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RESEARCH ARTICLE

Developmental profiles of young children with autism spectrum disorder and global developmental delay: A study with the Griffiths III scales

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Abstract

The purpose of this study was to identify developmental profiles associated with autism spectrum disorder (ASD) and global developmental delay (DD) in preschool aged Italian children. Developmental profiles were evaluated by means of a standardized tool widely used for the assessment of psychomotor development in early childhood, the Griffiths III scales, recently adapted and standardized for the Italian population. Specifically, we compared the Griffiths III profiles of children with ASD and DD (ASD + DD) with those of children with DD alone. Moreover, we inspected the psychometric function of single items by comparing children with ASD + DD and children with DD with typically developing (TD) children from the Griffiths III normative sample. In this way, we aimed to isolate the effects of each diagnostic class on psychomotor abilities and on the psychometric function of single items. The ASD + DD and DD groups were found to share the presence of lower age equivalent scores relative to their chronological age in all the developmental domains considered: *Foundations of Learning*, *Language and Communication*, *Eye and Hand Coordination*, *Personal–Social-Emotional* and *Gross Motor Skills*. However, the DD group displayed a homogeneous profile with similar levels of delay in all developmental domains, while children with ASD + DD exhibited relative weaknesses in the *Language and Communication* and *Personal–Social-Emotional* scales. The analysis of the psychometric function drawn for each item has confirmed different profiles in social-communicative and non-verbal items between the two diagnostic groups and in relation to TD normative sample. The Griffiths III is a valid psychometric tool for identifying atypical developmental profiles and its use may be recommended during the diagnostic process of ASD and DD, to detect specific strengths and weaknesses and guide person-centered treatment.

Lay Summary

The present study has provided evidence that Griffiths III is a useful tool for identifying specific developmental profiles of autism spectrum disorder (ASD) + global developmental delay (DD) and DD alone. Griffiths III may optimize the diagnostic process of neurodevelopmental disorders, help to early identify the risk of socio-communicative disorders in children suspected of having developmental disabilities, such as autism spectrum disorder and global developmental delay, and guide tailored treatments. The results of the present study have immediate

clinical relevance, supporting the definition of good practices in the diagnostic process. ASD, DD and the co-occurrence of these conditions leads to an elevated need for support in the domains of social competences, personal independence and daily living. Furthermore, there is a need for early identification with subsequent timely and tailored treatment that may reduce long-term costs for sanitary and social systems.

KEYWORDS
autism spectrum disorder, developmental profiles, global developmental delay, Griffiths III

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder with wide clinical heterogeneity, characterized by early onset of significant difficulties in social behaviors and communication, restricted interests, and repetitive patterns of behavior (APA, 2013). The etiological factors of ASD remain largely unknown (Masini et al., 2020; Yoon et al., 2020) and diagnostic markers are currently only behavioral (APA, 2013). According to the most updated United States data (Maenner et al., 2023), the average age of diagnosis is around 4 years, although early identification has increased over time (Shaw et al., 2021). A recent European survey of 2032 respondents across 14 European countries (Italy included) reports an average age of access to diagnostic services around 3 years (standard deviation of 17 months) and an average age of access to intervention services around 3.5 years, even though the first concerns usually arrive from parents and family members at around 18 months of age of the child later diagnosed with ASD (Bejarano-Martín et al., 2020).

One of the fundamental challenges for clinicians is to identify diagnostic tools that should be valid and reliable, and also suitable to intercept the individual variability intrinsic to early onset neurodevelopmental disorders and to early distinguish specific functional profiles[1] for different diagnostic classes. The most consistent and valid tools supporting ASD clinical diagnosis are tests based on parental report and structured play sessions designed to identify core features of ASD (Randall et al., 2018), such as Autism Diagnostic Interview-Revised (Lord et al., 1994) and Autism Diagnostic Observation Schedule-2 (Lord et al., 2012). Together with the assessment of core symptoms, the description of cognitive, psychomotor, behavioral, and daily-living adaptive functioning is very important during the diagnostic assessment to identify possible underlying intellectual disabilities in ASD, describe the functional profile in each developmental domain, determine the need for support and guide tailored treatments (Braconnier & Siper, 2021; Klinger & Renner, 2000). In fact, children with ASD often experience additional developmental disorders (APA, 2013) and DSM 5—oriented diagnosis requires clinicians to specify if the ASD is accompanied by limitations in intellectual or language functioning and/or associated with other neurodevelopmental, mental or behavioral problems, such as Attention Deficit and Hyperactivity Disorder, language and communication disorders, obsessive–compulsive disorders, mood-anxiety disorders and epilepsy (APA, 2013; Jacob et al., 2019). In particular, Intellectual Disability (ID) is present in 37.9% of children with ASD aged 8 years with information on cognitive abilities in the United States (Maenner et al., 2023) and is one of the most disabling ASD co-occurring conditions, being associated with reduced adaptive functioning in children (Hedvall et al., 2013; Lee et al., 2022) and reduced quality of life of caregivers (Vaz et al., 2021). ID is a condition characterized by significant limitations in both intellectual functioning and adaptive behavior during childhood or adolescence (APA, 2013). Tools for diagnosis of ID encompass both intelligence tests such as Wechsler Intelligence Scales (Wechsler, 2003, 2012) or Leiter International Performance Scale (Roid et al., 2013) and caregivers' reports about adaptive behavior levels such as Vineland Adaptive Behavior Scale (Sparrow et al., 2016) or Adaptive Behavior Assessment System (Harrison & Oakland, 2003). During early childhood, it is difficult to assess ID because children's abilities are quite variable and still subjected to modifications (Lee et al., 2022); therefore, children under 5 years of age with significant delay in more than one developmental domain, who are unable to undergo standardized intellectual evaluation, are instead diagnosed with global developmental delay (DD; APA, 2013; Shevell et al., 2003). DD is diagnosed when the child has at least two standard deviations below average in two or more developmental domains, namely gross or fine motor, speech/language, cognition, social/personal and/or activities of daily living (Shevell, 2008; Shevell et al., 2003), assessed with standardized developmental tests such as Griffiths Scales (Green et al., 2016;

[1]The term *developmental profile* in this paper is not used as "longitudinal", rather it is referred to profiles describing the level of acquired abilities in the most important developmental areas evaluated by developmental scales in young children (foundation of learning, language, eye-hand coordination, personal-social-–emotional and gross motor domains).
The term *psychomotor* is used with a similar meaning to "developmental", but refers more to abilities than profiles, since developmental scales measure psychomotor abilities.
The term *functional profile* refers to the general functioning of the child relative to his abilities and includes developmental profile and other aspects of child functioning such as behavior, intelligence and adaptive-daily living skills.

Griffiths, 1970; Stroud et al., 2016). The prevalence of ID/DD varies considerably at regional levels, ranging from 1% to 10% in high-middle income countries (Gil et al., 2020; Pinchefsky & Shevell, 2017; Zablotsky et al., 2019). Although ID and DD share complementary features and pre-school children with DD are at higher risk to present ID during school age, an infant or child with DD will not necessarily have ID in later years; in the same way, many children who have mild-to-borderline ID may have had an early development within the normal range and may not be identified until school age when the context (e.g., school) poses them higher requirements that they meet with difficulty (Carulla et al., 2011; Pinchefsky & Shevell, 2017). A combined diagnosis of ASD and ID/DD significantly impacts the need for support in the areas of social competences as well as personal independence and daily living (Green & Carter, 2014; Liss et al., 2001; Perry et al., 2009). Children with both ASD and ID/DD may make slower progress in their social development than those with ASD alone or ASD associated with language disorder only (Bennett et al., 2014; Zachor et al., 2007). Children of the first type tend to show worse long term cognitive outcomes (Hedvall et al., 2013), thus requiring earlier intensive intervention to promote their developmental progress (Hinnebusch et al., 2017).

ASD, ID/DD or a co-diagnosis of these conditions, represent a great challenge for the healthcare system: the early age onset, the wide phenotypic variability within the same diagnostic group and different special needs in several functional domains, require the activation of person-centered, specific and integrated therapeutic and assistance programs (Márquez-Caraveo et al., 2021). The early identification of specific and reliable developmental profiles associated with ASD and DD that could predict functional and adaptive outcomes together with other biological and environmental factors, represents the opportunity of modifying atypical developmental trajectories in the period of maximum cerebral plasticity in the 0–5 years range (Dawson, 2008; Lai et al., 2014; Remer et al., 2017), with a possible reduction of long term costs for the socio-sanitary system. In this framework, comparing the developmental profile of children with co-occurring ASD and DD and children presenting only DD could help to differentiate the two conditions, separating overlapping aspects (e.g., limitations in intellectual functioning) from features specific for ASD (e.g., challenges in communication and social interaction). Diagnostic criteria for ASD and DD both include some difficulties in communication as part of their core symptomatology; young children with DD may often lack early social communication skills, and may be difficult to be distinguished from children with ASD (Veness et al., 2014; Ventola et al., 2007). Thus, the challenge of the differential diagnosis is particularly relevant in young children, and clinicians would benefit from tools that could discriminate between the two conditions during the diagnostic process. To guide accurate diagnosis and functional assessment, the developmental profiles should be specific and derived from updated and standardized psychometric instruments, such as developmental and/or intellectual scales, to ensure the highest validity and replicability of data that can orient clinical etiopathogenetic investigations and therapeutic interventions.

To date, there is a limited number of studies in the literature investigating the functional and developmental profiles in ASD and ID/DD since early ages with the aim to identify predictive profiles that could differentiate the two conditions, support the process of differential diagnosis, inform individualized interventions and predict long-term functional outcomes. Some studies addressed differences in developmental profiles between ASD and other neurodevelopmental disorders confirming that social, linguistic and communication weaknesses differentiate ASD from other developmental disorders in general (e.g., Torrens & Ruiz, 2021), language disorders (Barbaro & Dissanayake, 2012; Delehanty et al., 2018; Özyurt & Eliküçük, 2018) and DD (Barbaro & Dissanayake, 2012; Delehanty et al., 2018; Mitchell et al., 2011). Moreover, school-age children with ASD without ID show an intellectual profile with better performances on visual than auditory, in particular working-memory, tasks (Audras-Torrent et al., 2021), confirming the strength in visual–spatial and abstract reasoning abilities and weaknesses in verbal abilities as a possible specific marker of ASD intellectual functioning. A recent case report on a child with ASD and mild global delay, provided evidence of a Griffiths III profile with peaks and valleys form, presenting extremely low scores in language-communication (B scale) and personal-social–emotional (D scale) scales and scores within the borderline range in the eye-hand coordination (C scale) and gross motor (E scale) scales (Jansen et al., 2020). Developmental scales, such as Griffiths scales, directly measure the child's psychomotor abilities in the most important developmental domains such as learning-cognitive abilities, language and communication, eye-hand coordination, personal-social and gross motor skills. They are particularly suitable for the investigation of functional profiles, given their strong feasibility and validity demonstrated in diagnostic and follow-up contexts (Barnett et al., 2004; Del Rosario et al., 2021; Green et al., 2020; Li et al., 2020; Scandurra et al., 2019), and they can replace the intelligence scales in describing both the global cognitive level and the specific psychomotor profile and guide the diagnostic characterization in preschool age children with ASD (Jansen et al., 2020). The updated version of the Griffiths scales, Griffiths III (Green et al., 2016; Stroud et al., 2016), has been recently adapted and standardized for the Italian population (Lanfranchi et al., 2019), and this makes the Italian context particularly suitable for the application of Griffiths III for clinical and research purposes.

The present study aimed to explore the developmental profile, as assessed with the Griffiths III, of Italian children with co-occurring ASD and DD (ASD + DD),

comparing the profile of children with ASD + DD with that of a group of children with DD but not ASD (DD). In a first analysis, we compared the mean Griffiths III profiles of children with ASD + DD with that of children with only DD (between scale comparison). In a second exploratory analysis at the item level (within scale comparison), we compared the psychometric functions (curves of difficulty) of each item obtained by children with ASD + DD, children with only DD and TD children from the normative sample used as a reference point. This analysis was carried out only for the items that have a satisfactory number of observations and allows to make inferences about the item difficulties distributions across different ages among the three groups. According to the characteristics of ASD + DD and DD, we expected lower age equivalent scores in both groups with respect to their chronological age in all the developmental domains considered. However, we expected different profiles in the two clinical groups: a flat profile, characterized by similar levels of delay in all developmental domains in children with only DD, and a peaks and valleys profile in children with ASD + DD, with relative weaknesses in the language-communication and personal-social–emotional domains. Moreover, we expected that the same specific weaknesses and strengths could be evident also when comparing the single items psychometric distributions between ASD + DD, DD and the TD normative sample.

METHODS

Participants

Seventy-four children aged between 6 and 68 months were involved in the study. Participants were recruited among children who were referred for clinical purposes to the Pediatric Neuroscience Department of Fondazione IRCCS Istituto Neurologico Carlo Besta between 2018 and 2021 (convenience sampling method). Inclusion criteria were having an age between 1 and 72 months (the normative age range of the Griffiths III) and having received clinical diagnosis of DD or ASD with DD according to DSM 5 (APA, 2013). A neurological exam was conducted by a child neurologist at the first visit, and included the assessment of the neurological functional domains of posture and muscle tone, reflexes, involuntary movements, coordination and balance, fine manipulation, sensory function, and cranial nerve function. Children with minor neurological signs at the clinical neurological exam, as defined by Hadders-Algra (2002) (e.g., difficulties with muscle tone regulation, posture, balance, coordination, mildly abnormal reflexes) were included, but children with suspected congenital or acquired disorder of the central nervous systems (e.g., with signs of cerebral palsy, muscular dystrophy or evidence of frank acquired neurological pathology) were excluded.

Participants were divided in two groups depending on the presence or absence of a concomitant diagnosis of DD and ASD: 39 children were in the ASD + DD group (MCA months = 42.6; SDCA months = 15.3) and 35 children were in the DD group (MCA months = 31.7; SDCA months = 16.5). Diagnosis of DD was given by experienced child neurologists and developmental neuropsychologists (Matilde Taddei, Sara Bulgheroni, and Chiara Pantaleoni) according to DSM 5 criteria that is, children presented developmental milestone delay in regards to more than one area of motor, speech and language, cognition, social functioning or activities of daily living, and confirmed by the presence of at least two developmental areas investigated by Griffiths III more than two standard deviations below average. For all the children, the diagnosis of ASD was given by the same experienced child neurologists and developmental neuropsychologists (Matilde Taddei, Sara Bulgheroni, and Chiara Pantaleoni) according to DSM 5 criteria, and confirmed by standardized ASD diagnostic instruments such as Autism Diagnostic Observation Schedule-Second Edition (ADOS-2) (Lord et al., 2012), Autism Diagnostic Interview-Revised (ADI-R) (Lord et al., 1994) and/or by Telemedicine-based ASD Evaluation Tool for Toddlers and Young Children (TELE-ASD-PEDS) (Corona et al., 2020; Wagner et al., 2021) or Brief Observation of Symptoms of Autism (BOSA) (Lord et al., 2020). TELE-ASD-PEDS and BOSA have been used for the assessment in time of social distancing in the lockdown period due to COVID-19 pandemic.

All of the children that participated in this study were Italian. Information about bilingual exposure and socio-demographic data of the clinical sample is given in Table 1. All the participants' parents gave their informed consent for personal data use for scientific aims before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki. The formal approval from the ethic committee and ethic code assignment are not required in accordance with current regulation.

TABLE 1 Socio-demographic characteristics of the two groups.

Variable	ASD + DD	DD
N (total)	39	35
Mean age months (SD)	42.6 (15.3)	31.7 (16.5)
Male/female	32/7	24/11
Preterm birth	7 (18%)	6 (17%)
Italian as L1	29 (74%)	34 (97%)
Only child	18 (46%)	13 (37%)
Mother education level (*n*)		
Graduate	9	12
College	13	12
Middle school	8	3
Unknown	9	8

Abbreviations: ASD + DD, autism spectrum disorder and developmental delay; DD, developmental delay; L1, first language; SD, standard deviation.

Moreover, with the purpose of comparing the development of children in the ASD + DD and DD group with typical development, the data of the normative sample of the Italian children from the Griffiths III were utilized. The procedures for sample recruiting, data collection and an extensive description of the sample have been published in the study for Italian validation and standardization of Griffiths III (Lanfranchi et al., 2019).

Measures

Griffiths III

All the participants were assessed using the Griffiths III scales (Green et al., 2016), a direct measure of child psychomotor development, in their Italian adaptation (Lanfranchi et al., 2019). The Griffiths III allows the assessment of 5 developmental domains (see Table 2 for a brief description of domains): *Foundations of Learning* (A Scale), *Language and Communication* (B Scale), *Eye and Hand Coordination* (C Scale), *Personal-Social–Emotional* (D Scale), and *Gross Motor Skills* (E Scale). In each scale, the items assess the main developmental milestones for that particular domain. The Griffiths III scales allow for the computation of a number of pooled scores. In order to avoid floor effect and following the suggestion by Toffalini et al. (2019) about the assessment of individuals with ID (and DD) to the purpose of this study raw scores were converted into Age Equivalent (AE) scores. Moreover, developmental quotients (DQ) were considered. Similar to the original version, the Italian adaptation of the Griffiths III showed high reliability, both in terms of internal coherence (with values ranging from 0.83 to 0.99 depending on the scale and age band considered) and test–retest (with values ranging from 0.96 to 0.99 depending on the scale considered). Moreover, high construct, convergent and discriminant validity were demonstrated (Lanfranchi et al., 2019).

TABLE 2 Griffith III scales.

Scale	Description
A. Foundations of learning	Measures the development of thinking, verbal and non-verbal cognition, memory, executive functions
B. Language and communication	Measures language development, including expressive language, receptive language, and communication skills
C. Eye–hand coordination	Considers fine motor skills, manual dexterity, bimanual coordination, and visual perception skills
D. Personal–Social-Emotional	Measures constructs relating to the child's developing sense of self and growing independence, interactions with others, adaptive behavior and aspects of early emotional development
E. Gross motor	Assesses postural control, balance, gross body coordination

Procedure

As for the two clinical sample of children with ASD + DD and DD, during the first visit to the Pediatric Neuroscience Department of Fondazione IRCCS Istituto Neurologico Carlo Besta, children who exhibited signs of neurodevelopmental disorder received an initial assessment of approximately 40 min by a pediatric neurologist, including current health, developmental history, family history, together with the neurological exam. For children suspected of presenting with ASD and DD, the neurologist scheduled a cognitive-behavioral evaluation including the administration of Griffiths III, either as outpatient or inpatient. On the day of the first appointment scheduled for the behavioral assessment a trained and qualified developmental neuropsychologist (Matilde Taddei and Sara Bulgheroni) completed the Griffiths III. The assessment was performed in a quiet examination room approximately 15 square meters in size and with no distracting objects. The Griffiths III administration and scoring was implemented according to the Italian adaptation and administration manual and normative data (Lanfranchi et al., 2019). A full Griffiths III evaluation takes approximately one and a half hours to complete. If a child had a lack of compliance due to emotional-motivational or attentive issues during the evaluation, a new appointment was made, but the evaluation had to be completed within 1 week. According to the clinical needs, the evaluation was completed with interviews and checklists administered to parents/caregivers and structured play sessions administered to the child. Procedures for the Griffiths III administration and data collection referred to the TD normative sample are extensively described elsewhere (Lanfranchi et al., 2019).

Data analysis

A Bayesian approach was adopted to all data analysis. It had the crucial advantage of facilitating the estimation process especially in the secondary analysis at the item level, by means of informed priors based on information drawn from the normative (typically developing) population (see details below). More generally, the advantages of a Bayesian approach encompass using any available prior information directly in the analysis, an emphasis on estimating parameters with uncertainty, and an emphasis on a probabilistic account of the phenomenon at hand rather than on simplified accept/reject inferential conclusions (e.g., Kruschke, 2015; Kruschke & Liddell, 2018). Bayesian models were estimated using the "brms" package of R (Bürkner, 2017), based on the STAN coding

language. All models were fitted using the MCMC Bayesian estimation method, with four chains each with 2000 iterations (the first 1000 iterations in each chain are discarded as warmups; so, the final models are based on 4000 samples). Evidence was examined via posterior distributions: the median values were considered as the point-estimates for parameters, while 95% Bayesian Credible Intervals (BCIs) were estimated using the quantile method. We interpreted parameters with their 95% BCIs excluding the null-value as likely different from zero and worth commenting.

The primary analysis examined whether mean profiles of scores might differ, in terms of level and shape, across the five scales between the ASD + DD and the DD group (between scales comparison). Mixed-effects models were used. The response variable was the age equivalent scores (an additional analysis was conducted on standardized scores), which were treated as measurements repeated by participants in each scale. Scale and group were entered as the fixed effects. The parameters concerning the effect of group and the scale x group interaction were examined. Random intercepts were set for participants. Very diffuse prior distributions were set for the parameters of the "scale" factor. Specifically, based on a loose default expectation of observing a flat profile (which is what we expect, by definition, in the general population), priors were set as normal with $M = 0$, and a large SD = 20, thus N (0, 20) (this prior is very weakly informed and centered on zero; we obtained the same results by using default uninformed priors of maximum likelihood estimation). Uninformed default priors were set for all other coefficients.

A secondary analysis was conducted on yes/no responses at the item level (within scales comparison). As responses were binomial, logistic regressions were used, with age equivalent as the predictor. We followed an IRT-like approach. We calculated the item characteristic curve (ICC) separately for each item and each group. The estimated parameter of interest for each item was the age equivalent at which the probability of a "yes" response for that item is 50% (there is no chance level). Unfortunately, starting and ending points meant that there were no complete observations for all participants in all items, as is normal for a test that assesses development. For the first and last items in each scale, there were even no observations at all. We calculated the ICCs only for items for which there were at least five observations, including at least one success and one fail, in at least one group. To facilitate estimation, informed Bayesian priors based on the TD population (i.e., the normative sample) were set for both intercept and slope in each model. For both coefficients, prior distributions were normal with their mean values equal to those estimated for the TD normative sample in a previous round of analysis, conducted with the same method but with completely uninformed, uniform default priors (and using actual age instead of age equivalent, as this is the normative sample). The SDs of the prior distributions used for the clinical groups were equal to 1.00 for the intercept (to avoid excessive leverage of the prior on the posterior distribution) and 0.50 for the slope. Additionally, the slope was bound to be positive (as we consider it as implausible that the probability of solving an item might decrease as children grow). All estimates for the secondary analyses were redone with uninformed default priors and the results are reported in the Appendix S1.

RESULTS

Between scales comparison

The primary analysis compared the age equivalent scores of the ASD + DD and DD group in the five Griffiths scales. The descriptive statistics are reported in Table 3.

The estimated mean scores with 95% BCIs are shown in Figure 1, along with all individual profiles. Overall, the mean difference in age equivalent between the two groups across the five scales was negligible, $B = 2.04$ months (95% BCI: −2.54, 6.56), slightly in favor of ASD + DD group. Since the ASD + DD group was older in terms of chronological age, the same difference was strongly negative when standardized scores were considered, $B = -17.64$ (−25.86, −9.41) as reported in Supplemental materials. A peaks and valleys profile emerged for the ASD + DD group with relative strengths in scales A—*Foundations of Learning*, C—*Eye and Hand Coordination*, and E—*Gross Motor Skills* and relative weaknesses in scales B—*Language and Communication* and D—*Personal-Social–Emotional* (Figure 1). Taking "scale A" as the intercept (as the one that assess cognitive development), the drop in scale B was $B = -8.10$ (−9.81, −6.39), scale C was nearly exactly equal, $B = 0.43$ (−1.34, 2.11), scale D again had a drop, $B = -6.35$ (−8.12, −4.67), and scale E was even slightly superior, $B = 3.16$ (1.40, 4.86). On the contrary, all discrepancies observed within the profile of the DD group were negligible in terms of magnitude (all Bs ranged between −1.01 and −3.05 taking "scale A" as reference), showing as a consequence a more homogeneous profile. Figure S1 shows the same profile calculated on standardized scores

TABLE 3 Mean (and standard deviation in parentheses) equivalent age in the two clinical groups for each scale.

Scale	ASD + DD	DD
A. Foundations of learning	23.61 (10.93)	21.23 (11.13)
B. Language and communication	15.49 (10.72)	18.83 (11.17)
C. Eye–hand coordination	24.00 (10.79)	20.23 (11.82)
D. Personal–social–emotional	17.23 (8.26)	19.11 (11.17)
E. Gross motor skills	26.74 (8.78)	18.17 (9.95)

Abbreviations: ASD + DD, autism spectrum disorder and developmental delay; DD, developmental delay.

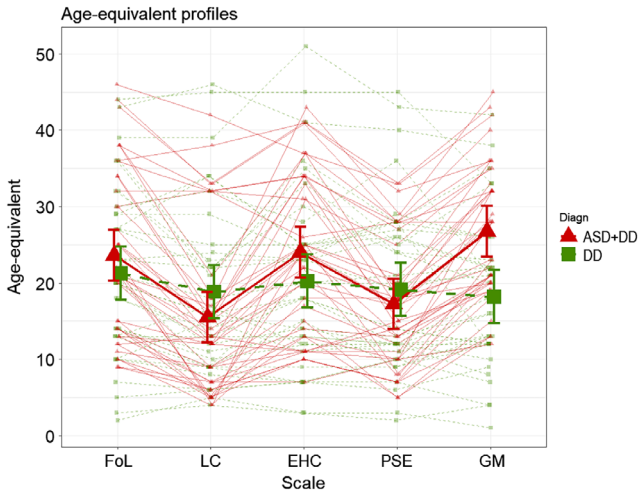

FIGURE 1 Estimated mean age equivalent scores by scale and group. Error bars represent 95% Bayesian Credible Intervals (BCIs) of the estimates. Small dots and lines on the background represent individual observations. ASD+DD, children with autism spectrum disorder and global developmental delay; DD, children with global developmental delay; EHC, eye and hand coordination; FoL, foundations of learning; GM, gross motor skills; LC, language and communication; PSE, personal–social-emotional.

(since many individual profiles were at floor, the average profiles appear slightly flatter).

Single items

The second explorative analysis compared the psychometric function (curve of difficulty) of each item for children with ASD + DD, DD and TD children belonging to the normative sample of the test. Figures 2–6 show the estimated values of the psychometric function for all items in all groups (provided when there are at least five observations, and the estimate is non-negative, which may happen for the TD normative sample in a few early items that are generally reached even in newborn children). Specifically, the figures show the estimated age (*chronological* age for the TD normative sample and age *equivalent* for children with ASD + DD and DD) at which each item has its ideal difficulty in that group (i.e., at which the probability of solution is estimated as 50%). BCIs are reported only when they did not span larger than 15 months, after which we considered the estimates as excessively unreliable. In the latter cases, we placed a white question mark over the dots in the figure and reported no BCIs, as a warning that the estimates must be taken with caution. Unfortunately, this was the case for most items, suggesting a paucity of data for this analysis (despite the informed priors). Nonetheless, for at least a few items information could still be drawn. To facilitate the interpretation of the graphs, the corresponding sub-domain referred to each item within each scale is reported (as abbreviation) next to each item's acronym.

The analysis drawn for each item generally confirmed a different pattern of performance between items requiring more social-communicative engagement and non-verbal items in the two diagnostic groups relative to the TD normative sample, revealing specific profiles also within each developmental scale and not only between scales as shown in the first analysis. For what concerns the *Foundations of Learning* (A scale), children with ASD + DD tended to perform at higher age equivalent than the TD normative sample in the first year items, that involve foundation of learning, visual attention, non-verbal reasoning and visual-perceptual abilities, mainly by means of material exploration and manipulation. Moreover, they tended to perform at a similar age equivalent than the TD normative sample second year items, mainly "hole form boards" involving non-verbal visuo-perceptual abilities. From the third year onward children with ASD + DD tended to perform at the same, or even at lower, age equivalent than the TD normative sample non-verbal visuo-perceptual and cognitive tasks, such as those that involve activities with "hole form boards" and blocks, while they tend to perform at higher age equivalent than the TD normative sample verbal cognitive and memory items that involve, directly or indirectly, language. Children with DD seemed to show a difficulty trend in the middle between children with ASD + DD and TD, that is they tended to perform the first items at a lower age equivalent than children with ASD + DD but at higher age equivalent than TD, while sometimes they performed the third year's items at a higher age equivalent than children with ASD + DD and quite similarly to the TD normative sample. In the *Language and Communication* scale children with ASD + DD tended to perform at higher age equivalent not only with respect to the TD normative sample but also with respect to children with DD the great majority of the items involving communicative intention and expressive and receptive language, highly related to social responsiveness and attention to voice, in particular in the first 3 years. In the *Eye and Hand scale* children with ASD + DD tended to perform at a higher age equivalent than the TD normative sample first year items. It is important to mention that these items, that mainly assess early fine motor abilities such as grasping, are performed in the interaction with the clinician, that for example offers to the child a wooden ring with a string and observes if the child grasps the ring (c1.6), reaches for ring and grasps (c1.9), resists adult who tries to take the ring (c1.8), grasps the string (c1.11). For the fine motor and bilateral coordination items from the second year onward, that require less interaction with the clinician to be performed (spontaneous appropriate use of the material is often automatic independently from verbal instruction, for example, blocks to stuck, ring on ring pole), children with ASD + DD tended to perform these items at the same age equivalent than the TD normative sample. However, children with ASD + DD tended to perform at lower age

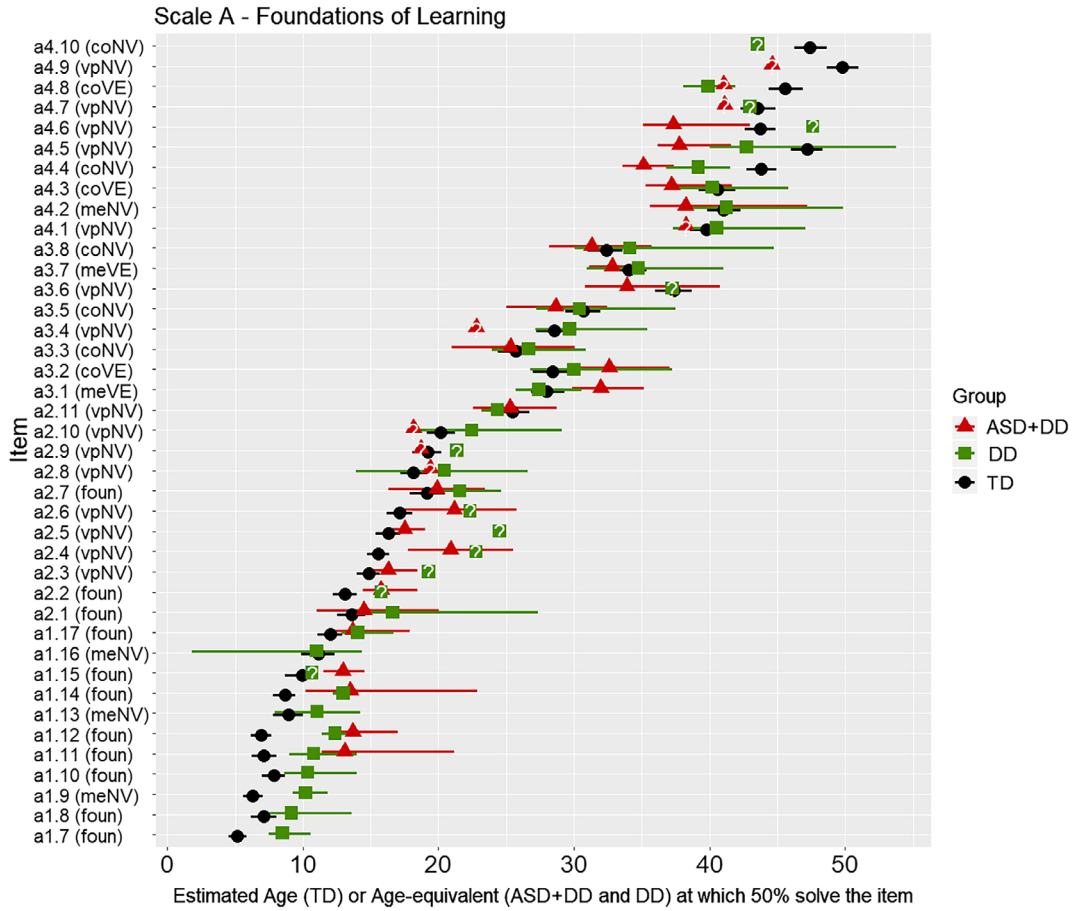

FIGURE 2 Scale "A"—estimated age at which an item is solved with 50% probability, divided by group. Error bars represent 95% Bayesian Credible Intervals (BCIs). Estimates with a white question mark "?" on them means that their 95% BCI are larger than 15 months and thus we considered them as unreliable. Estimates for ASD + DD and DD were computed with parameters from the typically developing normative sample (TD) curves used as informed Bayesian priors (see Section 2). Only items for which at least five observations in the autism spectrum disorder (ASD) + global developmental delay (DD) and/or DD group are shown. Estimates were computed only for items and groups where there were at least five actual observations. Dots with white question marks indicate that the estimates are highly unreliable and should not be taken with caution (see text for details). coNV, cognition nonverbal; coVE, cognition verbal; foun, foundations of learning; meNV, memory nonverbal; meVE, memory verbal; vpNV, visuo-perceptual nonverbal.

equivalent than the TD normative sample the items of the third and fourth year that involve bricks or blocks (e.g., c3.1 blocks; c3.3 tower of bricks) or drawing (e.g., c3.6 vertical strike; c3.9 horizontal strike; c4.1 copy a circle). The trend of children with DD was similar to that described for scale A *Foundation of Learning*, somehow in between children with ASD + DD and TD. In the *Personal Social Emotional* scale children with ASD + DD tended to perform at higher age equivalent not only with respect to the TD normative sample, but also with respect to children with DD the great majority of the items assessing social, personal and emotional development. Finally, for what concerns the *Gross Motor scale* from the second year onward children with ASD + DD tended to perform at a lower age equivalent than the TD normative sample (and children with DD) items that assess coordination and balance skills such as running (e2.8, e3.4), climbing stairs (e.g., e2.6, e2.7), throwing a ball (e.g., e2.14, e3.2), jumping (e.g., e4.1, e4.3).

By way of illustration of the single item analysis, Figures 7, 8 show examples of the psychometric function (ICC) drawn for two items, one in which the group with ASD + DD is estimated as reaching the criterion at a lower age equivalent than the TD normative sample, and the other in which the group with ASD + DD is estimated to reach the skill at an higher age equivalent. Figure 7 shows that, for item a4.4, "draw a person" the group with ASD + DD reached the criterion (i.e., 50% probability of positive solution) at about 34 months of age equivalent, while the TD normative sample reached it at about 43 months of age equivalent. Figure 8 shows that, for item b2.12, "use two word sentences" the criterion is reached at around 32 months of age equivalent by the group with ASD + DD, and at about 25 months of age equivalent by the TD normative sample.

All analyses on items were replicated with uninformed default priors and the results were comparable as reported in Figures S2–S8.

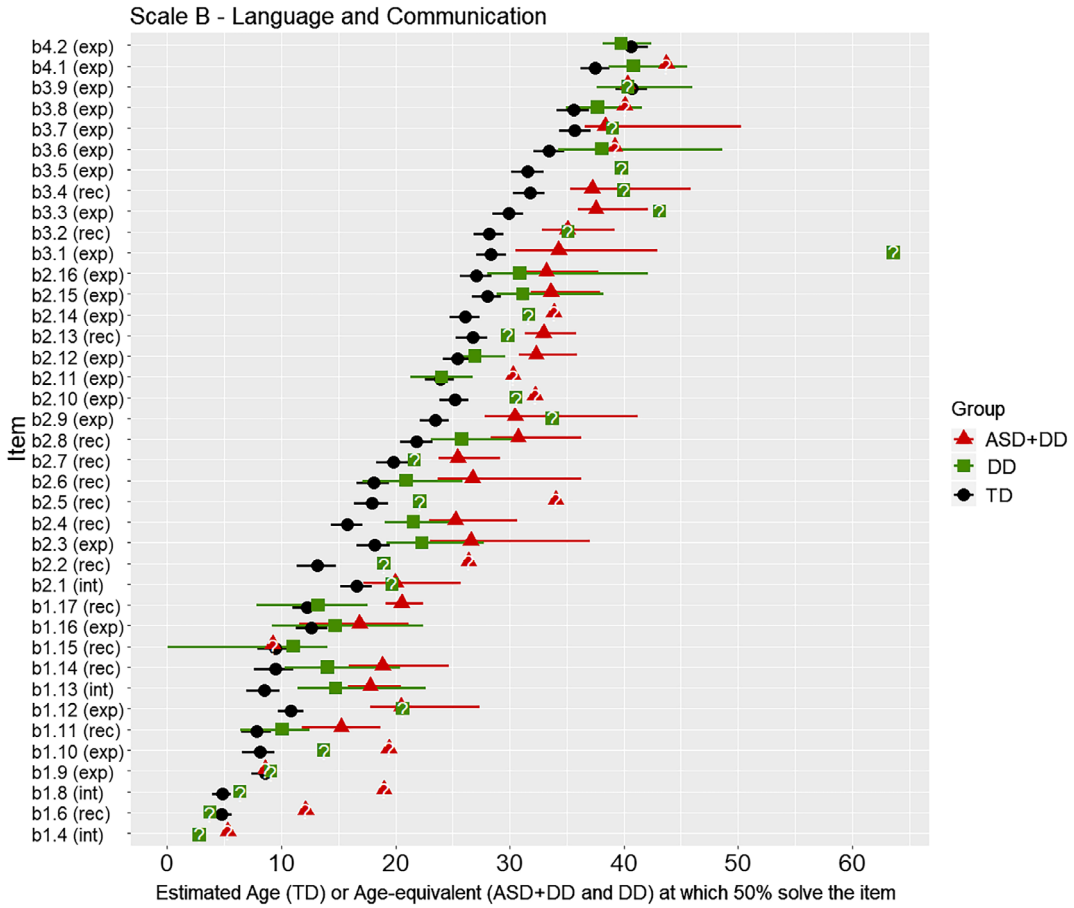

FIGURE 3 Scale "B"—estimated age at which an item is solved with 50% probability, divided by group. See Figure 2 caption for details. Estimates were computed only for items and groups where there were at least five actual observations. Dots with white question marks indicate that the estimates are highly unreliable and should not be taken with caution (see text for details. exp, expressive language; int, intention to communicate; rec, receptive language.

DISCUSSION

The purpose of the present study was to identify the developmental profiles associated with ASD + DD and DD in pre-school aged Italian children. To assess the developmental profiles, we administered the Griffiths III scales, a standardized tool for the assessment of neurodevelopment in early childhood, recently adapted and standardized for the Italian population. By means of dual comparison of children with co-diagnosis of ASD and DD with children with DD alone, having as a reference point TD children of the Italian normative sample, we have pointed at isolating the effects of each diagnostic class on psychomotor developmental profiles. As expected, the two diagnostic groups ASD + DD and DD shared the presence of lower age equivalent scores with respect to their chronological age in all the considered developmental domains. This is coherent with the core clinical characteristics of DD, with a child presenting a significant delay in reaching the developmental milestones compared to other children of the same chronological age. Moreover, in line with our hypothesis, the between scales analysis has shown different developmental profiles in the two diagnostic groups: the group with DD displays a homogeneous profile with similar levels of delay in all developmental scales, while children with ASD + DD show relative weaknesses in *Language and Communication* and *Personal-Social–Emotional* subscales.

An explorative analysis was implemented at the single item level to compare the distribution of age equivalent at which each psychomotor acquisition is reached in children with ASD + DD and children with only DD, comparing them with the TD normative sample of the normative sample (within scales analysis). This analysis, despite being cross-sectional and therefore not specifically referring to the longitudinal trajectories of psychomotor acquisitions, allows to make inferences about the item difficulties distributions across different ages among the three groups. The analysis of the psychometric function drawn for each item confirmed different pattern of performance in social-communicative and non-verbal items among the two diagnostic groups with respect to the TD normative sample: in visuo-perceptual, fine-

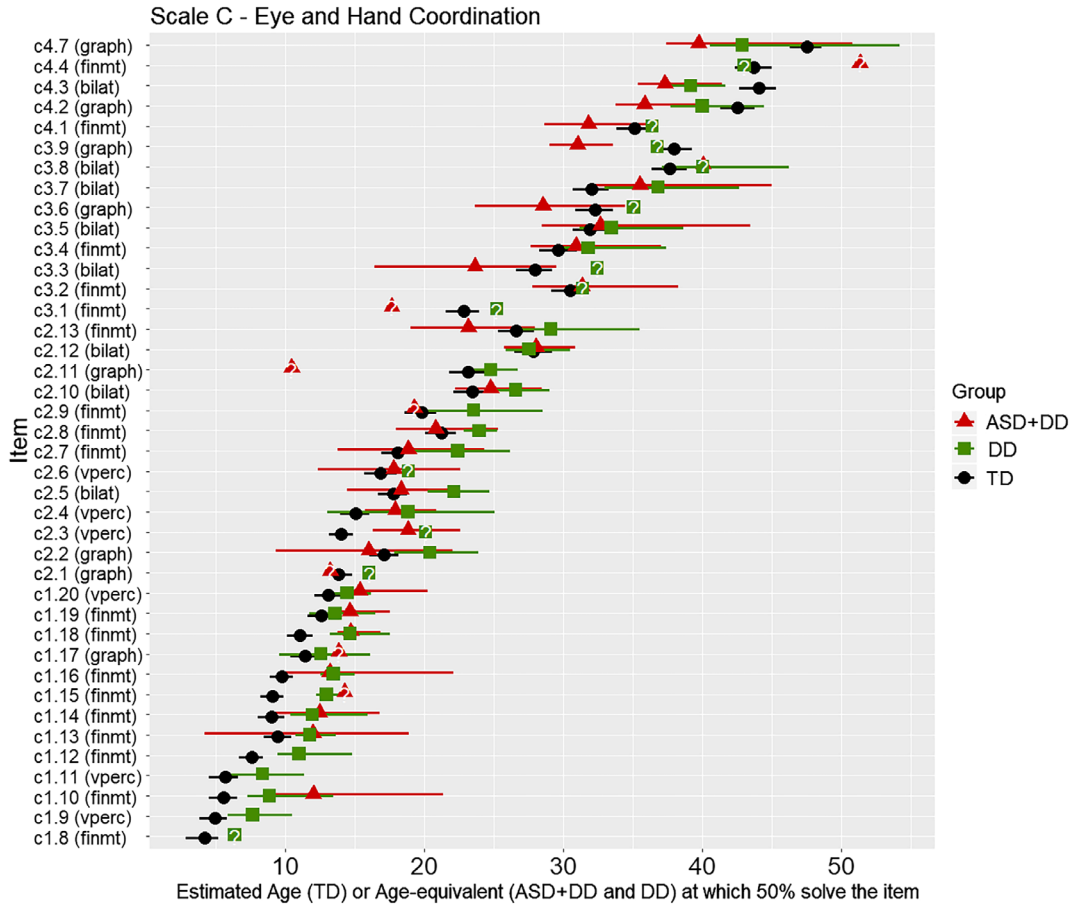

FIGURE 4 Scale "C"—estimated age at which an item is solved with 50% probability, divided by group. See Figure 2 caption for details. Estimates were computed only for items and groups where there were at least five actual observations. Dots with white question marks indicate that the estimates are highly unreliable and should not be taken with caution (see text for details). bilat, bilateral coordination; finmt, fine-motor; graph, graphomotor; vperc, visuoperceptual.

motor, non-verbal reasoning and non-verbal cognitive items (for example, blocks assembly, constructive and visuo-motor abilities, color matching, form board solving) children with ASD + DD were found to acquire abilities at a lower age equivalent than children with DD but also than the TD normative sample, and this is particularly true for the items referred to the second, third and fourth years of age, that require assembling blocks, perceptive matching, forms-boards, drawing a person, requiring less interaction with the examiner. This pattern is well exemplified by Figure 7. On the contrary, children with ASD + DD acquire abilities that involve language (for example, communicative vocalization, object and verbal concept identification, digit span) or that require interaction with the examiner (for example, showing shared enjoyment, obey to simple instructions) at a higher age equivalent than the TD normative sample and the DD group, confirming a specific profile of this domain in the two diagnostic groups, well exemplified by Figure 8. Thus, the different pattern of performance in verbal (and socio-communicative) versus non-verbal developmental domain among the two diagnostic groups is evident not only comparing different scales, but also comparing items requiring verbal (and socio-communicative) versus non-verbal processing within the same scale. This is particularly evident in the Scale A *Foundation of Learning* (Figure 2), investigating cognition, memory and learning abilities by means of both verbal and non-verbal tasks. This item-level analysis should be considered explorative since few items have a satisfactory number of observations, but it still supports clinical evidence and may pave the way for future more systematic studies in this direction. For example, to conduct further factorial analyses on the *Foundation of Learning* Scale providing separated psychometric measures of verbal and non-verbal abilities related to cognition, learning and memory, may enable a more accurate definition of the functional profile and increase the clinical predictive power of the developmental scale with respect to future intellectual disability.

The results of the present study confirm that children with ASD + DD present weaknesses in social and communicative psychomotor developmental domains since early years (Li et al., 2020), and that social and

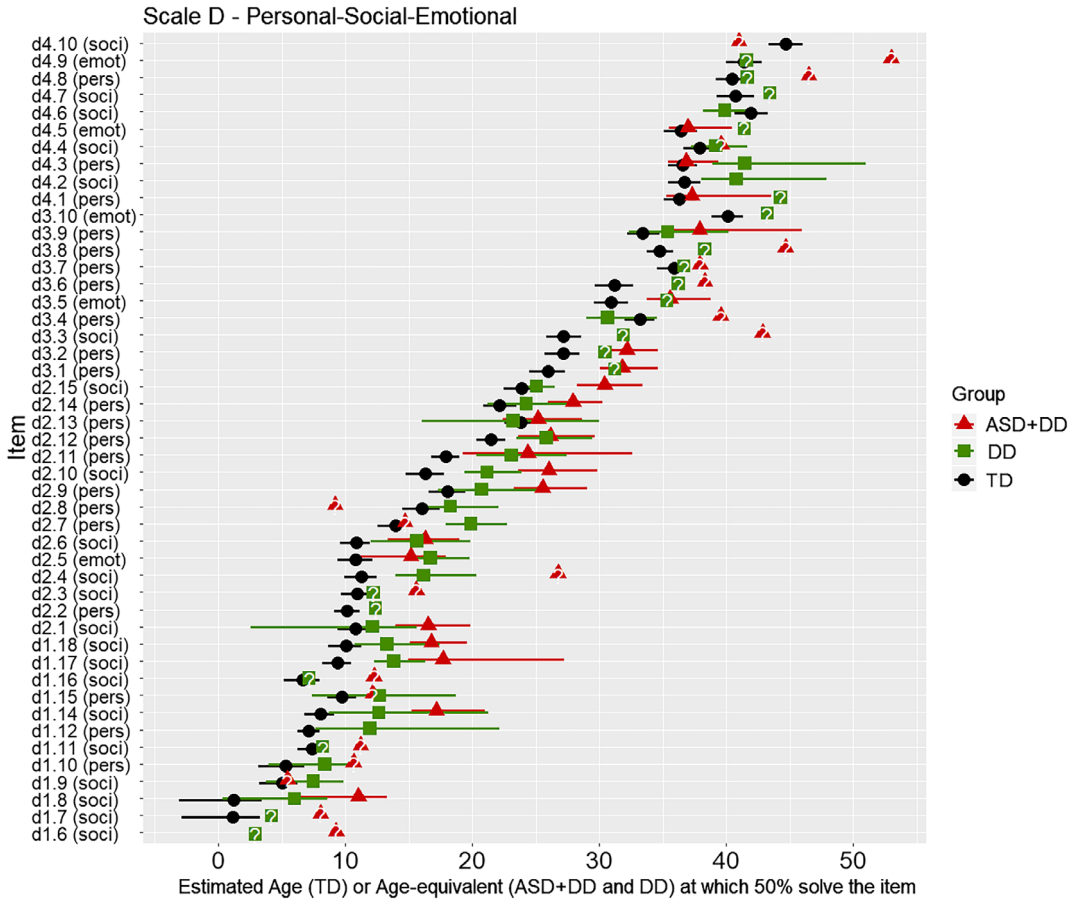

FIGURE 5 Scale "D"—estimated age at which an item is solved with 50% probability, divided by group. See Figure 2 caption for details. Estimates were computed only for items and groups where there were at least five actual observations. Dots with white question marks indicate that the estimates are highly unreliable and should not be taken with caution (see text for details). emot, emotional; pers, personal; soci, social.

communicative abilities measured at early ages may differentiate children with ASD + DD from that with only DD, and from typically developing children (Delehanty et al., 2018). Young children with co-diagnosis of ASD and DD were found to not only present with some degree of language delay with respect to their peers, but also specifically lack social bases of language (for example, use of gestures, facial expressions, imitation, joint attention and eye-contact) and thus are at risk for weaker/atypical language development and verbal learning (Torrens & Ruiz, 2021). This aspect differentiates children with ASD + DD from children with ASD with fluent language and without intellectual disability, which may present sufficient development of imitation, joint attention, use of gestures, words and phrases to communicate around their special interests, but present subtler difficulties in the social use of language (Lord et al., 2022). Differently, in children with DD but not ASD, despite the presence of some degree of delay in expressive and receptive language, the acquisition of joint attention skills, social responsiveness, social referencing and social imitation leads to better responsiveness to language, drawing them closer toward the path of typical development (Barbaro & Dissanayake, 2012). For what concerns the non-verbal domain, children with ASD + DD display a slowdown with respect to children with DD in the items of the first year of life, caused by a reduced, repetitive or disorganized initiative toward objects and the environment. This trend seems to be recovered in subsequent items (second and third years), in relation to the greater interest in visuo-perceptual processing and activities compared to the verbal ones, facilitating compensation strategies that favor learning and success in tasks mediated by visual-perceptual support, not requiring direct and constant interaction with the examiner. It has been widely described that social and communication concerns for children with suspected ASD become evident very early during development, between 12 and 18 months of age (Salgado-Cacho et al., 2021; Plate et al., 2022), with some early signs also before (Chericoni et al., 2016; Davidovitch et al., 2018) and are the target of early intervention to at-risk infants. On the other hand, children with ASD notably benefit by the presentation of visual support during cognitive performances (Samson et al., 2012); moreover, relative strengths in visuo-spatial and abstract reasoning and visual working memory have

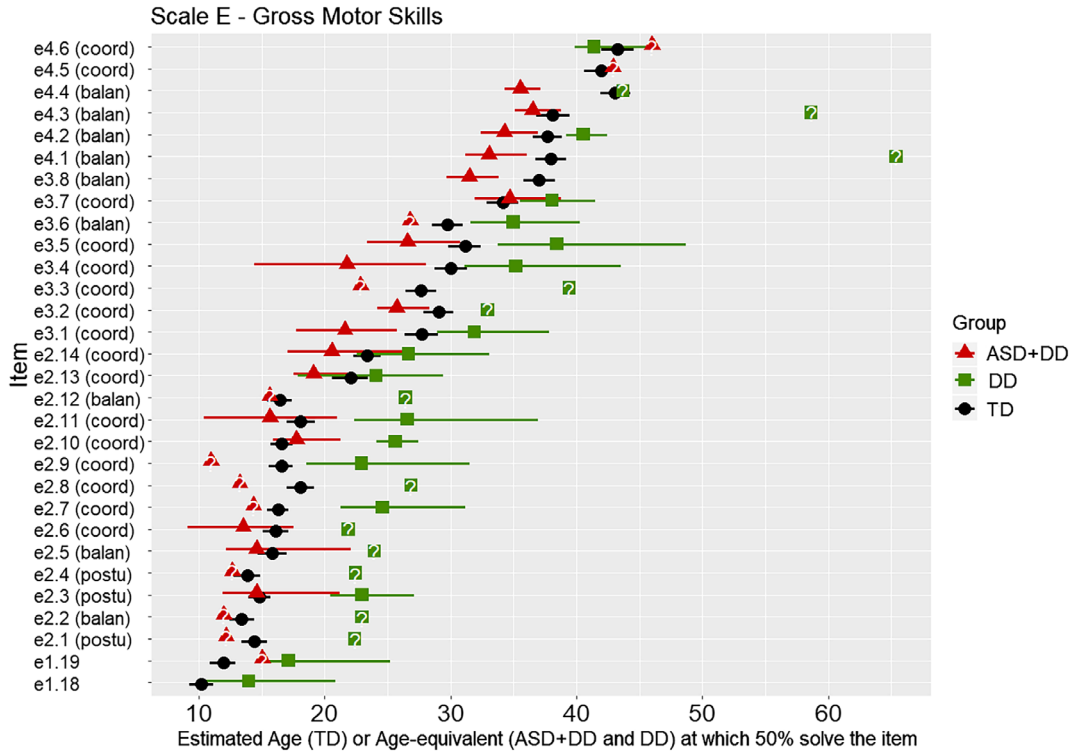

FIGURE 6 Scale "E"—estimated age at which an item is solved with 50% probability, divided by group. See Figure 2 caption for details. Estimates were computed only for items and groups where there were at least five actual observations. Dots with white question marks indicate that the estimates are highly unreliable and should not be taken with caution (see text for details). balan, balance; coord, coordination; postu, postural.

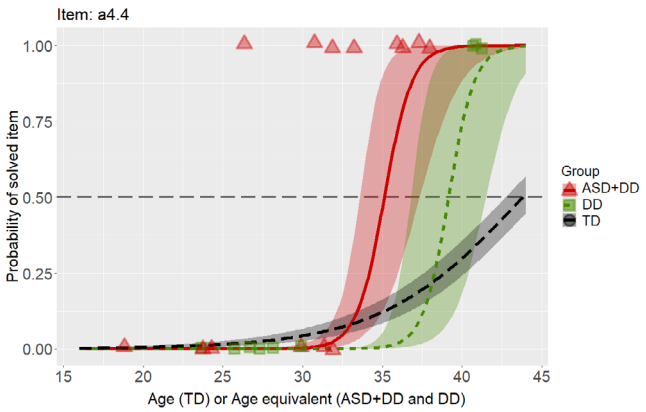

FIGURE 7 Example of psychometric function for an item in which both autism spectrum disorder (ASD) + global developmental delay (DD) and DD group are estimated as reaching the 50% criterion at lower equivalent age than the TD normative sample. Curves for ASD + DD and DD are estimated using parameters from the TD curve as informed Bayesian priors (see Section 2). Shaded areas represent 95% Bayesian credible bands. Dots represent fail (0) and success (1) observations for ASD + DD and DD.

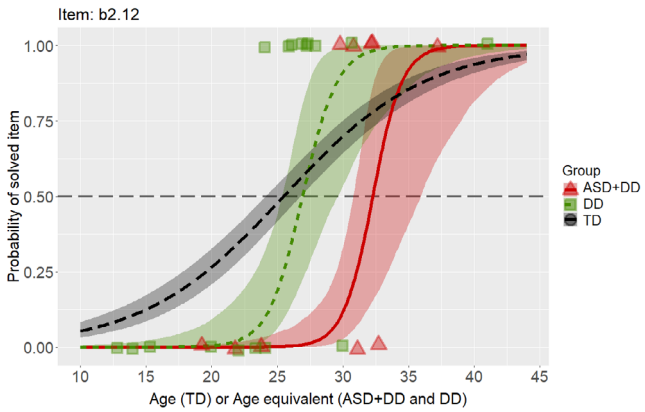

FIGURE 8 Example of psychometric function for an item in the autism spectrum disorder (ASD) + global developmental delay (DD) group (but not the DD group) is estimated as reaching the 50% criterion at higher equivalent age than the TD normative sample. Curves for ASD + DD and DD are estimated using parameters from the TD curve as informed Bayesian priors (see Section 2). Shaded areas represent 95% Bayesian credible bands. Dots represent fail (0) and success (1) observations for ASD + DD and DD.

been described in children with ASD at different ages as a possible specific marker of their intellectual functioning (Audras-Torrent et al., 2021; Mouga et al., 2020). The presence of communicative and social weaknesses and non-verbal strengths in children with ASD, both in terms of age equivalent comparisons and single items psychometric distributions, described in our study, confirms that the core features of ASD translate into a specific psychomotor functioning profile already evident in pre-school age also in children with co-occurring ASD and DD.

From a methodological point of view, the present study provides evidence of the Griffiths scales' efficacy in describing and discriminating specific psychomotor profiles related to discrete diagnostic classes in pre-school

aged children. The Griffiths III, and its recent Italian standardization, is confirmed as a tool valid for the ASD diagnostic phase, more often occurring around 3–4 years of age, and suitable to describe the profile of functioning and provide information on the concomitant presence of language and/or psychomotor-intellectual disability, necessary to guide both the clinical investigations and therapeutic interventions. Moreover, Griffiths III seems to be effective in identifying specific psychomotor profiles and may be used, together with other ad-hoc early detection instruments, to early intercept risks for socio-communicative disorders in children with suspect ID/DD (Delehanty et al., 2018; Thurm et al., 2019). Children with DD display considerable variability in their communicative and adaptive functioning, at least partly due to the large number of potential underlying causes, but their developmental delays may be more likely to persist into subsequent age periods than those of children with specific developmental delay (e.g., language delay alone, Everitt et al., 2013; Thomaidis et al., 2014), and a co-diagnosis of DD and ASD predicts worse functional and adaptive outcomes in social, communicative and daily living skills (Hedvall et al., 2013). On the other hand, to specifically explore early developmental profiles in children with ASD and a co-diagnosis of DD is particularly important, since non-verbal cognitive abilities seem to be strongly related to later language acquisition in children with ASD (Mouga et al., 2020) and early interventions on social abilities such as imitation, joint attention, eye-contact, social orientation and responsivity may lead to significant improvement not only in verbal but also in general cognitive and adaptive abilities (Colombi et al., 2018; Lin et al., 2020). In this vein, thanks to their specificity in describing the skills' profile, the Griffiths III are a particularly useful tool to define individualized goals for intervention.

The present results have immediate impact on the clinical practice: in fact, collecting evidence about psychometric behavioral instruments may optimize the diagnostic assessment improving the ability to early intercept the socio-communicative risk in children suspected of having global developmental delay. Continued efforts to characterize the early development of children screened and diagnosed through differing methodological approaches are needed to inform our understanding of the larger, overall population of children with neurodevelopmental disorders. Moreover, the present results may be helpful to clarify to parents and teachers the core and early functional correlates of specific neurodevelopmental conditions such as socio-communicative disorders, and to guide tailored individual plans since early childhood, with the aim to optimize the developmental trends and longitudinal outcomes. For example, both children with ASD + DD and DD could benefit from being clear and specific when giving instructions, break down tasks in small steps, set consistent classroom and domestic routines, giving opportunity to success and to be praised and reinforced. On the other hand, parents and teachers of children with ASD or suspected ASD should be aware that the child would benefit even more by visual rather than verbal cues for learning, thus it could be useful to demonstrate the task or using another child as a model to demonstrate the correct behavior, using a visual schedule, video or poster to help the child understand what is expected.

Limitations of the present study are mainly represented by the convenience sampling method, as often revealed in clinical studies: the need to select the participants during clinical practice has limited the apriori selection and balancing of the sample (e.g., excluding children with minor neurological signs or screened for neurogenetic syndromes, balancing the samples with respect to sex/gender, age and bilingualism) and has caused the paucity of data for the single items analysis resulting in several excessively unreliable estimates. While the sex/gender distribution of our clinical samples is quite representative of male to female ratio in ASD and DD populations (3.1:1), in our ASD + DD sample only 74% of children have Italian as first language: bilingualism may interfere with testing administration and should be controlled in future studies. Moreover, the numerosity of clinical samples is limited, and for this reason the results remain at an exploratory level. Further studies with broader samples are needed in order to generalize the obtained results. In particular, the inclusion of a further clinical sample of children with ASD without DD could allow to control for the possible addictive effect of ASD and DD on social-communicative difficulties and to confirm that the specific grade of social weakness is caused by the single presence of ASD, rather than by the addictive impact of ASD and DD. The sample recruiting during the pandemic period did interfere with the application of instruments for directly assessing core symptoms of ASD, such as ADOS-2, which have been occasionally replaced by tools for ASD assessment in times of social distancing; thus, the assessment for ASD could not be consistent across participants. Finally, future studies should provide indices of informant-based levels of adaptive functioning (e.g., Vineland Adaptive Behavior Scales or Adaptive Behavior Assessment Systems), to investigate how the identified developmental profiles may predict the adaptive functioning.

In conclusion, the present study has provided evidence that Griffiths III are useful for identifying specific developmental profiles of autism spectrum disorder associated to global developmental delay and of global developmental delay alone. The Griffiths III may optimize the diagnostic process of neurodevelopmental disorders, help to early identify the risk of socio-communicative disorders in children suspected of having developmental disabilities, and guide person-centered treatments.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

All the participants' parents gave their informed consent for personal data use for scientific aims before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki.The formal approval from the ethic committee and ethic code assignment are not required in accordance with current regulation.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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