore, boring. Gifted children usually perform well if they are interested in the task or are otherwise motivated. Lack of interest or motivation can produce inaccurate results on objective tests of attention and subjective evaluations, such as behavior checklist ratings compiled by parents and teachers. In this unique population of children, behaviours that may appear as attention or hyperactivity disorders may indicate boredom and disinterest (Webb *et al.*, 2016). Inadequate assessment can lead to dangerous misdiagnoses, resulting in inappropriate counseling and school interventions. Researchers have recently developed and tested new tools that use virtual reality (VR) to assess EFs (Climent, Banterla and Iriarte, 2010; Rizzo *et al.*, 2006). VR-based assessment tools allow children to dynamically interact with realistic scenarios and situations that reproduce aspects of their everyday life.

The present study aimed to explore the correlation between the cognitive profile of gifted students, as measured by the WISC-IV paper-and-pencil test, and their attentional profile assessed through AULA, a virtual reality-based attention assessment tool. A previous study by Diaz-Orueta *et al.* (2014) explored the correlation between WISC-IV indices in a sample of subjects with average cognitive ability and a diagnosis of ADHD, demonstrating the reliability of the VR-based attention assessment tool in discriminating clinical subjects. To our knowledge, no studies have yet been conducted analysing the attentional profile of gifted children using a VR-based attention assessment tool. Therefore, we expect to provide valuable new information on the peculiar attentional functioning of gifted children.

# 2. THE RESEARCH

## 2.1 Participants

Fifteen intellectually gifted children participated in the study, twelve boys and three girls. The average age was 9.6 years (SD=2.3), ranging between 6 and 14 years. All participants were Italian, had medium-high socio-economic status, and lived in northern regions. Children involved in the study had no reported history of significative behavioural or emotional problems.

## 2.2 Instruments and Procedure

***Aula Nesplora -AULA-*** (Climent & Banterla, 2010; Climent et al., 2011). Aula is a Continuous Performance Test (CPT) performed in a VR environment that reproduces the conditions of a classroom. The tool assesses attention, impulsivity, processing speed, and motor activity in subjects between 6 and 16 years.

The virtual environment is presented through a Virtual Reality Visor, which allows head movements to be recorded through the presence of sensors.

The test consists of two main tasks. The first task is based on an "NO-X" paradigm (i.e., "Press the button when you DO NOT perceive the target stimulus"); and the second task is a "X" paradigm (i.e, "press the button whenever you DO perceive the target stimulus"). Stimuli are presented both on a visual and auditory basis. At the same time, previously randomized visual and/or auditory distractors (equal to those that may appear in a real classroom, such as environmental noises) appear progressively. The sequence of presentation of the two tasks is first "NO-X" and then "X". The administration lasts approximately 20 minutes. Different measures are provided by different sensorial modalities (visual or auditory), presence/absence of distractors, and task type ("No-X" or "X" condition). The Cronbach's alpha of the test is .72.

For the purposes of this exploratory study were taken into account omission errors (i.e., when the subject does not respond by pressing the button when he/she should have to) and commission errors (i.e., when the subject press the button when he/she should not have to); reaction time and standard deviation of correct responses were examined for Task1 and Task 2 and both auditory and visual sensorial modalities.

***WISC-IV Wechsler Intelligence Scale for Children- Fourth Edition*** (Wechsler, 2003; Italian translation and validation by Orsini, Pezzuti and Picone, 2012). The Wechsler Intelligence Scale for Children-IV (WISC-IV) is a general intelligence test consisting of 15 subtests, 10 core tests and 5 supplemental. The 10 mandatory subtests contribute to the measurement of four index scores: the verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and Processing Speed Index (PSI). The full-scale IQ score FSIQ is computed from 10 main subtests (three related to Verbal Comprehension, three to Perceptual Comprehension, three to Perceptual Reasoning, two to Working Memory, and two to Processing Speed) that reflect the general cognitive ability. The scale can be administered to children and adolescents between 6 and 16 years and 11 months.

Referring to the procedure, participants were recruited voluntarily from a center specialized in the assessment and psychological support for gifted children. Parents were given oral and written information about the purpose of the study and signed informed consent and privacy forms. The assessment battery was administered in a quiet room with proper light and temperature and carried out over two days. On the first day, the entire WISC- IV battery was administered, and on the second day, the Aula test was administered. All subjects were assessed by a licensed and experienced psychologist, experienced in the assessment of gifted children and well-trained about the use of the Aula test.

## 2.3 Data Analysis

A correlational analysis was performed to explore the relationship between gifted children's attention/disattention and impulsivity scores, measured by the AULA tool, and their cognitive profile measured through WISC-IV indices.

### 2.3.1 Results

Descriptive statistics have been calculated for the five WISC-IV indexes and reported in Table 1.

Table 1. Mean and standard deviation for WISC-IV indexes and for full IQ

| WISC_IV indexes | Mean | Standard Deviation |
|---|---|---|
| ICV | 137.200 | 8.809 |
| IRP | 133.333 | 8.499 |
| IML | 116.929 | 10.759 |
| IVE | 104.733 | 14.058 |
| FSIQ | 132.867 | 8.626 |

*Note*: ICV= Verbal Comprehension Index; IRP= Perceptual Reasoning Index; IML= Working Memory Index; IVE= Processing Speed Index; FSIQ= Full Scale of overall intelligence

Correlations have been carried out between the WISC-IV indexes and the total scores of Aula tool variables. Significant negative correlations have been found between the total number of commission errors with the IVE index and the FSIQ. Moreover, a significant positive correlation has been found between the total number of commission errors and the IRP index (Table 2).

Table 2. Pearson's correlations between WISC-IV indexes and AULA variables (total scores in both Task 1 No-X and Task 2 X)

| | WISC-IV indexes | | | | |
|---|---|---|---|---|---|
| AULA variables | ICV | IRP | IML | IVE | FSIQ |
| Total Omission errors | -0.167 | -0.489 | 9,53E-01 | -0.629* | -0.563* |
| Total Commission errors | 0.113 | 0.604* | 0.223 | -0.043 | 0.199 |
| Total RT Hit | 0.316 | -0.008 | 0.035 | -0.183 | 0.058 |
| Total DS RT Hit | 0.180 | -0.457 | -0.128 | -0.308 | -0.388 |

*Note*: * *p* value <.05

Significant negative correlations emerged between the number of omission errors during the AULA task with the presentation of distractors and the WISC-IV FSIQ, and also with the IRP and the IVE indexes. Furthermore, a significant positive correlation was found between the number of commission errors children' made under the influence of distractors and the IRP index.

A significant negative correlation was found between the number of omission errors committed by children during the presentation of the stimuli without distractors, the IRP, the IVE indexes, and the full IQ scale.

Regarding gifted children's performance under and without the influence of visual and auditory distractors, a significant negative correlation was found between the number of omission errors committed during the presentation of the stimuli without distractors with the IRP and IVE indexes and FSIQ.

Furthermore, emerged a positive correlation between the number of commission errors perpetrated during the presentation of stimuli without distractors and the IRP index. Finally, a significant negative correlation was found between the correct answers' reaction times standard deviation in the distractor-free condition, with the IRP and IML indexes, and with the FSIQ (Table 3).

Table 3. Pearson's correlations between WISC-IV indexes and AULA variables related to performance under the influence of both visual and auditory distractors and in absence of distractors condition)

| | **WISC-IV Indexes** | | | | |
|---|---|---|---|---|---|
| **AULA Variables** | **ICV** | **IRP** | **IML** | **IVE** | **FSIQ** |
| Omission errors with distractors | -0.172 | **-0.495*** | 0.040 | **-0.692**** | **-0.577*** |
| Commission errors with distractors | -0.001 | **0.694**** | 0.151 | 0.377 | 0.365 |
| RT Hit with distractors | 0.238 | 0.123 | 0.094 | -0.079 | 0.138 |
| DS RT Hit with distractors | 0.337 | -0.236 | -0.233 | -0.131 | -0.169 |
| Omission errors without distractors | -0.229 | **-0.491*** | -0.005 | **-0.588*** | **-0.584*** |
| Commission errors without distractors | -0.040 | 0.426+ | 0.162 | -0.221 | -0.033 |
| RT Hit without distractors | 0.191 | -0.204 | 0.022 | -0.393 | -0.164 |
| DS RT Hit without distractors | -0.205 | **-0.576*** | -0.032 | -0.345 | **-0.601*** |

*Note*: * *p* value <.05; ** *p* value <.01; + significant trend

A significant negative correlation emerged between the number of omission errors in Task 1, the IVE index, and the FSIQ. Additionally, a significant negative correlation was found between the correct answers' reaction times standard deviation in Task 2, and the IRP index (Table 4).

Table 4. Pearson's correlations between WISC-IV indexes and AULA variables differentiated for Task 1 (NO-X paradigm) and Task 2 (X paradigm)

| | WISC-IV Indexes | | | | |
|---|---|---|---|---|---|
| **AULA Variables** | **ICV** | **IRP** | **IML** | **IVE** | **FSIQ** |
| Omission errors (NO-X) | -0.085 | -0.430 | -0.037 | **-0.638**** | **-0.525*** |
| Commision errors (NO-X) | 0.064 | 0.401 | -0.139 | 0.069 | 0.088 |
| RT Hit (NO-X) | 0.267 | 0.146 | 0.011 | 0.100 | 0.222 |
| DS RT Hit (NO-X) | 0.200 | -0.389 | -0.183 | -0.274 | -0.337 |
| Omission errors (X) | -0.399 | -0.306 | 0.170 | -0.405 | -0.460 |
| Commision errors (X) | -0.050 | 0.322 | 0.335 | -0.202 | 0.019 |
| RT Hit (X) | 0.341 | 0.049 | 0.232 | -0.266 | 0.066 |
| DS RT Hit (X) | 0.118 | **-0.610*** | 0.254 | 0.266 | 0.020 |

*Note*: * *p* value <.05; ** *p* value <.01

A significant negative correlation was found between reaction times in correct answers for visual stimuli and the IVE index. Regarding auditory stimuli, a significant negative correlation was found between the number of omission errors, the IRP and IVE indices, as well as for the FSIQ. Lastly, a significant negative correlation was found between the standard deviation of of correct responses reaction times to auditory stimuli and IRP and IVE indices, and also for the FSIQ (Table 5).

Table 5. Pearson's correlations between WISC-IV indexes and AULA variables for visual and auditory stimuli conditions

| | WISC-IV Indexes | | | | |
|---|---|---|---|---|---|
| **AULA Variables** | **ICV** | **IRP** | **IML** | **IVE** | **FSIQ** |
| Visual Omissions errors | -0.278 | -0.384 | 0.065 | -0.488 | -0.474 |
| Visual Commision errors | -0.396 | 0.118 | 0.046 | 0.138 | -0.135 |
| RT Visual Hit | 0.322 | -0.296 | 0.108 | **-0.525*** | -0.204 |
| DS RT Visual Hit | 0.119 | -0.384 | 0.097 | -0.371 | -0.276 |
| Auditory Omissions errors | -0.150 | **-0.554*** | -0.105 | **-0.685**** | **-0.668**** |
| Auditory Commision errors | 0.386 | 0.494 | 0.247 | -0.104 | 0.329 |
| RT Auditory Hit | 0.210 | -0.011 | -0.056 | -0.116 | 0.023 |
| DS RT Auditory Hit | 0.232 | **-0.499*** | -0.073 | **-0.691**** | **-0.531*** |

*Note*: * *p* value <.05; ** *p* value <.01

### 2.3.2 Discussion

The IQ score being a standardized measure of intelligence, is considered a decisive variable in the definition of intellectual giftedness; however, it is not sufficient to explain the individual's developmental trajectory. In order to explain the development of high abilities and performance, it is also necessary to take into account other variables, of which executive functions are particularly relevant. Indeed, numerous studies have highlighted the relationship between high cognitive abilities and executive functions (Dunst *et al.*, 2014; Rocha *et al.*, 202; Shi *et al.*, 2013).

The present study aimed to investigate the correlations between the cognitive profile of intellectually gifted children and their attentive performance in Nesplora Aula (Climent, Banterla and Iriarte, 2011).

Our preliminary findings, with appropriate caution due to the small size of the sample, suggest that the WISC-IV composite indexes IRP and IVE, as well as the FSIQ, are elements that play a significant role in explaining the relationship between intelligence and attention in gifted children. Analyzing the emerged results in detail, it is possible to observe a negative correlation characterizing IRP, IVE indexes and the full

IQ score with respect to omission errors. This evidence emerges both in the presence and in the absence of distractors. With respect to omission errors during divided attention condition there is evidence of significance only in relation to the auditory sensory modality. In general omission errors are ascribable to inattention and occur when the subject does not press the button in response to the stimulus being presented. This measure is therefore related to selective and focused attention (Iriarte et al., 2016). The negative correlation that emerged at the above mentioned indexes highlights that as the score at the composite indexes IRP and IVE increases, as well as for FSIQ, errors of omission, and thus inattention, decrease. The absence of correlation regarding the visual sensory condition deserves to be further explored.

Concerning commission errors, the results show a positive correlation with the IRP index only in the condition under the influence of distractors. Commission errors occur when the subject presses the button when he/she should not have to and denote difficulty in inhibitory control. This evidence could indicate that high scores on the visual-perceptual reasoning index may lead the child to be more impulsive or to lack control in inhibiting responses. This result requires further analysis, investigating in more detail the influence of the type of distractor (visual or auditory).

Finally, concerning correct answers, reaction times and the associated standard deviation, the results showed negative correlations in relation to the composite index IRP and the FSIQ. Reaction time is the period required to respond to a stimulus. It tends to be longer in subjects with attention deficits because they tend to process information more slowly (Ptacek *et al.*, 2019). The negative correlation that emerged shows that high IRP scores correlate with lower reaction time variability in correct responses, in the condition without distractors and with respect to the auditory sensory modality.

## 3. CONCLUSIONS

The relationship between intelligence and attention is well described in the literature, but the nature of this interplay has been scarcely explored in intellectually gifted children. Our results reveal that some aspects of intelligence, measured by the WISC-IV, appear to be related to attention and inhibitory control. Although the study is exploratory, it offers the opportunity to advance new hypotheses for a more comprehensive understanding of intellectually gifted children.

A deeper comprehension of the unique characteristics of the cognitive profiles of these children allows for the design of interventions that could support them in the school context. These evidences are also relevant for counseling interventions to support the families of gifted children (Renati, Bonfiglio and Pfeiffer, 2017) and for developing specific training to improve their executive functions (Bonfiglio *et al.*, 2020; Renati *et al*., 2021).

Further studies should involve a larger sample of subjects and a control group. Additionally, extending the assessment battery to assess executive functions through other traditional assessment instruments would be appropriate.

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