

## **The cognitive profile of intellectual giftedness**

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**Contributions:** AF-M and JAD developed the concept of the study and provided ideas for the study design. AF-M and DA prepared the measures and necessary material. AF-M implemented the data collection and testing of the participants. The data analysis and interpretation was executed by JAD. DA drafted the manuscript along with AF-M under the supervision of JAD.

# The cognitive profile of intellectual giftedness

## Abstract

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Previous literature has suggested the existence of a close relationship between individuals' intellectual abilities and their cognitive profile, understood as their performance in tasks tapping into the different cognitive domains. This relationship has typically been discussed in populations characterized as having high intellectual abilities, as is the case of gifted children and adolescents. In this study, the cognitive profile in domains of memory, attention, coordination, perception, and reasoning of a group of gifted children and adolescents was contrasted with a control group similar in age distribution, gender and socioeconomic level but with normotypical development. The results indicated that participants in the gifted group scored higher than those in the control group in all cognitive domains. The differences in cognitive abilities were not consistent across all areas, meaning that some cognitive abilities did not show significant differences, while others did. These results help to identify a more precise cognitive profile of gifted individuals, yielding a better understanding of the relationship between intelligence and cognitive abilities. The study provides evidence that allows delving into the most differential and characteristic aspects of giftedness.

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**Keywords:** giftedness; talented children; cognitive skills; executive functions; IQ.

# El perfil cognitivo de las altas capacidades

## Resumen

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La literatura previa ha sugerido la existencia de una estrecha relación entre las capacidades intelectuales de los individuos y su perfil cognitivo, entendido como su rendimiento en tareas que abordan los diferentes dominios cognitivos. Esta relación se ha discutido típicamente en poblaciones caracterizadas por tener altas capacidades intelectuales, como es el caso de los niños y adolescentes superdotados. En este estudio se contrastó el perfil cognitivo en dominios de memoria, atención, coordinación, percepción y razonamiento de un grupo de niños y adolescentes superdotados con un grupo de control similar en distribución de edad, sexo y nivel socioeconómico, pero con desarrollo normotípico. Los resultados indican que los participantes del grupo de superdotados tuvieron una puntuación mayor que el grupo control en todas las áreas cognitivas. Las diferencias en las habilidades cognitivas no fueron consistentes entre todas las áreas, lo que significa que algunas habilidades cognitivas no mostraron diferencias significativas, mientras que otras sí lo hicieron. Estos resultados ayudan a identificar un perfil cognitivo más preciso de las personas con altas capacidades, a comprender mejor la relación entre inteligencia y las capacidades cognitivas, y aportan evidencias que permiten profundizar en los aspectos más diferenciales y característicos de la superdotación.

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**Palabras clave:** altas capacidades; niños superdotados; capacidades cognitivas; funciones ejecutivas; CI.

## Introduction

Intelligence, understood as a person's ability to learn from experience and to adapt, shape, and select environments (Sternberg, 2012), is a broad concept that has been studied for more than a century (Binet and Simon, 1904; Spearman 1904). A large part of the literature on intelligence has focused on identifying what makes a person intelligent, with children with high intellectual abilities being the target subjects of many studies (namely, gifted, or talented children with a high IQ).

While it is true that the broad concept of intelligence is still used to refer to gifted children, research has tried for years to further refine the concepts underlying intelligence, resulting in the g-factor, often more or less successfully parameterized as intelligence quotient (IQ) in a series of standardized tests. However, these concepts remain unspecific and insufficient to describe the complexity of the concept of intelligence. In this regard, a wide variety of relevant factors should be considered, such as motivation and creativity (Renzulli, 1978), or personality (Fries et al., 2022).

One of the most interesting trends is to break down the intelligence concept into cognitive abilities (Chekaf et al., 2018; Rowe et al., 2014; Wai et al., 2022), which makes it possible to study how these are profiled in gifted children. While some authors open the debate as to whether these profiles are reliable and how they should be interpreted (Canivez and Watkins, 1998), these models are broadly accepted (Fiorello et al., 2002). In this way, intelligence would be the tip of an iceberg composed of a large pool of cognitive abilities (Gow, 2016; Schneider and Newman, 2015). The age variation of intelligence (Breit et al., 2020; Sternberg, 2012) also serves as an additional clue of the potentially intimate relationship with cognitive abilities, as both change in a similar way (Borella et al., 2019; Gow 2016). With these premises and based on the systematic review conducted by Bucaille et al. (2021), a natural research question would be how different gifted children's cognitive abilities would be as compared to their peers with normotypical intelligence.

Domain-general cognitive abilities could be understood as a set of brain processes that allow a person to perform from the most basic activities, such as perceiving a stimulus in the environment, to more complex activities, such as organizing a week of hard work. As with intelligence, cognitive abilities have also been extensively studied for decades (Atkinson and Shiffrin, 1968;

Baddeley and Hitch, 1974; Broadbent, 1958; Diamond, 2013; Lezak, 1982; Norman and Shallice, 1986; Sohlberg and Mateer, 1989). Individual cognitive abilities or processes tend to be grouped into different cognitive areas or domains, such as attention (Sohlberg and Mateer, 1989), memory (Baddeley and Hitch, 1974), or executive functions (hereafter EFs; Lezak, 1982), among others. This latter set of cognitive abilities (i.e., EFs) represents one of the cognitive areas that is to be most tightly associated with intelligence (Chen et al., 2019; Deary et al., 2009; Debraise et al., 2020; Gray et al., 2022; Takeuchi et al., 2021). This close relationship between EFs and intelligence is endorsed by neuroimaging data showing that these cognitive skills are mainly managed by the prefrontal cortex of the human brain (Friedman and Robbins, 2021; Jones and Graff-Radford, 2021) and that intelligence is also related to this same area (Sternberg, 2012).

One could think of two types of approaches when measuring intelligence depending on whether the tests focus on the g-factor or on an aggregate of cognitive abilities: mono-ability IQ tests (Raven, 1938), and composite abilities IQ tests (Wechsler, 2008). This lack of agreement in the approach to the assessment of intelligence puts the developers in a bind. Considering that the selected theory or definition will direct how the type of test and its outcome will be, the developers of such tests have made a great effort to choose the most robust and functional ones. Although the IQ score has traditionally been a basic concept for determining giftedness (Pfeiffer, 2015), in recent years there has been increasing interest at the international level in exploring beyond the concept of IQ. As Schneider and Flanagan (2014) point out, the developers of intelligence tests have based on a series of theories of intelligence, following a pattern of overlapping waves, starting in 1904 and lasting until current days. The first wave of tests measured general intelligence; the second wave focused on specific aspects of test performance (e.g., comparing the outcomes, such as failures and successes, on a specific type of item); the third wave introduced more rigorous psychometric methods for interpreting individual profiles; and the fourth wave of tests had well-developed operational theories, improving the interpretation of the results.

As noted by Zajda (2019) in his review about current models and theories of intelligence, Gardner (2012) grouped theories of intelligence into four types: (1) psychometric theories, based on individual differences in academic success; (2) cognitive theories, based on various processes involved in performance and specific mental operations; (3) cognitive-contextual

theories, which framed mental processes in a socio-cultural context; and (4) biological theories, which try to cover the relationship between intelligence, the brain, and its functions. In this line, over and above the selected focus and approach of each test (namely, the wave a test belongs to), the developers of intelligence tests also fall into one of these groups at the theoretical level. According to Britannica (2021), the most widely used intelligence tests today are the Stanford-Binet Intelligence Scale (Binet and Simon, 1904) and the Wechsler scales (Wechsler, 2008). Both tests can likely be categorized within psychometric and cognitive theories, respectively, at least in their early versions. In the case of the most current computerized intelligence tests, such as the Adaptive Test of General Intelligence (TAI; Abad et al., 2020), they would still be framed within the group of psychometric theories, since cognitive-contextual theories and biological theories are more difficult to operationally transfer to a test.

While these tests have traditionally been used to measure intelligence level and to validate categorization as high-IQ or talented (Cao et al., 2017; Gignac, 2015) they do not provide data on the specific cognitive profile associated with a given IQ, although some approaches have been made (Schneider, 2013). Stemming from the seemingly tight link between IQ and cognitive skills, the current study was set to obtain a more comprehensive and detailed view of the cognitive state of gifted children compared to their normative peers. By analyzing the differences between high-IQ and average-IQ children in different cognitive domains we will be in a better position to draw a much more accurate and precise profile for gifted and average children, exploring differences between these populations beyond an isolated data point of IQ (Guignard et al., 2016).

In the case of gifted children who already have an exceptional IQ, one could tentatively predict differences with respect to the general population also in their cognitive abilities, or at least in some of them (Steiner and Carr, 2003). While some data has been provided specifically concerning an enhanced performance of talented children in tasks tapping into working memory (Aubry and Bourdin, 2021; Aubry et al., 2021), it remains to be seen if and how the differences between gifted and average-IQ children extend to various cognitive domains and skills.

The current study explored whether gifted children have a better cognitive profile than the general reference population and their peers with normative intelligence, and if so, in which specific cognitive domains and subdomains would be these differences more salient. Thus, the aim of the study is to quantitatively identify the cognitive profile of giftedness and to delimit the relationship between intelligence and cognitive abilities.

## **Methodology**

### **Instruments**

A battery of computerized cognitive test was used to provide a quantitative description of cognitive domains and skills of the participants. The instrument used in this regard was the Cognitive Assessment Battery (CAB)<sup>TM</sup> (CogniFit Inc., San Francisco, US), validated against classical well-known tests (Haimov et al., 2008). This instrument is an online assessment battery widely used in children (Conesa and Duñabeitia, 2021; Reina-Reina et al., 2023), adults (Chandler et al., 2013), the elderly (Thompson et al., 2011), both healthy (Tapia et al., 2022) or with a pathological condition (Duñabeitia et al., 2023; Haimov et al., 2008). It is composed of a set of 17 neuropsychological tasks based on classical neuropsychological tests —such as the digit span task, the Stroop test, etc.— that can be performed either from a computer, tablet, or smartphone. The version of the test that was used provides an accurate and immediate measurement of 21 cognitive abilities, grouped into 5 cognitive domains. The Attention domain groups the cognitive abilities Focused Attention, Divided Attention, Inhibition, and Updating. The Perception domain includes the cognitive abilities of Visual Perception, Spatial Perception, Auditory Perception, Visual Scanning, and Recognition. The Memory domain contains the cognitive abilities of Short-Term Memory, Visual Short-Term Memory, Auditory Short-Term Memory, Contextual Memory, Visual Memory, Naming, and Working Memory. The Reasoning domain consists of the cognitive abilities of Shifting, Planning, and Processing

Speed. The Coordination domain includes the cognitive abilities Eye-Hand Coordination and Response Time.

## **Data collection**

The participants in this study were 176 Spanish children aged 8 to 17 years (i.e., 113 participants in the high-ability group, and 63 participants in the group of children with normotypical development). The participants in the sample of children with high abilities were recruited from Spanish associations and institutions for people with high abilities. All of them had the corresponding psycho-pedagogical report for the official diagnosis of high ability that accredits them within this population group. All the psycho-pedagogical assessments were carried out and signed by qualified professionals who had followed the official protocols of each Autonomous Community and thus were registered in the corresponding registry of each Community. In Spain, the identification protocols follow the guidelines of the state education regulations in force at any given time. They also use technically adequate detection instruments. The tests administered to participants in this sample, include the Wechsler Intelligence Scale for Children-V (WISC-V; Wechsler, 2014), the Stanford-Binet-5 (SB-5; Roid et al., 2004), the Kaufman Assessment Battery for Children-II (KABC-2; Kaufman et al., 2005), and the Woodcock-Johnson Test of Cognitive Abilities-IV (WJ-IV; Mather & Jaffe, 2016). All these tests can be identified as composite abilities IQ tests, which goes beyond simply measuring IQ. The participants of the sample of students with normotypical development came from schools in different Spanish provinces. A mandatory criterion for inclusion in the normotypical development group was a sufficiently good school performance as attested by their teachers.

As a double check for inclusion of participants in each group of the study, an initial screening was performed to ensure that they rigorously met the appropriate eligibility criteria (Del Rosal et al., 2011; Janos and Robinson, 1985; McCallister et al., 1996). For this purpose, a commercially available test was used (Matrices-TAI test, Adaptive Test of General Intelligence; Abad et al., 2020). For a child to be considered a participant in the high ability group, over and above having the pre-existing psycho-pedagogical report, their results in this test had to yield a General Index (GI) corresponding to a high or very high percentile according to the interpretation norms. This double-



check procedure ensured that all participants in the gifted group were in fact gifted children. After this initial selection, 113 participants were included in the high-ability group (36 females). Their mean age was 11.22 years ( $SD=2.14$ ).

In addition, all participants recruited from schools with normotypical development also completed the general intelligence test to ensure that, following the same general rules of test interpretation, they did not obtain scores corresponding to high or very high percentiles. This procedure avoided possible cases of children with high abilities that had not yet been identified. The final sample included in the normotypical development group consisted of 63 participants (22 females). Their mean age was 11.78 years ( $SD=2.12$ ).

Parents of children in the high ability and normotypical development groups completed a socioeconomic status questionnaire (MacArthur Scale of Subjective Socioeconomic Status; Adler et al., 2000) in which they self-assessed their perceived status, and the results showed no differences between the groups (mean of the high ability group= $6.42$ ,  $SD=1.01$ ; mean of the normotypical development group= $6.63$ ,  $SD=1.13$ ). All families were informed of the nature, purpose, and protocol of the present study and signed informed consent for the participation of their children. The protocol was approved by the Ethics Committee of the Universidad Nebrija.

## **Data analysis**

The cognitive data acquired were compared between the groups of gifted children and normotypical development children by means of repeated measures ANOVAs following two different approaches. First, the age- and gender-adjusted percentile scores obtained in each of the cognitive domains measured by the Cognitive Assessment Battery (CAB)<sup>TM</sup> were contrasted between the groups. And second, a series of repeated measures ANOVAs were carried out to explore the potential differences between the groups in the skills that constitute each of the cognitive domains. The whole analysis routine was run using *jamovi* (The jamovi project, 2022) operating on R (R Core Team 2021) using the packages *afex* (Singmann, 2018) and *emmeans* (Lenth, 2020).

## **Results**

The results obtained after data analysis of the descriptive data are reported in Table 1.

**Table 1**

*Means, standard errors, and 95% confidence intervals of the scores in each cognitive domain and in each skill for each of the groups.*

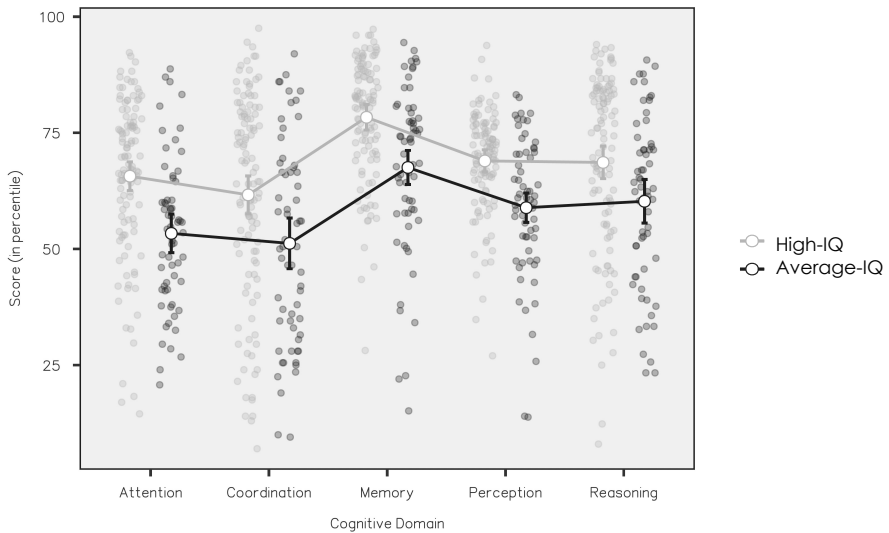
Cognitive Domain	High-IQ Group				Average-IQ Group			
	Mean	Standard Error	95% Confidence Interval		Mean	Standard Error	95% Confidence Interval	
			Lower	Upper			Lower	Upper
<b>Attention</b>	<b>65.7</b>	<b>1.57</b>	<b>62.6</b>	<b>68.8</b>	<b>53.3</b>	<b>2.10</b>	<b>49.2</b>	<b>57.5</b>
<i>Divided Attention</i>	73.3	1.97	69.4	77.2	62.8	2.64	57.6	68.0
<i>Focused Attention</i>	52.1	2.44	47.3	56.9	45.8	3.26	39.3	52.2
<i>Inhibition</i>	70.4	2.29	65.9	75.0	58.4	3.07	52.4	64.5
<i>Updating</i>	66.8	2.62	61.7	72.0	46.3	3.50	39.4	53.3
<b>Coordination</b>	<b>61.6</b>	<b>2.07</b>	<b>57.6</b>	<b>65.7</b>	<b>51.2</b>	<b>2.77</b>	<b>45.7</b>	<b>56.7</b>
<i>Eye-hand Coordination</i>	59.2	2.41	54.5	64.0	48.9	3.23	42.5	55.2
<i>Response Time</i>	64.1	2.70	58.7	69.4	53.5	3.61	46.4	60.7
<b>Memory</b>	<b>78.3</b>	<b>1.39</b>	<b>75.6</b>	<b>81.1</b>	<b>67.5</b>	<b>1.86</b>	<b>63.9</b>	<b>71.2</b>
<i>Auditory Short-Term Memory</i>	73.2	2.10	69.1	77.4	61.3	2.81	55.7	66.8
<i>Contextual Memory</i>	85.1	1.45	82.3	88.0	77.2	1.94	73.3	81.0
<i>Naming</i>	79.7	2.19	75.3	84.0	59.7	2.93	53.9	65.4
<i>Short-Term Memory</i>	75.8	2.13	71.6	80.0	66.4	2.85	60.8	72.0
<i>Visual Memory</i>	76.8	2.01	72.8	80.8	68.2	2.70	62.9	73.5
<i>Visual Short-Term Memory</i>	72.5	2.41	67.8	77.3	67.0	3.23	60.7	73.4
<i>Working Memory</i>	85.2	1.61	82.1	88.4	73.0	2.15	68.8	77.3
<b>Perception</b>	<b>68.9</b>	<b>1.20</b>	<b>66.6</b>	<b>71.3</b>	<b>58.9</b>	<b>1.60</b>	<b>55.7</b>	<b>62.0</b>
<i>Auditory Perception</i>	84.8	1.59	81.7	88.0	74.0	2.13	69.8	78.2
<i>Recognition</i>	80.2	1.80	76.7	83.8	67.3	2.42	62.5	72.1
<i>Spatial Perception</i>	52.9	2.68	47.6	58.1	45.3	3.58	38.2	52.4
<i>Visual Perception</i>	82.5	1.90	78.7	86.2	65.2	2.54	60.2	70.2

<i>Visual Scanning</i>	44.3	2.76	38.9	49.8	42.6	3.69	35.3	49.9
<b>Reasoning</b>	<b>68.6</b>	<b>1.77</b>	<b>65.1</b>	<b>72.1</b>	<b>60.3</b>	<b>2.38</b>	<b>55.6</b>	<b>65.0</b>
<i>Planning</i>	61.5	2.73	56.1	66.9	53.4	3.66	46.2	60.7
<i>Processing Speed</i>	68.3	2.63	63.1	73.5	60.6	3.53	53.6	67.5
<i>Shifting</i>	76.2	2.13	71.9	80.4	66.8	2.86	61.2	72.4

The first analysis approach concerned the exploration of the differences between groups (the Group factor with the levels gifted and normotypical) across the cognitive domains that were measured (the Cognitive Domain factor with the levels attention, memory, coordination, perception, and reasoning). The 2\*5 repeated measures ANOVA showed a significant main effect of Group ( $F(1,174)=23.6$ ,  $p<.001$ ,  $\eta^2_{\text{partial}}=0.119$ ), that showed an overall higher cognitive performance of the gifted group as compared to the normotypical group. The main effect of Cognitive Domain was also significant ( $F(4,696)=44.56$ ,  $p<.001$ ,  $\eta^2_{\text{partial}}=0.204$ ), showing that the percentile scores were different across the domains (see Table 1 and Figure 1). Importantly, the two factors did not interact with each other ( $F<1$  and  $p>.66$ ), showing that the higher scores obtained by the gifted group were similar across cognitive domains.

### **Figure 1**

*Mean score (in percentile) and individual data points in each of the cognitive domains obtained by each group. Data from the gifted group is represented in light grey, and data from the normotypical group is displayed in black. Error bars correspond to 95% confidence intervals.*



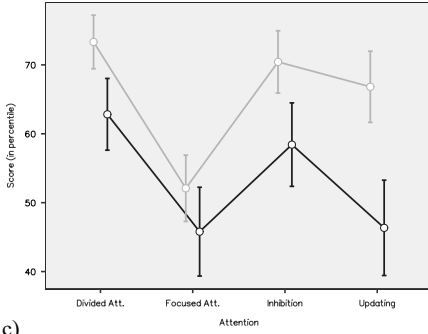
The second analysis followed a fine-grained approach aimed at investigating potential differences between the two groups at test in the magnitude of the contrasting differential effects in each of the skills that constitute each of the cognitive domains. The ANOVA on the data corresponding to the skills that jointly contribute to the **Attention** cognitive domain (namely, divided attention, focused attention, inhibition and updating) showed a significant interaction with Group ( $F(3,522)=3.14$ ,  $p=.025$ ,  $\eta^2_{\text{partial}}=0.018$ ). Post hoc pairwise comparisons using the Tukey correction method for multiple contrasts showed that the gifted and the normotypical groups significantly differed in all skills except for focused attention ( $t(174)=1.545$ ,  $p_{\text{Tukey}}>.77$ ; see Figure 2a). The ANOVA on the **Coordination** cognitive domain showed that the difference between the groups was similar for the two skills tested (eye-hand coordination and response time), given the lack of an interaction ( $F<1$  and  $p>.96$ ; see Figure 2b). The ANOVA on the skills constituting the **Memory** cognitive domain (auditory short-term memory, contextual memory, naming, short-term memory, visual memory, visual short-term memory and working memory) showed a significant interaction with the factor Group ( $F(6,1044)=3.18$ ,  $p=.004$ ,  $\eta^2_{\text{partial}}=0.018$ ). Post hoc pairwise tests demonstrated that the

groups did not significantly differ in short-term memory ( $t(174)=2.64$ ,  $p_{\text{Tukey}}=0.32$ ), visual memory ( $t(174)=2.56$ ,  $p_{\text{Tukey}}=0.37$ ), and visual short-term memory ( $t(174)=1.36$ ,  $p_{\text{Tukey}}=0.98$ ). The difference between groups in contextual memory closely approached significance ( $t(174)=3.29$ ,  $p_{\text{Tukey}}=0.07$ ), and the difference in the rest of skills were significant ( $t_s > 3.4$  and  $p_{\text{Tukey}} < .05$ ; see Figure 2c). The results of the analysis on the skills associated with the **Perception** cognitive domain showed a significant interaction with the Group factor ( $F(4,696)=2.87$ ,  $p=.022$ ,  $\eta^2_{\text{partial}}=0.016$ ), demonstrating that while the scores in some of the skills significantly differed between the gifted and normotypical groups (see Figure 2d), the scores in spatial perception ( $t(174)=1.69$ ,  $p_{\text{Tukey}}=0.80$ ) and visual scanning ( $t(174)=0.38$ ,  $p_{\text{Tukey}}=1$ ) were similar across groups. Finally, the analysis of the skills associated with the **Reasoning** cognitive domain showed similar differences between the groups in the three skills tested (planning, processing speed and shifting), as suggested by the lack of an interaction ( $F < 1$  and  $p > .93$ ; see Figure 2e).

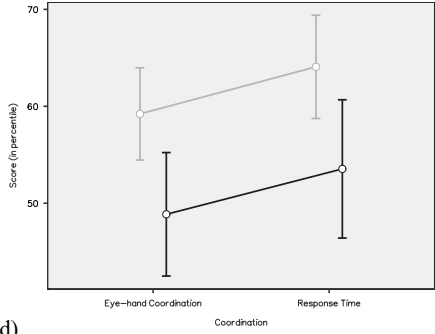
## Figure 2.

*Mean score (in percentile) of each of the cognitive skills obtained by each group grouped by domains: a) Attention, b) Coordination, c) Memory, d) Perception, e) Reasoning. Error bars correspond to 95% confidence intervals. Divided Att. = Divided Attention, Focused Att. = Focused attention; A.STM = Auditory Short-Term Memory, C.Mem. = Contextual Memory, STM = Short-Term Memory, V.Mem. = Visual Memory, V.STM = Visual Short-Term Memory, W.Mem. = Working Memory; Auditory P. = Auditory Perception, Spatial P. = Spatial Perception, Visual P. = Visual Perception, Visual Scan = Visual Scanning.*

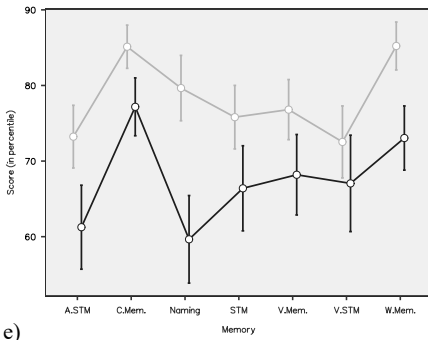
a)



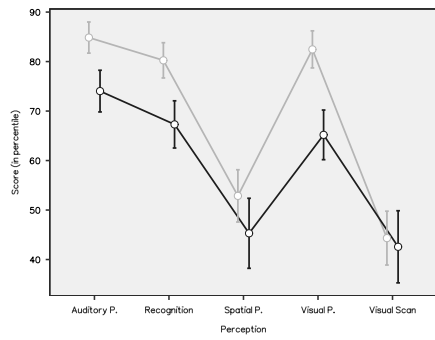
b)



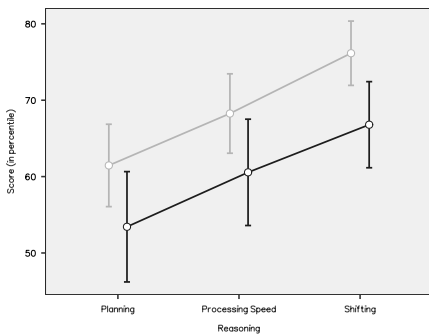
c)



d)



e)



○ High-IQ  
 ○ Average-IQ

## Discussion

The current study was designed to explore the potential differences between gifted children and a matched group of children with a neurotypical development in terms of their cognitive profile, stemming from the idea that the higher performance of the former group in IQ tests could be also linked to a higher performance in cognitive tests not directly tapping into comprehension-knowledge aptitude (Newton and McGrew, 2010). The results of this study help us conclude that there is an inherent difference not only in the intellectual profile, but also in the cognitive profile between talented or gifted children and their peers.

As a baseline measure, we observed that the normotypical group obtained scores close to the median, i.e, 50th percentile, which reinforces the idea that the measurement is correct and follows the expected distribution, and that the selected normotypically developing sample performs as expected for a control group. In contrast, the group of high-IQ children showed a significant overall difference in their cognitive scores as compared to the control group (a difference of around 11 percentile points), suggesting that intellectual giftedness comes hand in hand with cognitive giftedness too. These significant differences were found both in the overall score, in the scores of the five core cognitive domains, and in most of the scores of the individual cognitive abilities.

Another question at stake in the current study was whether gifted children excel in all cognitive abilities equally, or if the differences observed with their peers are unevenly distributed across cognitive domains. The general analysis showed that the mean differences obtained across the five tested cognitive domains were markedly homogeneous (i.e., 12 percentile points in Attention, 10 in Coordination, 11 in Memory, 10 in Perception, and 8 in Reasoning), demonstrating that the overall better cognitive performance of the gifted group was not restricted to a given cognitive domain or area. A more fine-grained analysis of each of the cognitive domains and the skills that were tested within them showed that there are cognitive abilities in which the scores of the group of gifted children were significantly higher than those of their normotypical peers, while these differences were much more modest or even negligible in other specific skills.

One interesting finding that deserves attention is the specific group of cognitive abilities in which the difference between talented children and adolescents and their peers is more marked. The importance lies in the fact that one could tentatively suggest that those cognitive skills could presumably

be more strongly associated with intelligence. In this line, our results showed that the gifted group obtained a significantly higher score in those cognitive abilities directly or indirectly related to EFs, such as working memory, inhibition, monitoring, or divided attention (see also Aubry, 2021). This finding endorses the idea that EFs have an important implication in what we understand today as intelligence, as already suggested before (Chen et al., 2019; Deary et al., 2009; Debraise et al., 2020; Gray et al., 2022; Takeuchi et al., 2021). Executive functions are highly complex cognitive abilities that allow for the abstract processing of information, and their proposed tight link with IQ stems from the idea that intelligence allows us to abstract information from our experience to adapt to the environment or context (Sternberg, 2012). Nonetheless, other cognitive abilities typically related to EFs such as planning and shifting (Miyake et al., 2000) did not show significant differences between the groups. One explanation for this may be given by Diamond (2011), when she stated that group differences are clearer the more complex the executive function is, and when the cognitive demand in an environment or stimulation program is not increasing, there tends to be no improvement in executive functions. Therefore, it can be inferred that the lack of cognitive challenge in the school stage can end in a lower activation of executive functions. This is an interesting starting point for future studies that could be aimed at deciphering the underlying components of executive factors that predict higher levels of intelligence and to experimental interventional approaches aimed at training different components of EFs and testing changes in the long term at IQ-related levels. Although different ways to improve intelligence have already been proposed (Dilmurod et al., 2020), by focusing on cognitive abilities, this process becomes more self-evident, given the large body of evidence demonstrating the effectiveness of cognitive training methods (Conesa and Duñabeitia, 2021; Diamond and Ling, 2016; Emihovich et al., 2020; Spencer-Smith et al., 2020).

On the other hand, the group of gifted children also showed significant and large differences as compared to controls in an array of basic cognitive abilities with a high perceptual load, such as naming, contextual memory, auditory short-term memory, auditory perception, recognition or visual perception. These results align well with recent data demonstrating the enhanced cognitive skills related with verbal comprehension and, critically, visuo-perceptual abilities of moderately gifted and gifted children (see Pezzuti et al., 2022). Together, these data provide tentative support to the hypothesis



of an earlier development of biological processes associated with sensorimotor and linguistic skills in gifted children that later in time may result in a higher IQ as compared to normotypically developing children (Vaivre-Douret, 2011).

Taken together, these findings help us quantify and qualify the core cognitive differences between gifted children and those with normotypical intellectual development, while acknowledging that the variability of the intellectual profiles of the sample limits the scope of these findings. Identifying these differences is not only interesting when assessing and recognizing high abilities in children, but also opens the possibility of refining and making more precise interventions aimed at favoring students' intellectual development in order to maximize their results in different contexts, but especially within the school environment. Applying progressive and scalable cognitive training programs in the classroom environment or in complementary activities according to the level of intelligence can favor a holistic attention to students and achieve the optimization of cognitive abilities, not only for students with high abilities, but also for students with normotypical development or those with greater difficulties. This would lead to an optimization of talents and could have a significant impact on school performance and personal development.

Although the results of this study are enlightening and help to answer the main questions initially posed, we deem it essential to continue research on the cognitive profile of gifted individuals to better understand the seemingly intrinsic relationship between intelligence and domain-general cognition. However, a cautionary note is advised when interpreting these results, given that it is important to bear in mind that the school context is multifactorial and that this study only addresses cognitive aspects. Future studies should be directed at collecting a much broader set of variables that consider the holistic and integral vision of educational intervention, so as not to neglect the personal, emotional, and social development of the students. Besides, another clear-cut limitations of the current study is its cross-sectional nature, which does not allow for solving the existing chicken and egg question arising from the origin of the differences. Whether the enhanced cognitive skills of gifted children boost intellectual abilities, or whether the higher intellectual abilities snowball to cognitive skills is a question that remains open. Future longitudinal and training studies could help us determine the origin of the

differences and better characterize the underlying core properties of giftedness.

In a nutshell, this study explores the cognitive differences between gifted children and their peers and shows that there are significant differences in their cognitive profiles. These differences are not limited to a particular cognitive domain but are found across different cognitive areas. Additionally, the study suggests that executive functions are more strongly associated with intelligence and are linked to higher IQ in gifted children. The findings can help in the identification of high-ability students and in developing interventions aimed at maximizing their intellectual development.

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