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Differences in Visuospatial Processing in Individuals With Nonverbal Learning Disability or Autism Spectrum Disorder Without Intellectual Disability

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Objective: Although previous reports produced converging empirical evidence of a core deficit on visuospatial processing in children with a nonverbal learning disability (NLD), few studies compared the visuospatial profile of individuals with an autism spectrum disorder (ASD) or NLD in visuoconstructive and visuospatial working memory tasks. Nor did any of these studies investigate the role of the local bias, typically observed in ASD, when comparing these clinical groups. The present study aimed to analyze whether NLD and ASD share any characteristics. ***Method:*** A group of participants with NLD ($n = 17$) was compared with another group who had ASD ($n = 17$) without intellectual disability (ID), and without a peak in visuospatial intelligence, and with a control group ($n = 17$). Participants aged from 8 to 18 years performed a visuoconstructive and a visuospatial working memory task in which global–local processing styles were manipulated. ***Results:*** The analysis of their visuospatial processing clearly distinguished between the neuropsychological profiles of the group with ASD without ID and the group with NLD: the latter performed less well than the former in all domains. The participants with ASD without ID had a more heterogeneous visuospatial profile, showing a diminished sensitivity to perceptual cohesiveness only in the visuoconstructive task. ***Conclusions:*** Examining different visuospatial domains and manipulating the cohesiveness of the stimuli might be useful for better discriminating between NLD and ASD without ID.

General Scientific Summary
This study is the first to compare participants with a diagnosis of NLD with individuals with ASDs without ID on visuospatial tasks in which a global or local analysis of the stimuli was manipulated. The results revealed that participants with NLD performed less well than individuals with ASDs in all the visuospatial tasks, irrespective of the global or local configurations of the stimuli. Visuospatial processing skills could therefore facilitate the distinction between these two profiles.

Keywords: visuospatial processing skills, nonverbal learning disability, autism spectrum disorder, high-functioning autism

Until now, the nonverbal learning disability (NLD) has not been recognized as a neurodevelopmental disorder by the international classification systems (*Diagnostic and Statistical Manual of Mental Disorders*–fifth edition [*DSM–5*], American Psychiatric Association, 2013; International Classification of Diseases–10th edition, World Health Organization, 1992), probably due to a lack of consensus on how it should be diagnosed (Cornoldi, Mammarella, & Fine, 2016; Mammarella, & Cornoldi, 2014). The absence of clear, shared criteria for its diagnosis may also explain why it has been confused with other neurodevelopmental disorders sharing some (but not all) of its symptoms. It had been noted in the past that Asperger syndrome resembles NLD in many respects (Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Rourke, 1995). Both conditions were known to be characterized by deficits in social function, pragmatics of language, and motor skills. These clinical similarities led some researchers to wonder to what extent the two conditions overlap (Klin et al., 1995). More recently, however, Ryburn, Anderson, and Wales (2009), and Nydén et al. (2010) came to the conclusion—using two different methods—that Asperger syndrome and NLD are two different conditions. Williams, Goldstein, Kojkowski, and Minshew (2008) also found that the discrepancy between verbal and visuospatial intelligence considered typical of NLD could be found in only 18% of their sample of individuals diagnosed with high-functioning autism. It is

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worth noting, however, that Ryburn et al. (2009); Nydén et al. (2010), and Williams et al. (2008) did not compare samples of individuals with NLD directly with samples of individuals with Asperger syndrome or high-functioning autism; they only tested participants with this latter condition.

In the *DSM–5* (American Psychiatric Association, 2013), Asperger syndrome and high-functioning autism have been placed in the same dimensional category, along a continuum labeled autism spectrum disorder (ASD). This international classification system allows for a distinction between cases of ASD with or without intellectual or language impairments. On these grounds, we cannot say whether NLD and ASD without intellectual disability (ID) are different conditions. To complicate matters further, there are still no shared criteria for diagnosing children with NLD (as mentioned earlier).

Nonverbal Learning Disability

NLD was first described by Johnson and Myklebust (1967) in referring to children with visuospatial difficulties who revealed problems when learning or encoding through pictures, processing gestures or motor patterns, and orienting themselves in space. Additional impairments were described in their social perception and regulation of attention. Rourke (1989, 1995) subsequently developed a model, grouping the assets and deficits of children with NLD into three main areas: neuropsychological, academic, and social-emotional/adaptational. In his later studies (Pelletier, Ahmad, & Rourke, 2001; Rourke, 2005, 2008), however, Rourke used *nonverbal syndrome* as an umbrella term covering different conditions and disorders (including Asperger syndrome), thereby prompting some skepticism (see, e.g., Spreen, 2011). In recent years, a remarkable effort has been made by researchers to identify criteria for diagnosing children who struggle with visuospatial and academic problems, and who may have social problems too. In particular, two systematic reviews (Fine, Semrud-Clikeman, Bledsoe, & Musielak, 2013; Mammarella & Cornoldi, 2014) were published as a first step toward finding a consensus on the inclusion and exclusion criteria for NLD. Cornoldi et al. (2016) finally suggested the following: (a) deficits of nonverbal intelligence together with average or above-average verbal intelligence; (b) weaknesses in at least two of the following visuospatial processing abilities—analysis and recognition of organized forms (Chow & Skuy, 1999; Semrud-Clikeman, Walkowiak, Wilkinson, & Christopher, 2010), reproduction of drawings by copying (e.g., in visuoconstructive tasks) or from memory (Semrud-Clikeman et al., 2010), and recall and manipulation of temporarily available visuospatial information (Garcia, Mammarella, Tripodi, & Cornoldi, 2014; Mammarella, & Cornoldi, 2005b); and (c) clinical and/or psychometric weaknesses in at least one of the following areas—fine motor abilities (Semrud-Clikeman et al., 2010), academic achievement in activities involving visuospatial skills (e.g., such as mathematics; Mammarella et al., 2013; Mammarella, Giofrè, Ferrara, & Cornoldi, 2013; Mammarella, Lucangeli, & Cornoldi, 2010) or the comprehension of visuospatial relationships and descriptions (Mammarella, Meneghetti, Pazzaglia, & Cornoldi, 2015; Mammarella et al., 2009); and nonverbal communication (Cardillo, Garcia, Mammarella, & Cornoldi, 2017).

Studies Comparing NLD With ASD Without ID

To the best of our knowledge, few studies have compared NLD directly with ASD without ID. Semrud-Clikeman et al. (2010) compared an NLD group with children who had ASD or ADHD on several neuropsychological tasks. They found the children with NLD more impaired than those with ASD without ID on measures of visuoconstructive skills, such as the visual–motor integration test (Beery, & Buktenica, 2006), and the Rey–Osterrieth complex figure test (Rey, 1941, 1968), and also on measures of visual perception, such as the judgment of line orientation test (Benton, Sivan, Des Hamsher, Varney, & Spreen, 1994). The NLD and ASD without ID groups' performance was similar in the fluid reasoning subtests, and in a test of spatial reasoning from the Woodcock–Johnson Cognitive III test set (Woodcock, McGrew, & Mather, 2001). When Semrud-Clikeman, Fine, and Bledsoe (2014) administered the same tasks to another sample of children, however, they found that the NLD group's performance was only worse than that of the ASD group in the spatial relations task. This latter finding supports the hypothesis that NLD weaknesses in reasoning tasks relate mainly to the manipulation of visuospatial information. Semrud-Clikeman et al. (2014) also collected three measures of executive functioning using the Delis–Kaplan Tests of Executive Functioning (Delis, Kaplan, & Kramer, 2001), finding differences between children with NLD, children with ASD, and typically developing (TD) controls, especially in the trail-making task, which involved visuospatial working memory and sequencing.

Neuroimaging studies have been conducted too. Semrud-Clikeman and Fine (2011) found that an unusually large number of children diagnosed with NLD revealed benign cysts or lesions of the brain, while this was not the case in children with ASD without ID, or controls. Another study (Fine, Musielak, & Semrud-Clikeman, 2014) found that the area of the splenium was significantly smaller in children with NLD than in those who had ASD without ID or ADHD, or in controls. Within the NLD group, those with a smaller splenium fared worse on spatial intelligence measures, whereas this association was not seen in the group with ASD without ID. In further research, Semrud-Clikeman, Fine, Bledsoe, and Zhu (2013) identified significantly larger volumes of the amygdalae and hippocampi bilaterally in a group of children with ASD without ID by comparison with controls or children with NLD. On the other hand, both the children with ASD without ID and those with NLD had smaller left and right anterior cingulate cortex volumes than controls. This was the first evidence of children with NLD differing in some respects from children with ASD without ID, but possibly sharing the same abnormal connectivity.

The Present Study

As the above literature review shows, few studies have directly compared children with NLD and ASD in terms of their performance in visuospatial tasks (e.g., Semrud-Clikeman et al., 2010), and studies on a wide range of visuospatial skills in these two clinical groups are still lacking.

A method often used to assess visuospatial processing in ASD is the global–local paradigm, according to which an individual may experience an event using a global or a local processing style (Förster & Dannenberg, 2010; Navon, 1977; Schooler, 2002).

When this paradigm was applied to individuals with ASD, previous studies revealed peculiarities in their processing of complex visual stimuli and a local bias, characterized by a focus on details (Caron, Mottron, Berthiaume, & Dawson, 2006; Kuschner, Bodner, & Minshew, 2009). Conflicting results have emerged, however (see, e.g., Mammarella, Giofrè, Caviola, Cornoldi, & Hamilton, 2014; Van der Hallen, Evers, Brewaeys, Van den Noortgate, & Wagemans, 2015), and when D'Souza, Booth, Connolly, Happé, and Karmiloff-Smith (2016) recently examined global versus local processing, they concluded that we need to reconsider the concepts of "local or global processors." They suggested that individuals with ASD are able to process both local and global information in differently atypical ways, depending on the type of task involved.

Although children with NLD are known to have visuospatial difficulties, their global and local processing styles have been little studied (Cardillo, Mammarella, Garcia, & Cornoldi, 2017). But assessing visuospatial processing styles seems to be a promising way to further clarify the differences between NLD and ASD without ID. In the present study, groups of children who had NLD or ASD without ID were therefore compared with TD children using two tasks to measure their visuoconstructive skills and visuospatial working memory. The paradigm proposed by Caron et al. (2006), which considers different levels of perceptual cohesiveness in the formation of global or local configurations, was used to manipulate the visuospatial processing requirement. Caron et al. (2006) distinguished between individuals with high-functioning autism on the grounds of their visuospatial abilities, that is, those with and those without a peak in visuospatial intelligence. To obtain comparable scores for visuospatial intelligence in our groups with NLD or ASD without ID, we opted to consider only individuals with ASD without ID who showed no such peak in visuospatial intelligence. In the light of previous studies, we expected the NLD group to perform less well than the ASD without ID group in both the visuoconstructive task (Semrud-Clikeman et al., 2010) and the visuospatial working memory task (Mammarella, & Cornoldi, 2005a, 2005b). We also expected a diminished influence of global configurations in the ASD without ID group, as previously reported by Caron et al. (2006).

Method

Participants

The study involved 51 participants ranging in age from 8 to 18 years, 41 males and 10 females. Three groups were identified for the purposes of this study: ASD without ID (n = 17), NLD (n = 17), and TD controls (n = 17). The three groups did not differ in chronological age, $F(2, 48) = 1.75$, $p = .18$; $\eta_p^2 = .07$, gender, $\chi^2(df = 2) = 1.71$, $p = .43$, full-scale IQ (FSIQ), $F(2, 48) = 3.02$, $p = .06$; $\eta_p^2 = .11$, or perceptual reasoning index, $F(2, 48) = 2.77$, $p = .07$; $\eta_p^2 = .10$. The participants' characteristics are summarized in Table 1.

All participants were recruited via local community contacts in northeast Italy, at specialized centers for neurodevelopmental disorders, or at local schools (for the TD children). Prior to their enrollment for the study, the participants with ASD without ID had been independently diagnosed with either high-functioning autism or Asperger syndrome according to *DSM* (fourth edition, text revision [*DSM–IV–TR*]; American Psychiatric Association, 2000) or International Classification of Diseases–10th edition (World Health Organization, 1992) criteria by outside practitioners at specialized centers. Before they were included in the present study, their diagnosis of ASD was confirmed first by administering the Autism Diagnostic Interview–Revised (Rutter, Le Couteur, & Lord, 2005), and then using *DSM–IV–TR* (American Psychiatric Association, 2000) criteria. The diagnostic algorithm of the Autism Diagnostic Interview–Revised was applied, and our inclusion criteria required scores above the cut-off on the three modules of the interview, including stereotyped behavior. Participants also had to have at least two symptoms considered in each of the three criteria of the *DSM–IV–TR* for a diagnosis of autistic disorder. Participants' level of intelligence was assessed by administering the Wechsler intelligence scales (Wechsler Intelligence Scale for

Table 1
Characteristics of the Groups With Autism Spectrum Disorders With No Intellectual Disability and No Visuospatial Peak (ASD), Nonverbal Learning Disability (NLD), and Typical Development (TD)

Measures	TD (n = 17), M (SD)	ASD (n = 17), M (SD)	NLD (n = 17), M (SD)	Group significance
Age (months)	164.65 (45.89)	162.5 (35.18)	141.65 (37.06)	*ns*
Wechsler intelligence scales[a]				
FSIQ	98.82 (7.02)	91.71 (6.25)	98.29 (13.3)	*ns*
PRI	98.94 (9.65)	97.82 (8.54)	90.24 (15.75)	*ns*
Vocabulary	10.41 (2.55)	9.41 (2.29)	13.41 (2.94)	NLD > ASD, TD
Rey–Osterrieth complex figure test				
Copy	28.35 (4.93)	23.65 (5.79)	17.91 (6.10)	NLD < ASD, TD
Recall	17.76 (6.82)	10.84 (7.29)	7.97 (4.03)	NLD, ASD < TD
ADI-R[b]				
RSI	3.88 (2.80)	17.53 (6.82)	5.88 (2.99)	ASD > TD, NLD
L/C	2.82 (2.22)	12.18 (4.65)	4.71 (2.71)	ASD > TD, NLD
RB/I	1.06 (1.03)	5.88 (4.17)	1.94 (2.59)	ASD > TD, NLD

Note. FSIQ = full-scale intelligence quotient; PRI = perceptual reasoning index; ADI-R = Autism Diagnostic Interview–Revised (Rutter, Le Couteur, & Lord, 2005); RSI = reciprocal social interaction; L/C = language/communication; RB/I = repetitive behaviors/interests.
[a] Standard scores on the Wechsler Intelligence Scale for Children (fourth edition, for participants aged 8 to 16 years) or Wechsler Adult Intelligence Scale (fourth edition, for participants from 16 years onwards). [b] high scores on the ADI-R reflect more severe autistic symptoms.

Children–fourth edition [WISC-IV] or Wechsler Adult Intelligence Scale–fourth edition [WAIS-IV], Wechsler, 2003, 2008, depending on their chronological age). Only individuals with ASD who reached a standard score of 80 or above on the FSIQ were included in the study. Participants with ASD without ID also had to score within the normal range (7 to 13) on the Vocabulary subtest (Wechsler, 2003, 2008), and be taking no medication (see Table 1). Finally, to select participants with ASD whose level of visuospatial intelligence matched that of the NLD group, the former could have scores on the perceptual reasoning index up to one standard deviation from the average (between 85 and 115). The participants with ASD without ID were consequently selected from a pool of 50 individuals with a diagnosis of Asperger syndrome or high-functioning autism whose parents/caregivers consented to their inclusion in the study. Before the experimental materials were administered, the children's perceptual reasoning indexes were obtained by administering the Wechsler intelligence scales (WISC-IV or WAIS-IV, Wechsler, 2003, 2008, depending on their chronological age), and participants with perceptual reasoning index scores more than one standard deviation from the average were excluded. It is worth noting that none of the participants with ASD had perceptual reasoning index scores below the normal range (<80).

Participants in the NLD group were diagnosed by private practitioners (child psychiatrists or psychologists), or at the hospital to which they referred. Their diagnosis was also confirmed by reviewing previous tests (if recent), or by conducting an updated assessment consistently with the latest recommended criteria (Cornoldi et al., 2016; Mammarella & Cornoldi, 2014; Semrud-Clikeman et al., 2010). Agreement among the two first authors was required for inclusion in the study. The following criteria were assumed to confirm a diagnosis of NLD: (a) a discrepancy between verbal and visuospatial intelligence (with scores at least one standard deviation [≥15] higher for verbal comprehension than on the PRI), as measured with the WISC-IV or WAIS-IV (Wechsler, 2003, 2008), depending on the participant's chronological age; (b) scores at least 1 *SD* below the average in a visuoconstructive task (Rey–Osterrieth complex figure test; Rey, 1968); (c) impaired social skills, as assessed by interviewing parents, and suggested by below-average scores on at least two subscales of pragmatics of language included in the parents' form of the Children's Communication Checklist–Second edition (Bishop, 2013); and (d) average scores in a word reading task (DDE-2; Sartori, Job, & Tressoldi, 2007) and scores at least 1 *SD* below average in an arithmetical task (depending on the participant's age, we used AC-MT 6–11, Cornoldi, Lucangeli, & Bellina, 2012; AC-MT 11–14, Cornoldi & Cazzola, 2004; MT 3 Advanced, Cornoldi, Pra Baldi, & Giofrè, 2017). The additional assessment measures of the NLD group are reported in Table 2. All clinical diagnoses of ASD without ID or NLD established at the specialized centers were confirmed by the consensus of two independent licensed psychologists.

The TD controls were healthy children of normal intelligence recruited at several schools in Northeast Italy. They had no history of psychiatric, neurological, or neurodevelopmental disorders, as reported by parents and teachers, and judging from an interview completed prior to their participation. Again, to match the TD group with the ASD without ID and NLD groups on their FSIQ and visuospatial intelligence, the TD participants were selected from a pool of 70 children whose parents/caregivers had consented to their participation in the study. Before the experimental materials were administered, the children's FSIQ levels and perceptual reasoning index scores were obtained by administering the Wechsler intelligence scales (WISC-IV or WAIS-IV, Wechsler, 2003, 2008, depending on the participant's chronological age). For the TD group, the inclusion criteria entailed FSIQ and perceptual reasoning index scores up to one standard deviation from the average.

Table 2
Means and Standard Deviations of the Additional Assessment Measures for the Nonverbal Learning Disability (NLD) Group

Measures	NLD (n = 17), M (SD)
Pragmatics of language (CCC-2)	
Initiation	5.94 (3.23)
Scripted language	8.06 (3.54)
Context	5.94 (4.28)
Nonverbal communication	7.24 (3.73)
Social relations	5.18 (3.99)
Interests	5.65 (2.50)
Reading decoding (DDE-2)	
Word reading (errors)	−.21 (.68)
Word reading (time)	−.44 (1.01)
Mathematics achievement (AC-MT battery)	
Written calculation (errors)	1.24 (.45)

Note. CCC-2 = Children's Communication Checklist (second edition); DDE-2 = Test battery for developmental dyslexia; AC-MT = Test battery for mathematics assessment. Pragmatics of language is expressed in scaled scores; reading decoding and mathematics achievement are expressed in *z* scores.

All participants in the study spoke Italian as their first language, and none had any visual or hearing impairments, or any other diagnosed neurological conditions. None of the individuals in the NLD or TD groups met the criteria for autism using the ADI–R (Rutter et al., 2005). Individuals who had comorbid psychopathologies as well as ASD without ID, or NLD were excluded. A signed informed consent form was obtained from all participants' parents, and the study was approved by the research ethics committee at the University of Padova in Italy.

Materials

The experimental tasks consisted of stimuli devised to have different levels of perceptual cohesiveness, a characteristic of figures that can be manipulated by varying the number of blocks/cells of opposite color (Caron et al., 2006), for instance. A given figure could have a minimum level of perceptual cohesiveness and prompt a local processing (many blocks/cells in the figure adjacent to blocks/cells of the opposite color), an intermediate level of perceptual cohesiveness (half the blocks/cells comprising the figure adjacent to blocks/cells of the opposite color, and the other half adjacent to blocks/cells of the same color), or a maximum level of perceptual cohesiveness and thus prompting a global processing (most of the blocks/cells were adjacent to others of the same color; see Figure 1).

Visuoconstructive task: The modified block design task (BDT). Visuoconstructive abilities and visuospatial processing styles were assessed using the modified block design task (BDT; Caron et al., 2006). Participants were shown a figure and asked to reproduce it by assembling a set of blocks with two red, two white,

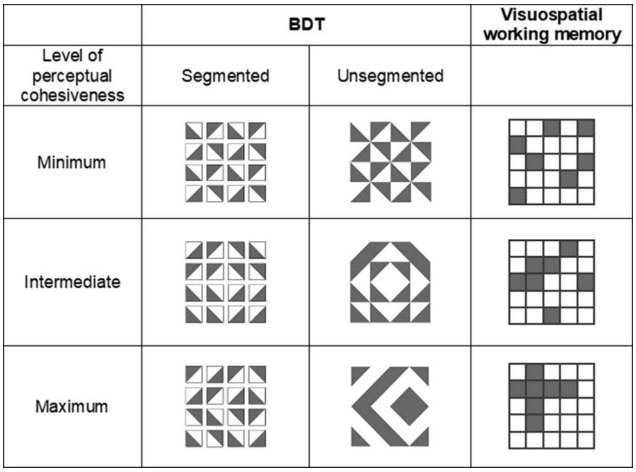

Figure 1. Examples of stimuli drawn from the block design task (BDT; segmented and unsegmented versions) and the visuospatial working memory task, presented for three levels of perceptual cohesiveness (minimum, intermediate and maximum).

and two bicolor surfaces. Two different conditions (i.e., unsegmented and segmented) of 18 items each were presented, plus three control items used to measure motor speed. The items also differed in terms of the level of perceptual cohesiveness (minimum, intermediate and maximum), and were balanced as regards matrix size (four, nine, or 16 blocks). The segmented version can be considered as a control task in which participants are obliged to adopt a local analysis of the stimuli for all levels of perceptual cohesiveness. In the unsegmented condition, on the other hand, a local processing is favored by a minimum level of perceptual cohesiveness, while a global processing is prompted when the stimuli show a maximum level of perceptual cohesiveness. Figure 1 shows examples of the stimuli used. The task was administered according to Wechsler's instructions (WISC-IV, Wechsler, 2003). First an example was shown by the experimenter and then it was reconstructed by the participant. Then the items comprising the task were presented. Participants were asked to respond as quickly and accurately as possible. A time limit was set for each set of blocks, which was 75 s, 120 s, and 180 s, for the four-, nine-, and 16-block designs, respectively (see Cardillo et al., 2017). Following the procedure proposed by Caron et al. (2006), the unsegmented condition was presented before the segmented one to avoid a facilitation effect. Accuracy was measured as the number of blocks correctly positioned on each design. Response times (RTs) in seconds were also recorded. To control for individual differences in motor speed, the time taken to complete the task in the control condition was subtracted from the RTs for each item.

Visuospatial working memory task. The visuospatial working memory task used here was a computerized task adapted from Carretti, Lanfranchi, and Mammarella (2013; see also Cardillo, Menazza, & Mammarella, 2018). Thirty-six items were presented in the form of white matrices with increasing numbers of cells, some of which were red (span: from four to nine). As in the BDT, the stimuli differed in level of perceptual cohesiveness (minimum, intermediate and maximum), and there were 12 items for each level of perceptual cohesiveness. The stimuli with a maximum level of perceptual cohesiveness prompted a global processing, while those with a minimum or intermediate level of perceptual cohesiveness were more amenable to being processed locally (see Figure 1).

Each matrix was shown for 3 s, during which participants were asked to memorize the configuration. Then, after a 0.5-s interstimulus interval, they were asked to recall the pattern on a white matrix of the same size, using the mouse to indicate where they had previously seen the red cells. The matrices were presented in order, from the lower to the higher spans, while a random order was used to present the items within each span. The proportion of cells correctly recalled on each matrix (i.e., the number of red cells correctly recalled out of the total number of red cells) was recorded.

Procedure

Participants were tested individually in a quiet room during two sessions lasting approximately 30 min each. They were administered the modified BDT (Caron et al., 2006) and the visuospatial working memory task (Cardillo et al., 2018) in a counterbalanced order. Participants received instructions for each task and practiced with each of them before starting the experiment. The visuospatial working memory task was programmed with the E-Prime 2 software (Schneider, Eschman, & Zuccolotto, 2007), and administered using a laptop computer with a 15-in. LCD screen.

Results

Data Analyses

Data analyses were conducted using R (R Core Team, 2015). The results for accuracy obtained with the BDT and visuospatial working memory task were analyzed with mixed-effects models, using the "lme4" package (Bates, Maechler, Bolker, & Walker, 2015). The appropriate family was used for the analysis, depending on the distribution of the data. To analyze accuracy, the "Poisson" family was used with counting data (such as the number of blocks correctly placed in the BDT), while the "Binomial" family was used with binary outcomes (like the proportion of cells correctly recalled for the visuospatial working memory task). For the BDT, the RTs for correct answers (in seconds) were analyzed as well. Since the outcome was skewed and positive, it was modeled by adopting generalized mixed-effects models with the "Gamma" family, and the "log" link function (which enabled the coefficients emerging from the model to be converted into estimated values). Graphical figures were obtained using the "sjPlot" package (Ludecke & Schwemmer, 2017).

The following fixed effects and their interactions were tested for the BDT and visuospatial working memory task: group (ASD without ID, NLD, and TD) and level of perceptual cohesiveness (minimum, intermediate, and maximum). The fixed effect of condition (segmented or unsegmented) was also considered for the BDT. Participants were included as random effects to take into account their variability in each mixed-effects model. The significance of both fixed and random effects was examined by means of a series of likelihood ratio tests for nested models based on the chi-square distribution (Pinheiro & Bates, 2000). The significance of the fixed effects was calculated by removing them from the full model one at a time.

Given the well-known limitations of the *p* value significance test (Burnham & Anderson, 2002), an information criterion approach was used. The Akaike information criterion (AIC; Akaike, 1974) was recorded for each model (where a lower AIC indicates a better model). The evidence ratio based on the Akaike weights was then used to quantify the evidence in favor of the existence of each fixed effect. The evidence ratio was calculated following the procedure suggested by Wagenmakers and Farrell (2004), as Exp $[(AIC_1 - AIC_2)/2)]$. In the present case, the evidence ratio indicates how much more likely it is that a model including a certain fixed effect will be the best model (Wagenmakers & Farrell, 2004) by comparison with the corresponding model excluding the same effect.[1] Table 3 summarizes the descriptive statistics by group (TD, ASD, and NLD) for the children's accuracy and RTs in the experimental tasks.

Visuoconstructive Task: Accuracy

A significant main effect of group was found, $\chi^2(2) = 25.86$, $p < .001$ (model with group: AIC = 12,440; model without group: AIC = 12,462; evidence ratio > 1,000). The model coefficients showed that the NLD group was less accurate than the other groups (*p*s < .001), while no differences came to light between the other two groups.

The main effect of condition was significant, $\chi^2(1) = 191.27$, $p < .001$ (model with condition: AIC = 12,440; model without condition: AIC = 12,630; evidence ratio > 1,000). The model coefficients showed that participants performed better in the segmented than in the unsegmented condition ($p < .001$).

The main effect of level of perceptual cohesiveness was significant too, $\chi^2(2) = 37.74$, $p < .001$ (model with level of perceptual cohesiveness: AIC = 12,440; model without level of perceptual cohesiveness: AIC = 12,474; evidence ratio > 1,000). The model coefficients showed that participants performed better on the minimum level of perceptual cohesiveness than on the intermediate ($p = .002$) or maximum levels ($p < .001$), and they were also more accurate on the intermediate level than on the maximum level of perceptual cohesiveness ($p = .002$).

The analysis revealed a significant Group × Condition interaction, $\chi^2(2) = 98.32$, $p < .001$ (model without interaction: AIC = 12,440; model with interaction: AIC = 12,346; evidence ratio > 1,000). For the unsegmented condition, the model coefficients showed that the NLD group was less accurate than either of the other two groups (*p*s < .001), while no differences emerged between the latter. For the segmented condition, the NLD group was less accurate than the ASD without ID group ($p = .008$), while no other differences emerged.

The Condition × Level interaction of perceptual cohesiveness was also significant, $\chi^2(2) = 54.12$, $p < .001$ (model without interaction: AIC = 12,440; model with interaction: AIC = 12,390; evidence ratio > 1,000). Specifically, in the unsegmented condition, participants were more accurate when responding on the minimum level of perceptual cohesiveness than on the intermediate or maximum levels (*p*s < .001), and they were also more accurate on the intermediate than on the maximum level of perceptual cohesiveness ($p < .001$). No differences emerged between the levels of perceptual cohesiveness in the segmented condition. The Group × Level interaction of perceptual cohesiveness was not significant, $\chi^2(4) = 8.88$, $p = .06$ (model without interaction: AIC = 12,440; model with interaction: AIC = 13,599; evidence ratio = 1.65).

Finally, the Group × Condition × Level interaction of perceptual cohesiveness was significant, $\chi^2(4) = 23.24$, $p < .001$ (model without interaction: AIC = 12,291; model with interaction: AIC = 12,276; evidence ratio > 1,000). As shown in Figure 2, the model coefficients indicated that there were no differences between the groups in the segmented condition, nor were there any differences between the levels of perceptual cohesiveness within each group. In the unsegmented condition, the NLD group was less accurate than the other two groups for all levels of perceptual cohesiveness (*p*s < .001), while no differences emerged between the TD and the ASD without ID groups. In addition, the NLD group revealed significant differences between all levels of perceptual cohesiveness: these children's performance was more accurate on the minimum level of perceptual cohesiveness than on the intermediate ($p < .001$) or maximum levels ($p < .001$), and more accurate on the intermediate than on the maximum level of perceptual cohesiveness ($p < .001$). The ASD without ID group also had a more accurate performance on the minimum level of perceptual cohesiveness than on the intermediate ($p = .004$) or maximum levels ($p < .001$), but no difference between the intermediate and maximum levels of perceptual cohesiveness. Finally, the TD group performed better on the minimum and intermediate levels of perceptual cohesiveness than on the maximum level ($p < .001$ and $p = .005$, respectively), with no differences emerging between the minimum and intermediate levels.

Visuoconstructive Tasks: Response Times (RTs)

A significant main effect of group emerged, $\chi^2(2) = 12.47$, $p = .001$ (model with group: AIC = 16,538; model without group: AIC = 16,546; evidence ratio = 54.60). The model coefficients showed that the NLD ($p < .001$) and the ASD without ID ($p = .02$) groups were slower than the TD group, while no other differences between the groups came to light.

The main effect of condition was significant, $\chi^2(1) = 367.04$, $p < .001$ (model with condition: AIC = 16,538; model without condition: AIC = 16,903; evidence ratio > 1,000), meaning that participants completed the task more slowly in the unsegmented than in the segmented condition ($p < .001$).

The main effect of level of perceptual cohesiveness was significant as well, $\chi^2(2) = 62.46$, $p < .001$ (model with level of perceptual cohesiveness: AIC = 16,538; model without level of perceptual cohesiveness: AIC = 16,596; evidence ratio > 1,000). Participants completed the task faster on the minimum level of perceptual cohesiveness than on the intermediate or maximum levels (*p*s < .001), and they were faster on the intermediate than on the maximum level of perceptual cohesiveness ($p < .001$).

[1] To compare models, we also used the AIC correction and the Bayesian information criterion (BIC). Using the AIC correction, the results were consistent with those obtained with the AIC. While the BIC was more restrictive, and as reported in the literature (Wagenmakers & Farrell, 2004; Scrucca, Santucci, & Aversa, 2010), it penalizes free parameters more strongly. Given the complexity of our models, in which also three level interactions were considered, we choose to consider the AIC because BIC penalized model complexity more heavily.

Table 3

Means and Standard Deviations by Group: Typical Development (TD), Autism Spectrum Disorders With No Intellectual Disability and No Visuospatial Peak (ASD), and Nonverbal Learning Disability (NLD)

Experimental tasks	Condition	Perceptual cohesiveness	TD, *M* (*SD*)	ASD, *M* (*SD*)	NLD, *M* (*SD*)
BDT accuracy	Segmented	Minimum	9.44 (4.80)	9.64 (4.93)	8.77 (4.75)
		Intermediate	9.60 (4.87)	9.64 (4.96)	9.16 (4.95)
		Maximum	9.49 (4.87)	9.60 (4.88)	8.98 (4.79)
	Unsegmented	Minimum	9.09 (4.88)	9.44 (5.02)	7.28 (4.88)
		Intermediate	8.63 (4.84)	8.25 (5.03)	5.28 (4.20)
		Maximum	7.52 (5.30)	7.87 (4.87)	4.09 (4.49)
BDT response times	Segmented	Minimum	15.35 (16.38)	27.71 (29.15)	27.41 (27.65)
		Intermediate	14.21 (15.11)	28.74 (29.17)	29.78 (29.00)
		Maximum	21.11 (30.09)	30.24 (31.39)	29.65 (30.14)
	Unsegmented	Minimum	29.34 (33.65)	32.66 (32.30)	52.98 (41.23)
		Intermediate	42.37 (41.57)	49.09 (41.92)	66.77 (43.95)
		Maximum	61.76 (47.71)	61.39 (43.99)	77.94 (38.94)
Visuospatial working memory task		Minimum	.62 (.26)	.55 (.25)	.44 (.22)
		Intermediate	.69 (.26)	.64 (.26)	.53 (.25)
		Maximum	.94 (.13)	.91 (.16)	.88 (.18)

Note. BDT = block design task. Means and standard deviations refer to accuracy (number of blocks correctly placed) and response times (in seconds) in the BDT, and to accuracy (proportion of cells correctly recalled) in the visuospatial memory task.

A significant Group × Condition interaction was found, $\chi^2(2) = 15.23$, $p < .001$ (model without interaction: AIC = 16,538; model with interaction: AIC = 16,526; evidence ratio = 403.43). As shown in Figure 3, the model coefficients indicated that the NLD group was slower than the ASD without ID ($p = .002$) or TD ($p < .001$) groups in the unsegmented condition, with no difference between the latter two groups. In the segmented condition, on the other hand, the ASD without ID and NLD groups were both slower than the TD group ($p = .02$ and $p = .007$, respectively), with no difference between the former two.

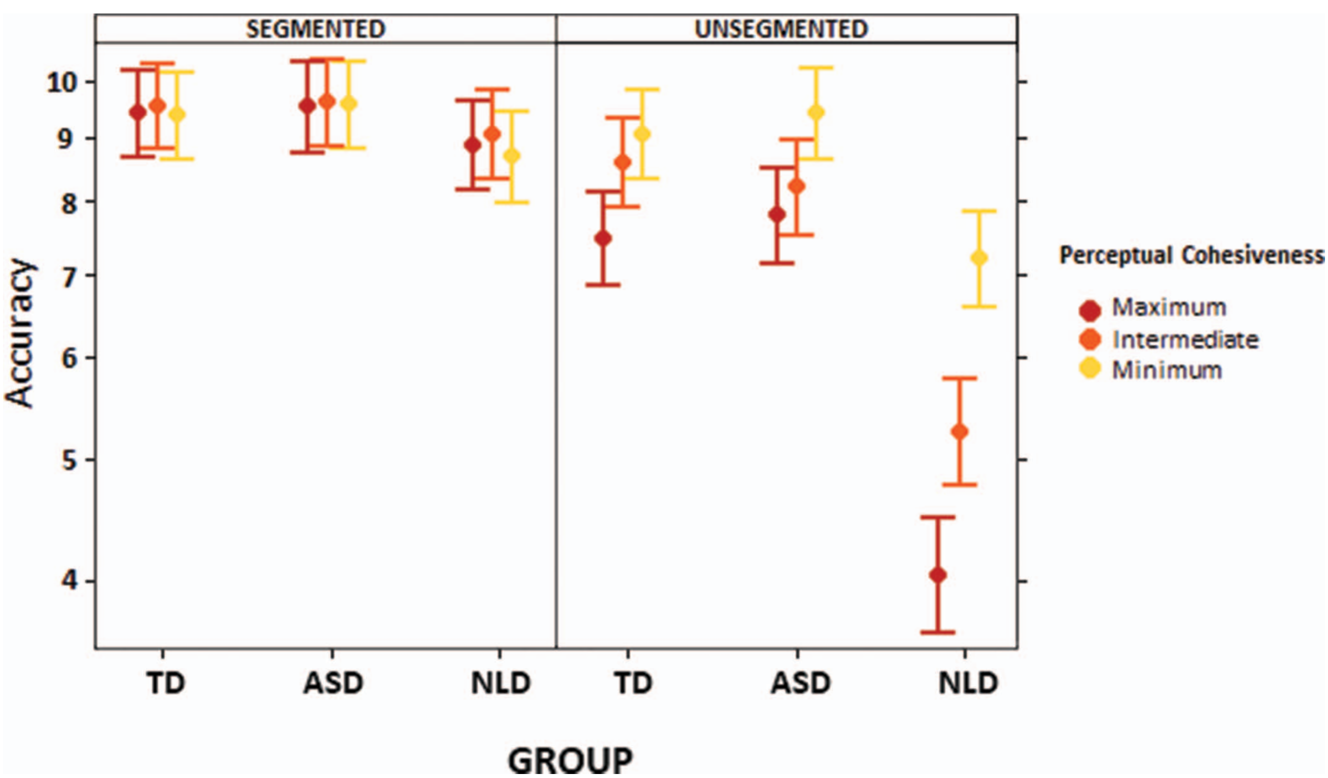

Figure 2. Visuoconstructive task (block design task). Predicted accuracy (i.e., number of blocks correctly placed) by group, condition, and level of perceptual cohesiveness in the block design task. Error bars represent 95% confidence intervals. TD = typically developing; ASD = autism spectrum disorder; NLD = nonverbal learning disability. See the online article for the color version of this figure.

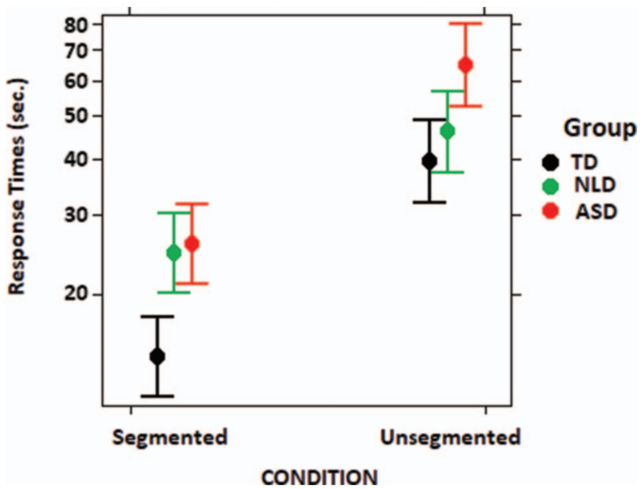

Figure 3. Visuoconstructive task (block design task). Predicted values for response times (in seconds) by group and condition in the block design task. Error bars represent 95% confidence intervals. TD = typically developing; ASD = autism spectrum disorder; NLD = nonverbal learning disability. See the online article for the color version of this figure.

The Condition × Level interaction of perceptual cohesiveness was also significant, $\chi^2(2) = 32.66$, $p < .001$ (model without interaction: AIC = 16,538; model with interaction: AIC = 16,509; evidence ratio > 1,000). In the unsegmented condition, participants were quicker to respond on the minimum level of perceptual cohesiveness than on the intermediate or maximum levels (*p*s < .001), and they were faster on the intermediate than on the maximum level of perceptual cohesiveness ($p < .001$). No such differences emerged between the levels of perceptual cohesiveness in the segmented condition. The Group × Level interaction of perceptual cohesiveness was significant, $\chi^2(4) = 9.87$, $p = .04$ (model without interaction: AIC = 16,538; model with interaction: AIC = 16,536; evidence ratio = 2.72), while the Group × Condition × Level interaction of perceptual cohesiveness was not, $\chi^2(4) = 2.51$, $p = .64$ (model without interaction: AIC = 16,496; model with interaction: AIC = 16,502; evidence ratio = .05).

Visuospatial Working Memory Task

A significant main effect of group was found, $\chi^2(2) = 13.52$, $p = .001$ (model with group: AIC = 5,702.3; model without group: AIC = 5,711.9; evidence ratio = 121.51), showing that the NLD group was less accurate than the others (*p*s < .02). No differences emerged between the other two groups. There was also a main effect of level of perceptual cohesiveness, $\chi^2(2) = 1743.2$, $p < .001$ (model with level of perceptual cohesiveness: AIC = 5,702.3; model without level of perceptual cohesiveness: AIC = 7,441.6; evidence ratio > 1,000). Participants recalled stimuli better when they were characterized by a maximum level of perceptual cohesiveness (*p*s < .001), and their recall was also better for intermediate than for minimum levels of perceptual cohesiveness ($p < .001$). Finally, the Group × Level interaction of perceptual cohesiveness was not significant, $\chi^2(4) = 8.12$, $p = .08$ (model without interaction: AIC = 5,702.3; model with interaction: AIC = 5,702.2; evidence ratio = 1.05; see Figure 4).

Discussion

Up until recently, the lack of clarity on NLD and the absence of explicit and consistent diagnostic criteria made it difficult to conduct systematic research on children with this disorder and led to them sometimes being confused with cases of ASD without ID (and the profile previously known as Asperger syndrome in particular). To shed more light on NLD, the present study compared a group of participants with NLD with a group of individuals with ASD without ID who had no peak in visuospatial intelligence. These two clinical groups had similar FSIQ and perceptual reasoning index scores, and were matched for age and gender.

The NLD and ASD groups were compared with a group of TD children on visuoconstructive skills and visuospatial working memory. The paradigm proposed by Caron et al. (2006), and previously employed to study global *vis-à-vis* local processing in ASD, was used to shed light on whether our ASD without ID group shared any characteristics with the NLD group in terms of visuospatial processing.

Based on generalized mixed-effects models, the results obtained in the visuoconstructive task revealed an impaired performance in the NLD group, particularly for the unsegmented condition, in which they were less accurate and slower than the other groups across all levels of perceptual cohesiveness: they were only able to arrange a mean from four to seven blocks according to the maximum and the minimum level of perceptual cohesiveness, respec-

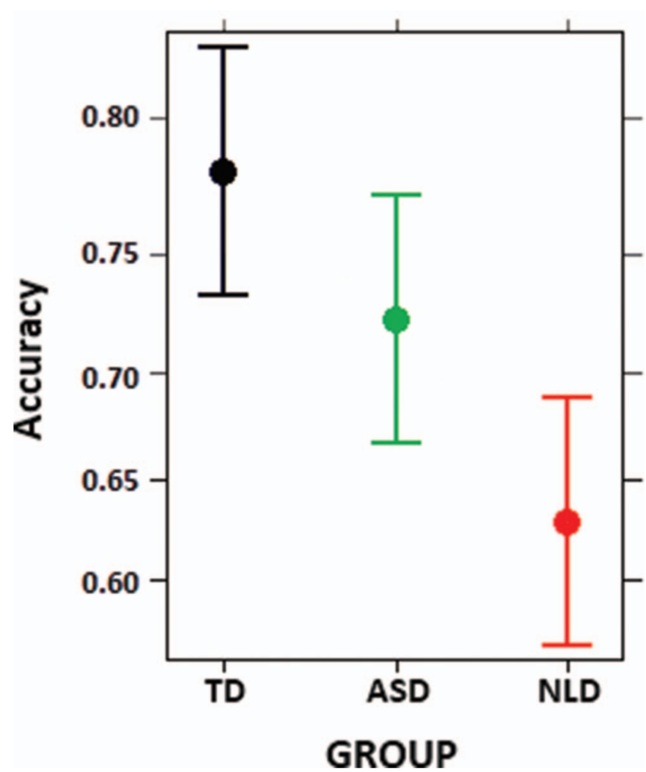

Figure 4. Visuospatial working memory task. Predicted accuracy (i.e., proportions of cells correctly recalled) by group in the visuospatial working memory task. Error bars represent 95% confidence intervals. TD = typically developing; ASD = autism spectrum disorder; NLD = nonverbal learning disability. See the online article for the color version of this figure.

tively). Despite this general weakness emerging in children with NLD in the unsegmented condition, important information can be gleaned from comparing this group's performance with that of the other two groups across all three levels of perceptual cohesiveness. When participants with NLD had to deal with stimuli with a minimum level of perceptual cohesiveness (a condition that prompts a local processing), the difference between these children and those in the other two groups was smaller, in terms of *Cohen's d* (TD vs. NLD = .36; ASD vs. NLD = .43), than when they had to reconstruct figures with intermediate (TD vs. NLD = .72; ASD vs. NLD = .63) or maximum (TD vs. NLD = .68; ASD vs. NLD = .79) levels of perceptual cohesiveness. In other words, our NLD group showed the typical effect of perceptual cohesiveness in the visuoconstructive task, just like the TD children. Although the NLD group performed less well than the other two groups, they benefited—like the TD group (but unlike the ASD group)—when it came to arranging blocks with a minimum level of perceptual cohesiveness. In the segmented condition, although a ceiling effect was found for accuracy, as expected (see also Caron et al., 2006), the NLD group was less accurate than the ASD without ID group. Our NLD group thus revealed a general weakness in the visuoconstructive domain, in agreement with previous studies (Semrud-Clikeman & Glass, 2008; Semrud-Clikeman et al., 2010).

The ASD without ID group performed normally in terms of accuracy, showing no differences vis-à-vis the TD controls. This finding is also consistent with previous reports (Altgassen, Kliegel, & Williams, 2005; Ryburn et al., 2009). On the other hand, our individuals with ASD without ID differed from the other two groups in that their accuracy did not change between the intermediate and maximum levels of perceptual cohesiveness. In other words, they were less sensitive to the level of perceptual cohesiveness in the visuoconstructive domain (Cardillo et al., 2018; Caron et al., 2006; Happé & Frith, 2006; Mottron, Burack, Iarocci, Belleville, & Enns, 2003). Our findings thus point to the crucial importance of manipulating global versus local processing to distinguish NLD from ASD. It is worth noting that the BDT used here was derived from the BDT of the Wechsler scales. While our participants with NLD and ASD did not differ statistically in terms of their perceptual reasoning index (which also includes the score obtained in the BDT), they did show a very different pattern of results in the BDT when the level of global–local processing was manipulated.

As regards visuospatial working memory, the NLD group performed less well than the others. This finding confirms that the neuropsychological profile of NLD features an impaired visuospatial working memory, irrespective of the level of perceptual cohesiveness of the stimuli (Garcia, Mammarella, Pancera, Galera, & Cornoldi, 2015; Mammarella, & Cornoldi, 2005a, 2005b), especially in tasks that involve to recall spatial locations (Chow & Skuy, 1999; Mammarella et al., 2010; Venneri, Cornoldi, & Garuti, 2003). No such deficits emerged in the group with ASD without ID, indicating that visuospatial working memory is not a typical weakness in their cognitive profile (Alloway, Rajendran, & Archibald, 2009; Cardillo et al., 2018; Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Happé, Booth, Charlton, & Hughes, 2006; Ozonoff & Strayer, 2001; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008; Williams, Goldstein, & Minshew, 2006). When the level of perceptual cohesiveness was considered in the visuospatial working memory task, all three groups were more accurate in recalling stimuli with a higher level of cohesiveness (characterized by global configurations). In other words, individuals with ASD without ID, and those with NLD benefited just like TD children from being presented with global rather than local stimuli, confirming that the former are easier to remember than the latter (Brown, Forbes, & McConnell, 2006; Brown & Wesley, 2013; Riby & Orme, 2013).

To sum up, our findings enabled us to clearly differentiate between the visuospatial profiles of individuals with NLD and those with ASD without ID. The NLD group's performance was worse in all the domains examined (i.e., in visuoconstructive and visuospatial working memory tasks).

The group with ASD without ID had a more heterogeneous visuospatial profile, with strengths and weaknesses, and different effects of local bias depending on the domain considered. In the visuospatial working memory task, their performance did not differ from that of the TD group and they benefited from being presented with global rather than local stimuli (Navon, 1977). In the visuoconstructive task, on the other hand, their accuracy suggested that they were less sensitive to the level of perceptual cohesiveness than the TD controls or NLD group. In other words, they spontaneously processed each block without being confused by the global configurations.

Further studies are needed to confirm and extend our results, and to overcome certain limitations of the present study, one of which concerns the small size of our samples. Clinical and educational implications can be drawn from the main results of our study. First, a better understanding of the visuospatial domain might also help in the differential diagnosis of individuals with NLD as opposed to ASD without ID, shedding light on the differences between their neuropsychological profiles. In the past, the lack of a clear understanding of NLD prevented progress in this field, which relies on well-established diagnostic tools. In agreement with previous reports (D'Souza et al., 2016), our results show that individuals with different clinical profiles could use local or global processing, with more or less success, depending on the demands of a task and the cognitive domain involved (Dukette & Stiles, 2001). It might therefore be well worth analyzing global–local processing with a view to interpreting the outcome of an assessment more effectively, and better distinguishing between individuals with NLD and those with ASD without ID. In addition, although the *DSM–5* (American Psychiatric Association, 2013) recommends using a single label for ASD, it is important to bear the idea of a spectrum in mind. As our work demonstrates, although individuals with ASD without ID who have no peak in visuospatial intelligence are not representative of the ASD population as a whole, they can provide crucial insight on the cognitive strengths and weaknesses associated with the condition. Finally, being able to distinguish NLD more clearly from the ASD profile may be crucial for the purpose of choosing the best intervention for the individuals concerned, and for guiding clinicians, teachers and educators to choose the best aids for these children.

In conclusion, despite the aforementioned limitations, we believe the present study sheds more light on the visuospatial profiles of ASD without ID as opposed to NLD, two neurodevelopmental disorders with some overlapping symptoms that contribute to making their diagnosis a challenge (Williams et al., 2008). Examining our participants' accuracy in visuoconstructive and visuospatial working memory tasks revealed clear differences between the two disorders. Manipulating the global–local processing styles also enabled a better interpretation of the results obtained, particularly as regards distinguishing between cases of NLD and children with ASD without ID, suggesting that global and local processing styles are a key research issue in this field.

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