Clinical Neuropsychiatry (2026) 23, 2, 154-164

RESEARCH PAPER

INTELLECTUAL PROFILES IN CHILDREN WITH UNILATERAL AND BILATERAL CEREBRAL PALSY: A MULTILEVEL ANALYSIS OF THE WISC-IV SCALE

Maria Chiara Di Lieto, Costanza Ruffini, Elisa Matteucci, Benedetta Del Lucchese, Elena Beani, Veronica Barzacchi, Antea Scrocco, Chiara Pecini, Giuseppina Sgandurra

Abstract

Objective: Cerebral palsy (CP) is a neurodevelopmental disorder primarily affecting motor functioning and often accompanied by cognitive impairments. Although intellectual profiles in children with CP are known to be heterogeneous, standard intelligence assessments often rely on a single global IQ score, which may obscure important intra-individual differences and limit clinical usefulness. This study aimed to explore intellectual functioning in children with unilateral and bilateral spastic cerebral palsy using a detailed multi-level analysis to examine how motor impairments may influence performance on WISC-IV indices and subtests.

Method: A cross-sectional study was conducted on 48 children aged 6-15 years with spastic cerebral palsy (24 unilateral, 24 bilateral). Inclusion required at least one WISC-IV index score above 80. Intellectual functioning was assessed through Full Scale IQ, four cognitive indices (verbal comprehension, perceptual reasoning, working memory, processing speed), and individual subtests. Participants were classified by cerebral palsy type and gross motor function level. Descriptive and comparative statistics identified significant group differences.

Results: Intellectual profiles showed marked heterogeneity. Over half of the children showed marked discrepancies among WISC-IV index scores, making the Full Scale IQ difficult to interpret as a representation of their overall cognitive functioning. Working Memory and Processing Speed were the most frequently impaired indices. Processing Speed deficits were consistent across CP types and motor levels, while Working Memory impairments were more pronounced in children with bilateral CP. Perceptual and verbal reasoning differences were more evident in bilateral cases. Greater motor impairment correlated with lower Perceptual Reasoning and Processing Speed scores, highlighting the influence of motor functioning on performance.

Conclusions: Detailed, multi-level assessments of WISC-IV performance provides a clearer understanding of cognitive functioning in children with CP. Considering indices and subtests in relation to motor constraints helps distinguish true cognitive abilities from motor-related limitations, supporting accurate diagnosis and targeted interventions.

Key words: cerebral palsy, intellectual profile, cognitive assessment, WISC-IV; working memory, motor impairment

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OPEN ACCESS

Citation: Di Lieto, M. C., Ruffini, C., Matteucci, E., Del Lucchese, B., Beani, E., Barzacchi, V., Scrocco, A., Pecini, C., Sgandurra, G. (2026). Intellectual profiles in children with unilateral and bilateral cerebral palsy: a multilevel analysis of the WISC-IV scale. *Clinical Neuropsychiatry, 23*(2)*,* 154-164.

doi.org/10.36131/cnfioritieditore20260204

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Funding: This work was supported by the Italian Ministry of Health - Grant ERANET-RC 2024-2025 (CATCH Hemi project-ERAPerMED2019-254), ACTON-DIP Project - RF2019, and was partially supported by Fondazione Mariani (DataNetCP).

Competing interests: None.

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Submitted October 2025, accepted February 2026

1. Introduction

1.1 Cerebral Palsy and cognitive development

Cerebral Palsy (CP) encompasses a group of non-progressive disorders affecting movement and posture, which lead to activity limitations and stem from brain damage occurring during fetal development or early infancy (Rosenbaum et al., 2007). This lifelong condition originates in early childhood and is observed in approximately 0.2% of live births, with evidence suggesting a rising incidence (O'Shea et al., 2009). Among its clinical forms, spastic CP is the most prevalent, accounting for about 90% of cases. While motor impairments are central to CP, a spectrum of additional challenges, including neurological, cognitive, neuropsychological, communicative, perceptual, emotional, and psychiatric disorders is frequently associated (Società Italiana di Neuropsichiatria dell'Infanzia e dell'Adolescenza [SINPIA], 2013). Early brain lesions in CP determine an alteration of the typical development of various cognitive functions, contributing to potential intellectual deficits or specific cognitive and neuropsychological impairments, thereby increasing the risk of psychopathological comorbidities and issues in schooling and work, reduced quality of life, and social participation (reviews: Almasri & Alquaqzeh, 2023; Fluss & Lidzba, 2020).

1.2 Heterogeneity of cognitive profiles

Cognitive development of children with CP shows a high inter-subjects variability that is strongly influenced by multiple clinical characteristics that define and determine different functional profiles and developmental trajectories. The location, timing, and extent of neurological lesions are some of the key predictors of general intellectual level, as well as the presence of epilepsy, premature birth, low birth weight, reduced fetal growth, and severe gross motor impairment being some of the most significant risk factors for the incidence of cognitive deficits. The prevalence of intellectual disability in CP varies widely (from 30% to 60%) across studies and is closely related to the clinical form of CP, the degree of neuromotor impairment, and the history of prematurity.

Research indicates a better functional outcome in children with spastic unilateral and bilateral CP compared to those CP forms where the cognitive performance is strongly dependent on the degree of motor and oro-motor impairment, as in dyskinetic CP or in tetraplegic and ataxic CP, in which interpreting cognitive data requires careful consideration (Ballester-Plané et al., 2018). Studies on children with spastic forms highlight that despite generally intact intellectual functioning, their cognitive profiles exhibit peaks and troughs, with features differentiating unilateral and bilateral CP, depending on characteristic of the lesions. In children with spastic bilateral CP, a significant discrepancy between verbal and non-verbal intellectual indices is widely documented (e.g. Ego et al., 2015; Fazzi et al., 2009; Ito et al., 1997; Sigurdardottir et al., 2008). Specifically, due to neuroanatomical damage around the periventricular area, which compromises the integrity of the optic radiations and parieto-occipital white matter (Fazzi et al., 2009; Pavlova & Krägeloh-Mann, 2013), visuo-spatial skills are often severely impaired whereas verbal skills usually fall within the normal range. In children with spastic unilateral CP, intellectual functioning tends to be preserved in both verbal and visuo-spatial domains, although still in favor of the former and several factors, such as timing (pre-peri-postnatal), type (e.g., middle cerebral artery infarction, unilateral periventricular infarction, ischemic stroke), and extension of the lesion, as well as the presence of epilepsy, can affect their intellectual profile. Specifically, children with unilateral lesions due to unilateral Periventricular Leukomalacia demonstrated better overall intellectual abilities compared to those with lesions due to middle cerebral artery infarction (Kitai et al., 2015), while cognitive functioning within normal limits is described in children with unilateral lesions due to ischemic stroke. The lateralization of the lesion does not seem to significantly impact cognitive functioning, with verbal reasoning abilities more preserved than non-verbal ones in both right and left lesions.

1.3 Limitations of Global IQ in CP and need for multilevel assessment

The common weakness observed in individuals with CP at the non-verbal indices of standardized psychometric scales (as Wechslers) could be attributed primarily to the presence of tasks requiring visuo-praxical motor planning and visuo-motor integration speed, such as the Block Design and Coding subtests. However, the issue of whether the deficits in the visuospatial domain could be totally ascribed to the motor impairment is still debated (Coceski et al., 2021). Although the differences between verbal and non-verbal intelligence indices in CP have been extensively studied, gaining a deeper understanding of whether performance within these indices is homogeneous and of the factors contributing to the presence of strengths and weaknesses, could enhance functional diagnosis and developmental prognosis. Based on the existing literature, relying solely on a global intelligence index to assess cognitive abilities in children and adolescents with CP may fail to provide an accurate representation of their true cognitive potential (Sherwell et al., 2014; Yin Foo et al., 2013). Indeed, recent research has shown that children with CP not only exhibit differences in overall test performance but also distinct patterns in the types and locations of errors during non-verbal intelligence assessments such as the Raven's Coloured Progressive Matrices, highlighting the need for a more detailed and nuanced analysis of cognitive profiles that goes beyond total scores to better capture underlying problem-solving strategies and specific cognitive strengths and weaknesses (Asano et al., 2023). Therefore, it is important to adopt a multi-level analytical approach that, in addition to the global intelligence index, allows for a more detailed examination of individual indices. This approach should distinguish among different processing modalities (e.g., verbal vs. visuo-spatial) and intelligence components (e.g. general abilities vs. cognitive competences indices), as well as narrow skills (e.g. subtests) composing different indices.

1.4 Objectives of the study

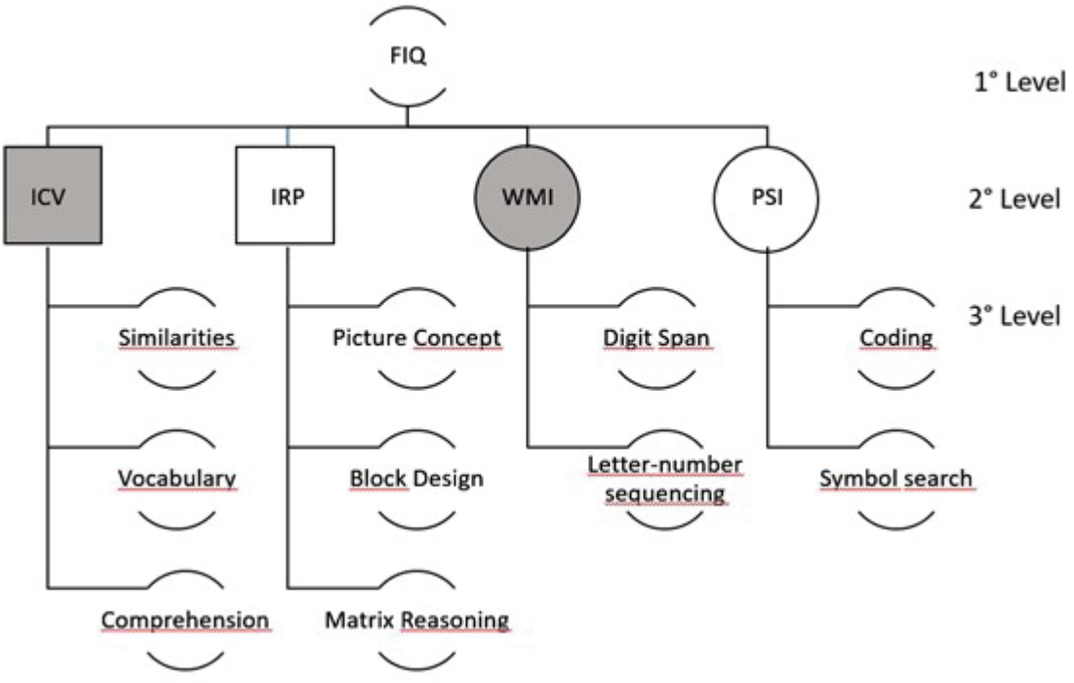
From this perspective, the present study aimed to describe the heterogeneity of the intellectual profile in children and adolescents with CP, focusing on the comparison between indices, modalities, and processes investigated, while considering the form of CP and motor functioning. To achieve this, we applied a multi-level analytical approach at the WISC-IV as reported in **figure 1**.

2. Method

2.1 Participants

Data used for this study refer to a larger sample of children with CP enrolled at the Department of

Figure 1. *Multi-level analytic approach. Legend: Square shape= General Abilities Indices; Circle shape = Cognitive Competences Indices; Gray shape = Verbal modalities; White shape = visuo-spatial modalities*



Developmental Neuroscience (IRCCS Stella Maris) from 2019 to 2023. Inclusion and exclusion criteria were defined to select the participants from the original group: capacity to perform the entire WISC-IV battery; at least one index (VCI or PRI) > 80. A sample of 48 children (32 Male and 16 Females) aged 6 to 15 (Mean Age=9.43 ; SD=1.89) with a diagnosis of CP, based on clinical evaluations and brain MRI data acquired after the age of 2 years, was involved in this study. The majority of the children were native Italian speakers of Caucasian ethnicity or had been residing in Italy for more than 5 years. The research project received approval from the Pediatric Ethic Committee of Tuscany (209/2022). Written consent for participation was obtained from all parents, who also provided informed consent for the publication of the study's results. According to the topography of motor impairment (Krägeloh-Mann & Cans, 2009), the sample was composed of 24 unilateral (uCP; 14 M, 13 left lesion side) and 24 bilateral CP (bCP; 18 M).

2.2 Instrument

2.2.1 Intellectual assessment

Intellectual ability was assessed in all children using the individually administered Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV), from which Full-Scale IQ (FSIQ), index scores, and subtest scores were obtained. The FSIQ is derived from 10 core subtests and allows the calculation of four primary index scores: the Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and Processing Speed Index (PSI). These index scores have a mean of 100 and a standard deviation of 15. Scores above 85 are considered within the normal range; scores between 71 and 84 are classified as borderline, and scores of 70 or below indicate cognitive impairment. The VCI includes three core subtests: Vocabulary, Similarities, and Comprehension. The PRI consists of Block Design, Picture Concepts, and Matrix Reasoning. The WMI comprises Digit Span and Letter-Number Sequencing, while the PSI includes Coding and Symbol Search. Although the WISC-IV also provides supplemental subtests for each index, these were not administered in the present study, as all children completed the full set of core subtests. For detailed descriptions of each core subtest, see Appendix 1.

2.2.2 Motor level classification

The Gross Motor Function Classification System (GMFCS) (Palisano et al., 1997) classifies the severity of movement impairment in children with CP, providing a standardized method to describe the child's gross motor function. Five motor levels are recognized: unrestricted walking (level I); walking without assistive devices but with spatial limitations (level II); walking with support and orthosis (level III); self-mobility with limitations (level IV); limited self-mobility dependent on using assistive technologies (level V).

Manual Ability Classification System ([MACS], Eliasson et al., 2006) describes manual abilities in daily life activities, focusing on handling objects and performing tasks independently or with assistance or adaptation. Five motor levels are identified: manipulates objects easily and successfully (level I); manipulates most objects but with a not perfectly good quality and/or a certain slowness in completing the task (level II); manipulates objects with difficulty; needs help to set up and/or modify activities (level III); manipulates a limited number of objects in adapted situations (level IV); does not manipulate objects and has severely limited skills in performing even simple actions (level V).

2.3 Statistical analysis

Descriptive analyses (mean, SD, skewness and kurtosis) were conducted on all measures across the entire sample. Differences in Indices and Subtests

between uCP groups with right and left lesions were investigated through the nonparametric Mann–Whitney U with Bonferroni corrections. To assess differences in age, gender, and motor functioning (MACS and GMFCS) between the uCP and bCP groups, t-test, chi-square, and Mann-Whitney U were conducted. Variables differing between the two groups were used as covariates in subsequent statistical models. Given the restricted range and lack of between-group differences in MACS scores, this variable was not included as a covariate in the WISC-IV analyses.

For the first level of analysis (WISC-IV Full IQ,- FIQ-), an ANOVA was conducted with CP form as the between-subjects factor and GMFCS as a covariate.

For the second level of analysis (WISC-IV comprehensive indices, - Indices -), scores of Indices were classified according to WISC-IV guidelines (as reported in Intellectual assessment paragraph). A mixed analysis of variance (ANOVA) was used to examine differences between Indices (VCI, PRI, WMI, PSI) while accounting for CP form and motor functioning. Indices were treated as the within-subjects factor, CP form as the between-subjects factor, and GMFCS as a covariate. Post-hoc pairwise comparisons with Bonferroni correction were performed between Indices across the whole sample and within each CP form. To explore the role of modalities and process type, the difference (Δ) between VCI and PRI (VCI_PRI Δ), VCI and WMI (VCI_WMI Δ), and PRI and PSI (PRI_PSI Δ) were calculated. Correlation analyses using Spearman Rho were conducted between CP form, GMFCS, and the Indices and Deltas. Three regression analyses were performed with Deltas as outcome measures and CP form and GMFCS as predictors.

For the third level of analysis (WISC-IV subtests, - Subtests -), a mixed ANOVA was employed to examine variations among the Subtests (similarities, vocabulary, comprehension; picture concepts, block designs, matrix reasoning; digit span, letter-number sequencing; coding, symbol search) in relation to CP form and GMFCS. In this analysis, the Subtests within each index served as the within-subjects factor, CP form as the between-subjects factor, and GMFCS as a covariate.

3. Results

3.1 Descriptive statistics

Descriptive statistics of the demographic and motor characteristics of the uCP and bCP groups are reported in **table 1**. The two groups did not differ for age (t(46)=-.97, p=.339), gender (χ^2(1)=1.5, p=.221), or

Table 1. *Descriptive statistics of the demographic and motor characteristics in the uCP and bCP groups*

	uCP (n=24)	*bCP (n=24)*	*p*
Age	M 9.17 (SD 1.53)	M 9.70 (SD 2.19)	.34
Gender	Male: 58.3% (14/24) Female: 41.7% (10/24)	Male: 75% (18/24) Female: 25% (6/24)	.22
MACS	Level I: 29.2% (7/24) Level II: 58.3% (14/24) Level III: 12.5% (3/24) Level IV: 0 Level V: 0	Level I: 36.4% (8/22) Level II: 59.1% (13/22) Level III: 4.5% (1/22) Level IV: 0 Level V: 0	.43
GMFCS	Level I: 95.6% (22/23) Level II: 0 Level III: 4.3% (1/23) Level IV: 0 LevelV : 0	Level I: 36.4% (8/22) Level II: 31.8% (7/22) Level III: 18.2% (4/22) Level IV: 13.6% (3/22) Level V: 0	<.001

Table 2. *Descriptive statistics of Full IQ, Indices and Subtests scores of WISC-IV in the entire sample*

WISC-IV	N	Min	Max	*M*	*SD*	Skewness	Kurtosis
Full IQ	47	58	121	88.21	14.49	.1	-.28
Indices							
VCI	48	74	130	96.58	13.13	.38	-.53
PRI	48	43	130	94.31	18.97	-.7	.38
WMI	48	46	133	88.00	17.68	.28	-.08
PSI	47	47	100	79.49	14.38	-.59	-.9
Subtests							
Similarities	48	6	16	10.00	2.49	.75	.10
Vocabulary	48	5	16	9.17	2.55	.58	-.16
Comprehension	48	2	15	9.10	3.23	-.14	-.82
Picture Concepts	48	1	16	9.79	3.31	-.2	-.35
Block Design	48	1	15	7.60	3.2	-.06	-.21
Matrix Reasoning	48	1	17	9.85	3.75	-.47	.13
Digit Span	47	1	17	7.60	3.36	.49	.1
Letter-number sequencing	48	1	16	8.60	3.25	.08	.27
Coding	47	1	10	6.06	2.96	-.32	-1.18
Symbol Search	47	1	14	7.06	2.82	.07	.28

motor functioning classified with MACS (U(44)=232.5, p=.428). Children with uCP had better GMFCS levels than children with bCP (U(43)=105, p<.001), thus, GMFCS was included as a covariate into the subsequent statistical models.

Descriptive statistics (mean, *SD*) of each WISC-IV measure in the uCP and bCP groups, and in the right and left uCP subgroups, are provided in Appendix 2 and 3, respectively. Since there were no significant differences (Bonferroni: p>.012) in WISC-IV Indices or Subtests scores between lesion sides within the uCP group, it was analyzed as a single entity in the subsequent analyses.

Descriptive analyses (mean, SD, skewness and kurtosis) of the WISC-IV measures across the entire sample indicated that all variables were normally distributed (**table 2**).

3.2 First level analysis (Full IQ)

In the overall sample, Full IQ (FIQ) had a mean value in the normal range (*Mean*=88.21, *SD*=14.49), with scores ranging from 58 to 121. Despite meeting the inclusion criteria of at least one index within the normal range (>80), a total of 53.19% (25/47) of children with CP had either a non-interpretable FIQ (21.28%, 10/47), due to significant discrepancies between Indices, or a FIQ falling within the borderline or deficit range (34.32%, 15/47). For one child, FIQ was not calculable due to the unavailability of the Processing Speed Index (PSI). An ANOVA, with CP form as a between factor and GMFCS as a covariate, revealed that neither CP form (F(1,43)=.001, p=.972) nor GMFCS (F(1,43)=3.04, p=.089) had a significant effect on FIQ.

3.3 Second level analysis (Comprehensive indices)

Differences in the distribution of normal (≥85), borderline (71-84) or deficit (≤ 70) scores across Indices for each CP form are presented in **table 3**. A higher percentage of borderline or deficient scores was found in PSI and WMI compared to PRI and VCI. However, these patterns varied between CP forms, particularly in the prevalence of deficit scores across the four Indices.

A mixed ANOVA was conducted with Indices as the within-subjects factor, CP form as the between-subjects factor, and GMFCS as a covariate. The results showed significant differences among the Indices across the entire sample (F(3,123)=3.76, p=.013, η_p^2 = .08) and a significant interaction between Indices and CP form (F(3,123)=4.27, p=.007, η_p^2 = .09); no other significant effects were found.

As shown in **figure 2**, in the uCP group, the PRI and VCI yielded the highest scores (PRI-WMI: p=.013; **PRI-PSI: *p*<.001;** VCI-PSI: p=.021), while in the bCP group, VCI was the highest score (VCI-PRI: p=.045) and PSI the lowest (**PSI-VCI: *p*<.001; PSI-PRI: *p*<.001; PSI-WMI: *p*=.002**).

In the overall sample, VCI significantly differed from WMI (p=.047), and PSI significantly differed from all other Indices (VCI: p<.001; PRI: p<.001; WMI: p=.004).

Differences between the verbal and visuo-spatial modalities (VCI_PRI Δ), as well as between the general ability and cognitive competence Indices in both the verbal domain (VCI_WMI Δ) and in visuo-spatial domain (PRI_PSI Δ) were calculated. Descriptive statistics for the Deltas are reported in **table 4**.

3.4 Third level analysis (subtests)

The distribution of normal (≥8), borderline (7-5) or deficit (≤ 4) scores across the Subtests of all Indices in the entire sample, revealed differences within each index. For VCI, normal, border or deficient scores were found in the Similarities (Normal: 87.5% (42/48); Borderline: 12.5% (6/48); Deficit: 0), Vocabulary (Normal: 66.67% (32/48); Borderline: 33.33% (16/48); Deficit: 0) and in Comprehension (Normal: 64.58% (31/48); Borderline: 29.17% (14/48); Deficit: 6.25% (3/48)) Subtests.

For PRI, normal, border or deficient scores were found in Picture Concepts (Normal: 72.92% (35/48); Borderline: 25% (12/48); Deficit: 2.08% (1/48)), Block Design (Normal: 54.17% (26/48); Borderline: 29.17% (14/48); Deficit: 16.66% (8/48)) and in Matrix Reasoning (Normal: 81.25% (39/48); Borderline: 8.33% (4/48); Deficit: 10.42% (5/48)) Subtests.

For WMI, normal, border or deficient scores were found in Digit Span (Normal: 50% (24/48); Borderline:

Table 3. *Percentage of children in the normal, borderline, deficit scores for WISC-IV Indices in the uCP and bCP forms*

	uCP (n=24)	*bCP (n=24)*	***Tot (n=48)***
VCI	Normal: 58.33% (14/24) Borderline: 41.67% (10/24) Deficit: 0	Normal: 83.33% (20/24) Borderline: 16.67% (4/24) Deficit:0	**Normal: 70.83% (34/48)** **Borderline: 29.17% (14/48)** **Deficit:0**
PRI	Normal: 95.83% (23/24) Borderline: 4.17% (1/24) Deficit: 0	Normal: 58.33% (14/24) Borderline: 16.67% (4/24) Deficit: 25% (6/24)	**Normal: 77.08% (37/48)** **Borderline: 10.42% (5/48)** **Deficit: 12.5% (6/48)**
WMI	Normal: 45.83% (11/24) Borderline: 33.33% (8/24) Deficit: 20.83 (5/24)	Normal: 70.83% (17/24) Borderline: 16.67% (4/24) Deficit: 12.5% (3/24)	**Normal: 58.33% (28/48)** **Borderline: 25% (12/48)** **Deficit: 16.67% (8/48)**
PSI	Normal: 79.16% (19/24) Borderline: 4.17% (1/24) Deficit: 16.67% (4/24)	Normal: 33.33% (8/24) Borderline: 29.17% (7/24) Deficit: 37.5% (9/24)	**Normal: 56.25 (27/48)** **Borderline: 16.67 (8/48)** **Deficit: 27.08 (13/48)**
Tot	**Normal: 69.8% (67/96)** **Borderline: 20.83%(20/96)** **Deficit: 9.37% (9/96)**	**Normal: 61.46% (59/96)** **Borderline: 19.79 (19/96)** **Deficit: 18.75% (18/96)**	

Legend: normal (≥85), borderline (71-84), deficit (≤ 70) scores

Figure 2. *Profile of the Indices in uCP and bCP forms*

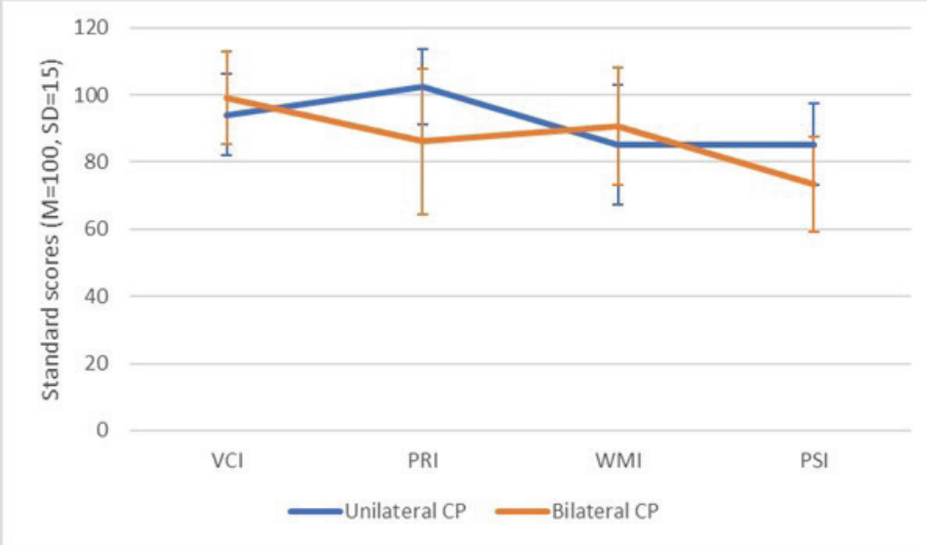


Table 4. *Descriptive statistics (mean, standard deviations) of VCI_PRI Δ, VCI_WMI Δ and PRI_PSI Δ in uCP and bCP groups*

	uCP			bCP		
	N	*M*	*SD*	N	*M*	*SD*
VCI_PRI Δ	24	-8.33	10.56	24	12.88	17.99
VCI_WMI Δ	24	8.83	19.49	24	8.33	14.82
PRI_PSI Δ	24	17.13	14	23	14.65	14.26

33.33% (16/48); Deficit: 16.66% (8/48)), Letter-number sequencing (Normal: 62.5% (30/48); Borderline: 29.17% (14/48); Deficit: 8.33% (4/48)) Subtests.

For PSI, normal, border or deficient scores were found in Coding (Normal: 38.30% (18/47); Borderline: 27.66% (13/47); Deficit: 34.04% (16/47)) and in Symbol Search (Normal: 48.94% (23/47); Borderline: 36.17% (17/47); Deficit: 14.89% (7/47)) Subtests.

Four mixed ANOVAs were conducted, with Subtests of each index as the within-subjects factor, CP form as the between-subjects factor, and GMFCS as a covariate.

VCI Subtests: no significant effect was found for the Subtests ($F(2,84)=.102$, $p=.90$, $\eta_p^2=.00$), nor was there any interaction between Subtests and CP form ($F(2,84)=.43$, $p=.65$, $\eta_p^2=.01$) or GMFCS ($F(2,84)=.87$, $p=.423$, $\eta_p^2=.02$).

PRI Subtests: a significant main effect of the Subtests was found ($F(2,84)=4.21$, $p=.018$, $\eta_p^2=.09$), with lower performances on the Block design subtest in comparison to Picture concepts ($p<.001$) and Matrix reasoning ($p<.001$). There was no interaction with the CP form ($F(2,84)=1.18$, $p=.313$, $\eta_p^2=.03$). GMFCS had a significant effect ($F(1,42)=5.54$, $p=.023$, $\eta_p^2=.12$), showing a worsening trend from level 1 to 3, with no significant interaction with Subtests ($F(2,84)=2.06$, $p=.133$, $\eta_p^2=.05$).

WMI Subtest: no significant effect was found for the Subtests ($F(1,41)=.1$, $p=.757$, $\eta_p^2=.00$), nor was there any interaction with CP form ($F(1,41)=1.55$, $p=.22$, $\eta_p^2=.04$) or GMFCS ($F(1,41)=1.35$, $p=.253$, $\eta_p^2=.03$).

PSI Subtests: no significant differences were found among the Subtests ($F(1,41)=.1$, $p=.758$, $\eta_p^2=.00$), nor was there any interaction between Subtests and CP form ($F(1,41)=.05$, $p=.826$, $\eta_p^2=.00$). GMFCS showed a significant effect on performances ($F(1,41)=6.55$, $p=.014$, $\eta p2=.14$), with a worsening trend from level 1 to level 3, but no significant interact with Subtests ($F(1,41)=.59$, $p=.446$, $\eta_p^2=.01$).

The absence of significant interactions between Subtests and CP forms is visually represented in **figure 3.**

4. Discussion

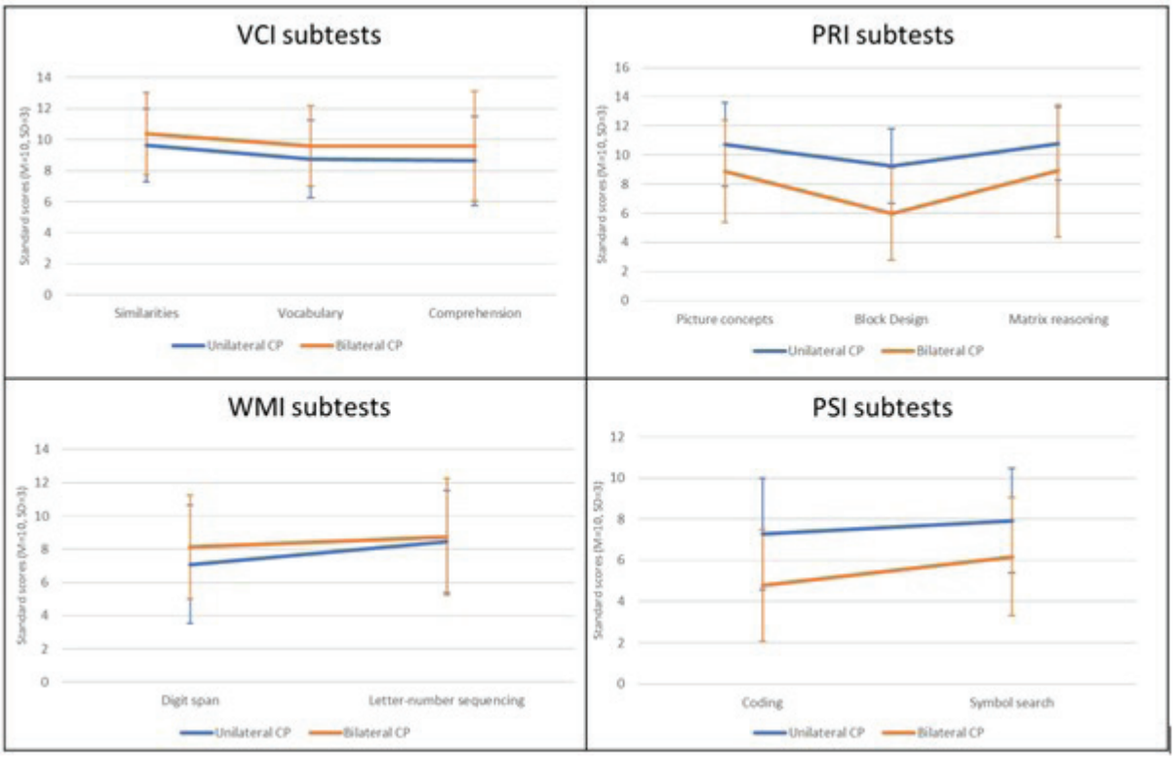
4.1 Aim and multi-level analytical approach

The primary aim of the present study was to explore the heterogeneity of the intellectual profile on the WISC-IV in children with different CP using a multi-level analytical approach, considering different CP forms and levels of motor functioning. The analysis began with an examination of FSIQ and progressively narrowed down to explore differences among Indices and Subtests. Specifically, variations in modalities (verbal vs. non-verbal: VCI vs PRI), types of intellectual processes within each modality (general abilities vs. cognitive competences: VCI vs WMI and PRI vs PSI), and narrow intellectual skills (subtests) were analyzed.

4.2 Intellectual profile heterogeneity and limitations of FSIQ

Results confirmed the high heterogeneity of the intellectual profiles in children with spastic CP, highlighting the limitations of relying solely on broad intellectual indices, such as Full IQ. Despite the mean FIQ being within the normal range, indeed, over half of the sample had not-interpretable scores, due to the discrepancies among subtest scores, or borderline/deficit FIQs, even though at least one index was in the normal range, as required by the inclusion criteria.

Figure 3. *Profile of the Subtests within each index in uCP and bCP forms*



4.3 Differences across intellectual indices

Regarding differences across intellectual indices (second level of analysis), a high percentage of borderline or deficient performances and lower scores in PSI and WMI were found relative to PRI and VCI, with variations depending on the CP forms. The wide discrepancy between general abilities and cognitive competence indices found enriches the existing literature on intellectual profiles in CP, aligning with findings in other neurodevelopmental disorders (Cornoldi et al., 2014; Devena & Watkins, 2012; Kahalley et al., 2016; Poletti, 2016; Weiss & Gabel, 2008). This result has important implications for diagnosis and intervention of children with CP. Furthermore, even within the cognitive competence indices, differences are found according to the CP form. PSI was consistently lower than VCI and PRI, regardless of the CP forms and GMFCS levels, while WMI was lower only in bCP. Although PSI is intended to measure speed of cognitive information processing, its subtests (e.g., Symbol Search and Coding) rely significantly on motor output. In children with CP, motor difficulties may therefore slow task performance independently of cognitive processing speed, making PSI a composite measure of cognitive and motor constraints rather than a pure index of processing speed. This is consistent with previous evidence that motor impairments in CP specifically compromise results on timed tasks requiring fine-motor control (Anderson et al., 2007; Bøttcher et al., 2010; Jascenoka & Walter, 2022). Future studies could consider motor-free measures to isolate cognitive processing speed more accurately in this population. Similarly, the greater strenght observed in the WMI in bCP compared to uCP may be related to the uneven cognitive profile typically reported in this bCP form, characterized by a dissociation between verbal and visuospatial abilities (Ego et al., 2015; Fazzi et al., 2009; Ito et al., 1997; Sigurdardottir et al., 2008). Although WMI subtests rely on verbal material, they also require active manipulation, attentional control and sequential processing, which may be particularly vulnerable in bCP despite relatively preserved verbal reasoning abilities. Given the widespread clinical use of the WISC-IV in children with CP, careful interpretation of scores is essential. To accurately understand a child's cognitive profile, it is necessary to examine performance across verbal and visuo-spatial modalities and at the level of individual subtests, taking into account motor-related constraints and modality-specific demands.

4.4 Verbal and visuo-spatial modalities

When analyzing verbal and visuo-spatial modalities, the comparable abilities between verbal and non-verbal reasoning (general abilities) in children with uCP were consistent with previous literature (Ballantyne et al., 2008). For the bCP group, the significant differences between VCI and PRI indices are well documented in the literature and are related to the common impairments in visuospatial processing due to the parieto-occipital lesions characteristic of this form of CP (Ego et al., 2015; Fazzi et al., 2009; Pavlova & Krägeloh-Mann, 2013; Sigurdardottir et al., 2008).

4.5 Subtest-Level analysis

Considering the scores of the subtests within each intellectual index (third level of analysis), no discernible differences were observed between subtests of the VCI or WMI indexes. However, when focusing on the PRI, variations among subtests emerged across CP forms depending on motor functioning, as children with more impaired gross motor functioning showed greater discrepancies between the subtests and lower scores in all subtests than children with less impaired motor functioning.

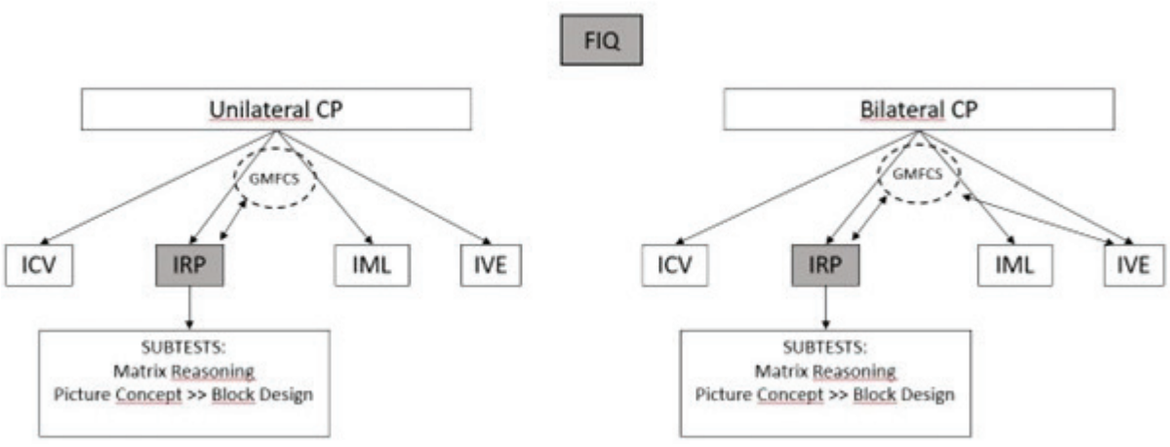
Block Design represents a particularly complex subtest, as it requires visuospatial analysis, visuoconstructive planning, fine motor dexterity, and timed execution. The subtest, which heavily relies on spatial awareness and fine motor manipulation, is more challenging than other PRI subtests that primarily involve visual representations (e.g., Coceski et al., 2021). In children with CP, motor impairments can slow performance independently of underlying cognitive abilities, making it difficult to disentangle visuospatial reasoning from motor execution demands. This aligns with previous research indicating that individuals with CP face challenges in tasks requiring both visuospatial processing and fine motor skills (Ito et al., 1997; Lorentzen et al., 2025; Sigurdardottir et al., 2008). In contrast, subtests such as Picture Concepts and Matrix Reasoning require minimal motor involvement, allowing a clearer estimate of cognitive abilities. Despite these challenges, Block Design remains clinically informative. Scores should be interpreted in the context of the child's motor profile and integrated with other indices and motor-free subtests. This approach allows clinicians to identify relative strengths and weaknesses, and to distinguish between limitations due to motor dysfunction versus cognitive abilities (Lorentzen et al., 2025). Therefore, although compromised, Block Design can provide valuable insights into the cognitive profile of children with CP when used as part of a multi-level, profile-based assessment.

Regarding PSI, no differences were observed among subtests; however, as expected, a significant effect of GMFCS levels was found, with children with more impaired gross motor impairment performing more poorly on both PSI subtests.

4.6 Clinical implications and interpretation guide

In light of these findings and of the proposed interpretation framework, some general considerations regarding the use of the WISC-IV in children with CP are warranted. The WISC-IV remains one of the most widely used instruments for the assessment of intellectual functioning in children with CP in clinical and educational settings. Understanding how motor impairment may differentially affect WISC-IV indices and subtests is of crucial importance. While WISC-IV scores reflect intellectual functioning, they may also be influenced by motor- and modality-related constraints, particularly in subtests with higher execution demands. This does not undermine the clinical utility of the instrument, but rather calls for a profile-based and hypothesis-driven interpretation. The multi-level analysis adopted in the present study, progressing from FIQ to intellectual indices and subtests, allowed to delineate which measures provide most informative insights into intellectual profiles of children with CP. This approach helps to identify indices and scores that do not exhibit intra-scale discrepancies and thus, are informative measures of intelligence and less affected by motor functioning. Based on these findings, the present study proposes, as represented in the flowchart in **figure 4**, a guide for interpreting intellectual assessment results in children with CP, according to CP forms and level of GMFCS. Specifically, in both unilateral and bilateral CP, FIQ does not represent a conclusive end-point of the intelligence assessment and, even when within normal limits, must be followed by the analysis of the indices and subtests where CP forms and motor impairments are likely to introduce differences. In the unilateral CP, both VCI and PRI are informative of the intellectual profile and generally preserved. However, the PRI should be interpreted with caution as performances in its subtests may vary depending on the degree of motor deficit. WMI and PSI represent the most compromised indices in the profile of uCP but still show good internal consistency within each index. In bilateral CP, VCI and WMI are informative indices of the intellectual profile, and they are generally preserved. In contrast, PRI and PSI are significantly affected and related to motor functioning and should therefore be interpreted with caution. Subtests with high motor demands, such as Block Design, exemplify the need for this cautious, profile-based approach. In the context of this multi-level approach, "interpret with caution" means that neither individual subtest scores nor broad global indices (e.g., FSIQ) should be used in isolation. Subtests may be influenced by motor or modality-specific demands, and global indices aggregate multiple processes, potentially masking discrepancies. Results should therefore be interpreted within the full profile—including indices, subtests, and motor-free measures—to delineate relative strengths and weaknesses and distinguish between limitations due to motor dysfunction versus underlying cognitive abilities. Motor-free measures are important tools to assess cognitive functioning in children with CP while minimizing the confounding effects of motor

Figure 4. *Flowchart to guide intellectual assessment, according to CP forms and level of GMFCS. Legend: in white the measures more unitary; in gray the measures that should be approached with caution*



impairments. Some subtests of the WISC-V offer partial solutions by reducing motor demands, but currently there are limited validated instruments that allow assessment of visuoconstructive skills or processing speed without requiring motor execution. This highlights a gap in the available cognitive assessment tools and underscores the need for careful, profile-based interpretation of WISC results, complemented by motor-free measures whenever possible. Using motor-free measures helps reduce the risk of underestimating abilities in children with motor delays and overestimating abilities when global indices mask profile discrepancies (Lorentzen et al., 2025). Placing more attention on these indices during assessments could provide insights into the cognitive profiles of children with CP, allowing clinicians to better distinguish between impairments related to motor dysfunction and those that reflect true cognitive challenges. This approach could guide more accurate diagnostic processes and the development of targeted interventions to support cognitive and functional outcomes.

4.7 Limitations and future directions

Despite the comprehensive multilevel analysis conducted in this study that can represent an enrichment of the existing literature, providing insights for clinical assessment of children with unilateral and bilateral CP, some limitations must be acknowledged. First, the sample size and inclusion criteria, while suitable for exploratory analysis within a relatively homogeneous group, may limit the generalizability of the findings, particularly in children with intellectual disabilities or more severe manual motor impairments. Second, the study's cross-sectional design restricts the ability to draw conclusions about the developmental trajectory of intellectual skills in children with CP. Longitudinal studies are needed to understand how these intellectual profiles evolve over time. Third, no detailed data were collected on lesion characteristics; future research with larger samples would be valuable in exploring potential interactions between intellectual profiles and specific lesion characteristics.

4.8 Conclusion

Overall, this study highlights the value of a multilevel approach to assessing intellectual functioning in children with CP. Considering both CP form and motor impairment allows for a more nuanced interpretation of intelligence scores and reveals how these factors interact to shape cognitive outcomes. This understanding is essential for developing targeted educational and therapeutic interventions that address the specific needs of each child.

Ethics approval and consent to participate

Parental consent/assent was appropriately obtained for all children participating in this study. The research was approved by the Tuscany Region Ethics Committee - Paediatric (Approval number: 209/2022). The study was conducted in accordance with the Ethical guidelines of the Italian Association of Psychology and the Declaration of Helsinki.

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Appendix 1.

Table A1. *Description of each WISC-IV indices and core subtests*

Index	Subtest	Description
Verbal Comprehension	Similarities	Child compares two words and explains their similarity—measures abstract verbal reasoning and concept formation.
	Vocabulary	Name pictured items and define words—assesses word knowledge, verbal concept formation, expressive language .
	Comprehension	Answer questions about social situations—tests verbal reasoning, common sense, and social judgment .
Perceptual Reasoning	Block Design	Reconstruct designs using blocks under time constraints—tests visual-motor coordination and spatial reasoning .
	Picture Concepts	Choose pictures that form a common category—assesses abstract, categorical reasoning .
	Matrix Reasoning	Complete visual matrices by selecting missing pieces—measures fluid, nonverbal reasoning .
Working Memory	Digit Span	Repeat numeric sequences forward/backward—evaluates attention and working memory .
	Letter-Number Sequencing	Recall mixed letters/numbers in specific order—measures working memory and sequencing .
Processing Speed	Coding	Transcribe symbols matching numbers under time pressure—assesses processing speed and visual-motor coordination .
	Symbol Search	Quickly scan and identify target symbols—measures attention and processing speed .

Appendix 2.

Table A2. *Descriptive statistics of the WISC-IV indices and subtests in the spastic uCP and bCP groups.*

		uCP		bCP	
		n	*M (SD)*	*n*	*M (SD)*
FIQ		24	90.54 (11.38)	23	85.78 (17.07)
Indices	VCI	24	94.08 (12.25)	24	99.08 (13.75)
	PRI	24	102.42 (11.31)	24	86.21 (21.68)
	WMI	24	85.25 (17.89)	24	90.75 (17.4)
	PSI	24	85.29 (12.21)	23	73.43 (14.19)
Subtests	Similarities	24	9.63 (2.34)	24	10.38 (2.63)
	Vocabulary	24	8.75 (2.49)	24	9.58 (2.60)
	Comprehension	24	8.63 (2.89)	24	9.58 (3.54)
	Picture concepts	24	10.71 (2.88)	24	8.88 (3.51)
	Block Design	24	9.25 (2.54)	24	5.96 (3.18)
	Matrix reasoning	24	10.79 (2.5)	23	8.92 (4.55)
	Digit span	24	7.08 (3.56)	23	8.13 (3.12)
	Letter-number sequencing	24	8.46 (3.06)	24	8.75 (3.49)
	Coding	24	7.29 (2.71)	23	4.78 (2.7)
	Symbol search	24	7.92 (2.54)	23	6.17 (2.87)

Appendix 3.

Table A3. *Differences between right lesion and left lesion in uCP at WISC-IV indices and subtests*

	uCP – lesion side		
	Right lesion	*Left lesion*	*p*
FIQ	93.73 (13.78)	87.85 (8.53)	.139
VCI	96.18 (14.49)	92.31 (10.26)	.838
PRI	104.09 (12.64)	101 (10.36)	.309
WMI	92.91 (18.77)	78.77 (14.82)	.042*
PSI	84.09 (11.82)	86.31 (12.93)	.519
Similarities	10.09 (3.08)	9.23 (1.48)	.702
Vocabulary	9.27 (2.41)	8.31 (2.56)	.317
Comprehension	8.64 (3.04)	8.62 (2.87)	.884
Picture Concepts	10.91 (2.88)	10.54 (2.99)	.748
Block Design	9.27 (2.9)	9.23 (2.32)	.977
Matrix Reasoning	11.18 (3.16)	10.46 (1.85)	.446
Digit Span	8.36 (3.7)	6 (3.19)	.086
Letter-number sequencing	9.73 (2.72)	7.38 (3.02)	.091
Coding	7.73 (2.37)	6.92 (3.01)	.553
Symbol Search	7.18 (2.09)	8.54 (2.79)	.364