Identifying Language and Cognitive Profiles in Children With ASD via a Cluster Analysis Exploration: Implications for the New ICD-11

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Abstract (241 words)

The new version of the International Classification of Diseases (ICD-11) mentions the existence of four different profiles in the verbal part of the Autism Spectrum Disorder (ASD), describing them as combinations of either spared or impaired functional language and intellectual abilities. The aim of the present study was to put ASD heterogeneity to the forefront by exploring whether clear profiles related to language and intellectual abilities emerge when investigation is extended to the entire spectrum, focusing on verbal children. Our study proposed a systematic investigation of both language (specifically, structural language abilities) and intellectual abilities (specifically, nonverbal cognitive abilities) in fifty-one 6- to 12-year-old verbal children with ASD based on explicitly motivated measures. For structural language abilities sentence repetition and nonword repetition tasks were selected; for nonverbal cognitive abilities we chose Raven's Progressive Matrices, as well as Matrix Reasoning and Block Design from the Wechsler Scales. An integrative approach based on cluster analyses revealed five distinct profiles. Among these five profiles, all four logically possible combinations of structural language and nonverbal abilities mentioned in the ICD-11 were detected. Three profiles emerged among children with normal language abilities and two emerged among language impaired children. Crucially, the existence of discrepant profiles of abilities suggests that children with ASD can display impaired language in presence of spared nonverbal intelligence or spared language in the presence of impaired nonverbal intelligence, reinforcing the hypothesis of the existence of a separate language module in the brain.

Lay summary

The present work put ASD heterogeneity to the forefront by exploring whether clear profiles related to language and cognitive abilities emerge when investigation is extended to the entire spectrum (focusing on verbal children). The use of explicitly motivated measures of both language and cognitive abilities and of an unsupervised machine learning approach, the cluster analysis, (1) confirmed the existence of all four logically possible profiles evoked in the new ICD-11, (2) evoked the existence of (at least) a fifth profile of language/cognitive abilities and (3) reinforced the hypothesis of a language module in the brain.

Keywords: ASD, profiles, ICD-11, nonverbal cognitive abilities, structural language, cluster analysis

Identifying language and cognitive profiles in children with ASD via a cluster analysis exploration: implications for the new ICD-11

A diagnosis of Autism Spectrum Disorder (ASD) includes specification of any accompanying language and/or intellectual impairment (APA 2013). To date, few studies have taken up the question of the nature of linguistic/cognitive profiles in verbal children with ASD by explicitly exploring the interaction between language (dis)ability and intellectual (dis)ability and their logically possible combinations (Geurts & Embrechts, 2008; Rapin et al., 2009; Tager-Flusberg, 2006; a.o.). The most recent attempt to identify and define these profiles is represented by the release of new diagnostic subcategories for ASD in the World Health Organization's International Classification of Diseases ICD-11 (WHO, 2018) (Table 1).

[Table 1]

As reported in Table 1, the ICD-11 describes four different profiles, which combine either spared or impaired *functional language* and *intellectual abilities*. Functional language impairment is specified as "a marked impairment in spoken or signed language relative to the individual's age, with the individual not able to use more than single words or simple phrases for instrumental purposes, such as to express personal needs and desires" and a deficit in intellectual abilities as "a performance below the average range on intellectual, conceptual, and practical domains of cognitive development" (WHO, 2018). Although these definitions provide general indications, they do not specify which particular domains of functional language and cognitive development should be evaluated or which measure(s) should be used for assessing linguistic and intellectual abilities.

In the literature on language in ASD three of the profiles reported in the ICD-11 have been robustly attested: the two "homogeneous" profiles, autism with normal language (ASD-LN) and normal IQ, and autism with impaired language (ASD-LI) and impaired IQ, and one of the "discrepant" profiles, ASD-LI with normal IQ, which has been compared to the profile that defines children with Developmental Language Disorder (DLD) (Williams et al., 2008). The existence of the fourth "discrepant" profile, ASD-LN with impaired IQ, has been evoked, but, as far as we know, it has been attested in very few studies (Joseph et al., 2002; Kjelgaard & Tager-Flusberg, 2001; Silleresi et al., 2018; Tuller et al., 2017). Assuming the probable existence of these four profiles, we pursued the idea of crossing the abilities mentioned in the ICD-11, proposing both an interpretation of the definitions of linguistic and intellectual impairment and the use of specific tools for their measurement.

Establishing the nature of linguistic and intellectual abilities in children with ASD is not an easy task, in part because phenotypical realizations of these abilities are characterized by notable heterogeneity. Concerning language abilities, besides universal difficulties with pragmatics (Boucher, 2003; Tager-Flusberg, 1981), many individuals with ASD also show deficits in structural aspects of language, notably phonology and morphosyntax (Boucher, 2012; Eigsti et al., 2011; Wittke et al., 2017). Studies on verbal children with autism have reported that roughly half of these children manifest mixed expressive/receptive structural language impairment (a group sometimes referred to as ASD-LI or ALI), while the rest present normal language abilities (ASD-LN or ALN) (Loucas et al., 2008; Tager-Flusberg, 2006). Whatever the definition of *functional language* in the ICD-11 may entail, in order to "use single words and/or simple phrases for instrumental purposes" an individual needs to be able to produce syllables (phonological abilities) and syntactic constructions (morphosyntactic abilities). For these reasons we propose to interpret "impaired functional language" as a deficit in structural language abilities, where "structural" refers to sound structure (phonology) and word/sentence structure (morphosyntax).

How can structural language abilities be evaluated in ASD? Regarding phonological abilities, several studies have claimed that Nonword Repetition (NWR) tasks are reliable indicators of phonological impairment in children with ASD, even in the absence of low performance on other phonological tasks, such as word repetition or articulation tasks (e.g., Kjelgaard & Tager-Flusberg, 2001). Most studies which have investigated phonological abilities in ASD have employed phonological short-term memory NWR tasks based on items of increasing number of CV syllables (Botting & Conti-Ramsden, 2003; Riches et al., 2011; Tager-Flusberg, 2015). As a result, we cannot be sure whether the low performance reported in these studies was due to a short-term memory deficit or to structural phonological impairment. More recently, NWR tasks have been constructed around the notion of phonological complexity by manipulating several aspects of syllable structure, such as consonant clusters (Gallon et al. 2007, Ferré et al. 2012). These tasks limit the effect of phonological short-term memory by including nonwords not exceeding 3-4 syllables in length. In the few studies on ASD that have used such tasks (Kjelgaard & Tager-Flusberg, 2001; Harper-Hill et al., 2013), low performance was reported for some children, who appear thus to have a phonological deficit. In this study we decided to employ a NWR having items varying in degree of phonological complexity, yet restricted in syllable length: the Language Impairment Testing in a Multilingual Setting (LITMUS)-NWR-French (Ferré & dos Santos, 2015) (see material and procedure section).

Regarding morphosyntactic abilities, impairment in ASD has been attested across numerous languages both via the use of standardized tests such as the Clinical Evaluation of Language Foundamentals - CELF (Lloyd et al., 2006 ; Ellis Weismer et al., 2017) and experimental tasks targeting specific constructions such as grammatical tense marking (English: Modyanova et al. 2017; Roberts et al. 2004; Mandarin: Zhou et al., 2015), pronominal clitics (French: Durrleman & Delage 2016; Prévost et al., 2018; English: Perovic et al., 2013), relative clauses (English: Riches et al. 2010; Hebrew: Sukenink & Friedmann, 2018), *wh*-questions (French: Prévost et al. 2017), and passives (French: Durrleman et al. 2017; Greek: Terzi et al., 2014; Persian: Gavarrò et al., 2014). Nonetheless, it has been claimed that neither standardized tests nor experimental tasks may be sufficient to isolate the source of impairment in children with ASD (Wittke et al., 2017 a.o.). Measures drawn from standardized tests rarely enable detailed analysis of specific morphosyntactic structures, and often involve multiple aspects of several different language domains, preventing distinct evaluation of these abilities (Prévost et al., 2017; Tuller et al., 2017; Wittke et al., 2017). Moreover, in experimental tasks which do target specific aspects of morphosyntax as well as in standardized language tasks, it is not always possible to tease apart language difficulties due to structural language impairment and those related to problems with pragmatics, as the two are so densely intertwined. In particular, children with ASD have been found to produce large numbers of unexpected errors which are distinct from those found in other children (both TD and language impaired) and which can be related to difficulties performing the task: not integrating language and visual stimuli, persevering a particular answer pattern, etc. (see, for example, Prévost et al., 2018; Roberts et al., 2014). Such tasks thus may ultimately obscure our understanding of the difficulties that children may have with structural aspects of language, including fundamental similarities with DLD.

In contrast, it has been argued that Sentence Repetition (SR) should minimize the potential effects of both pragmatics, as the items are presented devoid of any conversational context and the instructions are very simple (Polišenská et al. 2015; Silleresi et al. 2018), and lexical knowledge, as vocabulary can be carefully controlled. It is important to note that SR is not a task eliciting mere verbatim echoing of the stimulus: if adequately modeled in order to minimize the effect of short term memory and to include an adequate degree of syntactic complexity, it can evaluate the effects of different types of long-term linguistic knowledge on immediate recall (Lombardi & Potter, 1992). There is currently consensus that SR provides reliable information about children’s language abilities in clinical assessment, yielding high levels of sensitivity and specificity for individuals with structural language impairment (DLD) across a large number of languages (Conti-Ramsden et al., 2001; Marinis et al., 2017 a.o.). SR has also been used for the detection of language impairment in children with ASD (Botting and Conti-Ramsden 2003; Harper-Hill et al. 2013; Riches et al. 2010, a.o.). However, the specific SR tasks employed in these studies were highly memory based (involving extremely long sentences) and/or they lacked a variety of complex constructions. For the present study, we used an SR task targeting specific morphosyntactic structures of varying computational complexity: the LITMUS-SR-French (Prevost, Zebib, & Tuller, 2012). This task was designed to focus on specific constructions known to be difficult for children with language impairment, while also reducing the potential influence of memory effects (see material and procedure section).

Regarding intellectual abilities, current large-scale epidemiological studies have reported a mean rate of intellectually impaired children with ASD of 31% (IQ < 70), while the rest show normal intellectual abilities, including 25% of children in the borderline range (71-85) and 44% with average or above average IQ (> 85) (CDC 2018). The intellectual abilities of children with ASD are often classified through Full Scale IQ (FSIQ) scores. However, these scores have been reported to be hard to interpret because of the great heterogeneity of autistic abilities across intellectual domains (nonverbal, verbal, working memory, speed processing) (Mayes & Calhoun, 2008). There is evidence, in fact, that children with autism tend to display a relative, and sometimes absolute weakness (when compared to TD age-peers) on tasks evaluating attention, motor abilities, processing speed and verbal abilities, especially those tasks that entail measures of social and practical understanding and/or pragmatic-communicative skills. This is found on the various subtests of most, if not all, intelligence test batteries (Mackintosh & Mackintosh, 2011; Mottron, 2004). On the other hand, nonverbal (NV) reasoning has been demonstrated to be a relative strength of autistic individuals, especially on tasks based on abstract perception and visuo-spatial abilities (Barbeau et al., 2013; Mottron et al., 2006).

Moreover, most of the tests used for evaluating intellectual abilities involve direct use of language capacities both for comprehending the task instructions and producing verbalised responses.

Since we were seeking to detect profiles of language and intellectual abilities in children with ASD, we aimed at selecting cognitive scores which are as nonverbal as possible, just as we sought to use language measures capable of measuring as specifically as possible structural language abilities. Besides being good indicators of intellectual abilities in children with ASD (Nader et al., 2016), NV tests typically minimize the need for task instructions, experience-specific abilities, and other abilities which may be important for performing the task (e.g., fine motor or speech skills), focusing on abstract perception and fluid reasoning abilities. For these reasons we will interpret “impaired intellectual abilities” as a deficit in nonverbal intellectual abilities.

How can NV intellectual abilities be evaluated in ASD? If we consider the two main instruments used to evaluate human intelligence, Raven’s Progressive Matrices (RPM) (Raven, 1998), in research, and Wechsler Intelligence Scale for Children (WISC) (Wechsler, 2003), in clinical practice, there is evidence that RPM better evaluate intellectual abilities of individuals with ASD across the spectrum than on WISC FSIQ scores (Dawson et al. 2007; Hayashi et al. 2008; Nader et al., 2016). Regarding the internal structure of the Weschler Scale, it has been showed the Perceptual Reasoning Index (PRI) of WISC-IV highlights the enhanced spatial perception and abstract reasoning abilities of individuals with ASD in comparison to both FSIQ and the other indices and subtests of the Wechsler scale, including the Verbal Comprehension Index (Barbeau et al. 2013). Yet, even within the PRI, some studies have reported a further peak of abilities on the Matrix Reasoning and the Block Design subtests compared to the Picture Concepts subtest (Nader et al. 2015; Oliveras-Rentas et al. 2012). This may be due to the fact that children with ASD display their strengths more consistently on visuospatial tasks (Block Design) and on fluid reasoning tests (Matrix Reasoning), while they experience more difficulties when the task relies on language abilities (Picture Concepts) (Houskeeper, 2011). Picture Concepts, in fact, strongly relies on language since children are asked to verbalize their answers and provide sematic category motivation. We thus decided to use RPM, Block

Design and Matrix Reasoning of the WISC-IV to evaluate the intellectual (NV) abilities of children of ASD in our study, but not Picture Concepts.

Finally, are there other factors that may be related to either impaired language or impaired intellectual abilities in ASD? Current results in the literature have yet to reveal a complete picture. Notably, it remains to be seen whether generalized measures of severity of autism symptoms can predict performance on language and/or intellectual measures in ASD. Some studies have found significant correlations between autism severity and both language abilities and intellectual abilities (Gotham et al. 2009; Luyster et al. 2008; Tek et al., 2014), in contrast to others (Charman et al. 2011; Loucas et al., 2008).

The aim of the present study was to take a direct look at ASD heterogeneity by investigating whether clear profiles related to language and intellectual abilities like the ones described in the ICD-11 emerge when investigation is extended to the entire (verbal) spectrum. In order to explore this question, we considered possible links between structural language and NV abilities, as measured by specific repetition tasks for characterizing language capacities (LITMUS-SR-French and LITMUS-NWR-French) and specific NV tasks (RPM, Block Design and Matrix Reasoning) for characterizing intellectual abilities of children with ASD. We explored structural language and nonverbal abilities by using an integrative machine learning approach, cluster analysis, in order to see whether identifiable phenotypical profiles emerged.

We asked the following research questions: 1) when the measures selected for language and intellectual abilities are applied to a population sample from the entire spectrum, do clear profiles emerge? 2) Do these profiles resemble those presented in the new ICD-11 classification? For researchers, answers to these questions would provide fundamental information that could facilitate pinpointing the different phenotypes of autism; for clinicians, it would increase the possibility of developing treatments tailored to the specific needs of individuals, based on particular patterns of strengths and impairment.

Methods

Participants

Fifty-one verbal children with ASD aged 6-12 years old (*M* = 8;11, SD = 1;7), two girls and forty-nine boys, were recruited from the Autism Centre at the Regional University Teaching Hospital in Tours (France). Fourteen of these children were bilingual (home exposure from birth to at least one language other than French), reflecting the reality of the ASD population in France. All participants met the criteria for a DSM-5/ICD-11 clinical diagnosis of ASD, confirmed by the Autism Diagnostic Observation Schedule, ADOS (Lord et al., 2003), and/or the Child Autism Rating Scale, CARS (Schopler et al., 2010) and the Evaluation of Autistic Behaviors, ECA-R (Lelord & Barthélémy, 2003). For this study, the ADOS calibrated severity score, the ECA-R and the CARS global score were used as measures of autism severity. The main characteristics of our population are presented in Table 2.

[Table 2]

For all children the only inclusionary criterion was the production of utterances of at least three words, to ensure that language tests could be administrated; no exclusionary criterion was applied for intellectual ability. Information on the bilingual children's language exposure and use was collected via the Parents of Bilingual Children Questionnaire (Tuller, 2015). Of the 14 bilinguals, 10 were French-dominant and 4 were balanced bilinguals; these children's other languages were either Arabic (5), Farsi (2), English (2), Kurmanji, Lingala, Russian, Turkish or Vietnamese. Since the bilingual children did not differ from the other children with ASD, for any measure of language (SR: t(50) = 1.04, *p* = .304; NWR: t(50) = 0.52, *p* = .605), cognitive ability (RPM: t(50) = 0.62, *p* =

.540; Block Design: t(42)= 0.28, *p* = .783; Matrix Reasoning: t(42) = 1.13, *p* = .276), or autism severity (ADOS: t(50) = - 0.08, *p* = .930; CARS: t(50) = -0.90, *p* = .380; ECA-R: t(50) = -1.13, *p* = .228), all children were grouped together. We note, in particular, that poor vocabulary skills, which could be expected to impact on SR performance, were as frequent among the monolingual participants (15/37 had composite vocabulary scores below -1.25) as among the bilingual participants (6/14), and the two groups did not differ on this measure (t(50) = 0.24, *p* = .754). The study received approval from the Ethical Committee for Non- Interventional Research (CERNI) of Tours-Poitiers (France). Informed consent was obtained for all individual participants included in the study.

Materials and procedure

Language abilities were evaluated via the LITMUS-NWR-French and the LITMUS-SR-French (henceforth NWR and SR respectively). The design of the NWR task was conceived to concentrate on those complex phonological structures that have been identified as the source of errors in children with impaired phonology: syllable complexity, with more complex syllables including consonant clusters or consonants in syllable-final position (dos Santos & Ferré, 2018). The stimuli were controlled for word-likeness and, in contrast to many other NWR tasks, did not exceed three syllables in length, in order to minimize memory effects. The 50 nonwords of the task included simple consonant–vowel (CV) syllables, syllables with initial and median consonant clusters (CCV) and syllables with a final consonant (CVC#).

SR manipulated syntactic computational complexity, measured in terms of the nature and number of operations needed for the derivation of a syntactic construction. It was based on the fact that children with DLD show deficits in certain structure-dependent relationships, such as tense-marking (Franck et al., 2004) and long-distance dependencies necessitating movement (*wh*-questions and relative clauses), and in embedded clauses (Delage et al., 2008; Guasti & Cardinaletti, 2003; Hamann, 2006; Jakubowitz & Tuller, 2008; a.o.). The task contained five sentence structures (monoclausal sentences in the present tense, monoclausal sentences in the past tense, object wh-questions, sentence containing an argument clause, sentence containing a relative clause) each divided into two substructures, one less complex and the other more complex, consisting of three sentences each (for a total of 30 sentences). The structures were controlled for number of words and syllables in order to minimize working memory effects. For a detailed description of both NWR and SR tasks see de Almeida et al., 2017.

These two repetition tasks have been shown to be good indicators of impairment, in both monolingual and bilingual populations, accurately distinguishing between DLD and TD (de Almeida et al., 2017; Tuller et al., 2018; a.o.). Drawing from these findings, we hypothesised that these tools should also identify language impairment in monolingual and bilingual children with ASD. Based on the results in Tuller et al.'s (2018) study the repetition cut-off rate for impairment for monolingual children was established at 77% correct repetition for NWR (specificity, 83%, and sensitivity, 88%) and 78% for SR (specificity, 92%, and sensitivity, 93%) and for bilingual children at 77% for NWR (sensitivity 85% and specificity 74%) and at 75% for SR (sensitivity 81% and specificity 72%).

Children's nonverbal cognitive level was estimated through RPM and, when available, Block Design and Matrix Reasoning of the WISC-IV. Out of the 51 children included in our protocol, 43 had been administrated the WISC-IV battery. The eight remaining children had NV scores from another cognitive evaluation, the Echelles Différentielles d'Efficience Intellectuelle-Révisée, EDEI-R (Perron-Borelli, 1996). The relevant indices derived from EDEI-R have been shown to be consistent with RPM scores as well as with indices of the WISC (Jumel, 2014). A research assistant administrated the coloured RPM test. Block Design, Matrix Reasoning subtests (WISC-IV) and NV index (EDEI-R) had been administrated by hospital psychologists. The gap between administration of the psychometric subtests and the RPM, always in that order, was less than twelve months (*M* = 2.72, *SD* = 8.9) for each participant.

Each participant was tested individually in a quiet room, in two or more sessions (*M* = 2.01; *SD* = 0.4) whose duration varied from ten to thirty minutes depending on the child's level of attention and participation. Each session was audio-recorded for transcription and coding.

Data analysis

Due to the limited number of participants a Principle Component Analysis (PCA) was first conducted on all factors that could contribute to variability in our dataset. This allowed us to detect which variables accounted the most for data variability and to eliminate parameters that could create confounding effects. A cluster analysis was then conducted on the data selected from the PCA. Our aim in using this technique was to limit as much as possible all a priori suppositions on the number and nature of subtyping present in our sample (cfr. Lombardo et al., 2019), since this was our research question. The cluster analysis was run through a *hard clustering method (K-means clustering)* whereby each data point either belongs to a cluster completely or not. All statistical analyses were conducted with the R-studio version 1.1.423.

Both the PCA and cluster analysis were run exclusively on the 43 children who had WISC-IV scores. The results of the other eight children were analysed a posteriori by matching their profiles to those detected by the cluster analysis.

Results

Reducing the number of factors in describing language and nonverbal ability profiles

In order to alleviate confounding effects of intercorrelations among the different parameters, the data were projected along orthogonal Principal Components. The PCA analysis included measures of structural language (SR and NWR) and nonverbal abilities (RPM, Block Design and Matrix Reasoning), and autism severity scores (ADOS severity score and CARS and ECA-R global scores). Data were scaled for normalization purposes due to the presence of different kinds of measures (Buuren & Groothuis-Oudshoorn, 2010). The PCA revealed two components, which together accounted for 60.7% of the data variability (Fig. 1). Table 3 describes the variables' contribution to each component.

[Figure 1]

[Table 3]

Results suggested that a combination of both structural language and NVIQ measures accounted for the identification of Component 1 (44.4%). All measures of structural language and NV abilities contributed significantly to the first dimension, except for Block Design. Component 2 (16.3%) relied exclusively on nonverbal measures (Block Design and Matrix Reasoning). Autism severity scores were only marginally involved in explaining the variability of the dataset, justifying their exclusion from further analyses.

Cluster analyses

The PCA analysis showed that the measures most highly involved in explaining our dataset were a combination of both structural language and NVIQ abilities. A K-means clustering method was adopted in order to investigate whether clear profiles would emerge from the intersection of these abilities. Moreover, a function, independent of the K-means algorithm, determines the optimal number of clusters using different methods, *Sums of squares*, *Average silhouette* and *Gap statistics* (Kassambara, 2017). The clustering variables for nonverbal measures and language measures motivated above by the PCA analyses were RPM, Block Design, Matrix Reasoning, SR and NWR. We decided to focus separately on morphosyntactic/NV profiles and on phonological/NV profiles because some children showed discrepant performance on the two language tasks.

The optimal number of clusters was automatically estimated to be *five* for both morphosyntactic/NV profiles and phonological/NV profiles. Crucially, all three methods (the *Sums of squares*, the *Gap statistics* and the *Average silhouette)* returned the same result. We therefore ran the K-means algorithm with $k = 5$ for both morphosyntactic/NV and phonological/NV cluster analyses. The result was the distributions represented in Figures 2 (SR and NVIQ abilities) and 3 (NWR and NVIQ abilities).

[Figure 2]

[Figure 3]

Each of the five profiles, for phonological and morphosyntactic abilities, included both monolingual and bilingual children, suggesting that the bilingual children with ASD in our sample displayed the same profiles as their monolingual peers. We note that the very same cluster analyses performed over the 37 monolingual children with ASD (and thus excluding the 14 bilingual children) gave rise to the exact same five clusters (Silleresi, 2018).

The characteristics of the centroid (mean, SD) of each cluster allowed us to identify and tentatively label the five clusters as shown in Table 4.

[Table 4]

Three profiles showed "homogenous" abilities on both structural language and NV measures:

cluster 1 displayed low scores on both SR/NWR and NVIQ tasks and was thus labelled ASD-LI with low NVIQ abilities; clusters 4 and 5 showed normal scores on SR/NWR and average and high scores, respectively, on NVIQ tasks, hence the labels ASD-LN with average NVIQ abilities (cluster 4) and ASD-LN with high NVIQ abilities (cluster 5). Two profiles showed "heterogeneous" abilities displaying either impaired language abilities in presence of average NVIQ scores, ASD-LI with average NVIQ, or spared language abilities in presence of impaired NVIQ, ASD-LN with low NVIQ. In short, all four logically possible structural language / NV abilities combinations were detected. In addition, a fifth profile, the ASD-LN with average NVIQ, emerged.

Children assessed with the EDEI-R psychometric test

The eight children that were assessed via EDEI-R were not part of the cluster analysis. However, their scores for SR, NWR and RPM and their NV score of EDEI-R, allowed us to incorporate them into the clusters identified above (see Table 5). NV abilities of these eight children were considered to be impaired when performance was below the threshold on both RPM and the NV index of the EDEI-R, and to be unimpaired when performance was within norms on at least one test.

[Table 5]

Once these children were included, we calculated the prevalence of each cluster for both structural language abilities (see Table 6). As a corollary result we note that the prevalence of the five profiles was not exactly the same for morphosyntacic and phonological abilities.

[Table 6]

Discussion

In this study of structural language/nonverbal ability profiles in children with ASD, we placed heterogeneity in the centre of our investigation by extending work on language in autism to the entire spectrum, thus including verbal children with all levels of intellectual abilities. We applied domain specific measures of structural language (SR and NWR) and NVIQ (RPM, Matrix Reasoning and Block Design) to a group of 51 children with ASD, both monolingual and bilingual, aged 6 to 12, in order to see whether clear profiles, like the ones mentioned in the ICD-11, would emerge via a statistical approach based on PCA and cluster analyses.

Three main results emerged from our study. The PCA analysis suggested that severity of autism symptoms did not play a pivotal role in discriminating subtypes of ability profiles in children with ASD. This result appears to be in line with the transition from the DSM-IV and ICD-10 to the DSM-V and ICD-11, respectively, which is based on the idea of a *spectrum*, rather than discrete types of autism.

The cluster analysis suggested the existence of five profiles in both monolingual and bilingual children with ASD: three homogeneous profiles and two profiles displaying discrepant abilities. Among these five profiles, all four logically possible structural language / NV abilities combinations were detected. These results are in line with the findings reported in Joseph et al. (2002), Kjelgaard & Tager- Flusberg (2001); Silleresi et al. (2018) and Tuller et al. (2017). What is typically called *normal NVIQ* ended up being split into two clusters, *average level of NVIQ* and a *high level of NVIQ*, resulting into five profiles instead of the four originally expected. Among these five profiles, three emerged among LN children and two emerged among LI children, suggesting that it is inadequate to simply divide children into two groups on the basis of their language abilities (ASD-LI or ASD-LN). We note that the three LN-NVIQ profiles raise the question of the absence of three corresponding LI profiles, and in particular why no LI-High NVIQ profile was attested. The extreme paucity of relevant data in the literature makes it very difficult to conclude whether this could be the result of a so-called Matthew effect (Stanovich, 2009). Likewise, the relatively low number of children in the LN-Low NVIQ profile clearly deserves further investigation.

Our conclusion that all logically possible profiles are found (both homogenous and heterogeneous), in both monolingual and bilingual children, constitutes an invitation to explore these profiles and what may or may not be underlying them. Just how bilingualism impacts on which profile a given child will belong to is an extremely interesting question, and one that deserves a study in its own right. Our study has served only to show that bilingual children "end up" in each of the profiles; this means, notably, that a bilingual language environment for a child with autism, whether or not ID is present, does not preclude normal structural language functioning (see Gonzales-Barrero & Nadig, 2018).

The next step in our enquiry will be to investigate the issue of the phenotypical similarities between ASD-LI and DLD and between ASD-LN and TD, by comparing the performance in the five profiles of morphosynatctic abilities and the five profiles of phonological abilities with the performance of children with DLD and TD children. This will involve an analysis of the performance for each sentence type and each syllabic structure manipulated by the two repetition tasks, including error analysis, which will also determine whether the resulting phenotypical groups of children with ASD found in the present study correspond to different degrees of impairment (in phonology and/or syntax).

Implications for the ICD-11

We believe that the findings of this study illustrate rather clearly that progress in understanding language profiles in ASD is dependent on investigation of children across the spectrum and use of robust structural language and NV measures. Our study confirmed the existence of the four language profiles mentioned in the ICD-11 (ASD-LN with high NVIQ, ASD-LN with low NVIQ, ASD-LI with average NVIQ and ASD-LI with low NVIQ). The existence of all four logically possible profiles clearly indicates that the subcategories of the ICD-11 are a reality in the autism spectrum. First, the existence of, five profiles, with ASD-LN with normal NVIQ being split between average NVIQ and high NVIQ, suggests that maybe the four profiles introduced in the ICD-11 are not the only ones present in the autism spectrum. Second, the difference in prevalence between morphosyntactic and phonological ability profiles suggests that these two domains should be considered independently in the description of language ability profiles in the autism spectrum. This would entail both a clearer definition of "functional language" and a specification of possible discrepant structural language abilities in children with ASD. Third, the definition of "intellectual impairment" should be refined by specifying which domain of cognitive abilities should be considered most adapted to picture cognitive profiles in relation to language abilities.

Cognition and language: what is the relation in ASD?

From the vantage point of the existence of a language module in the human mind/brain, which thus could in principle be selectively spared, our results receive a natural interpretation. The existence of a double dissociation, such as the one found in the ASD-LI with average NVIQ profile and the ASD-LN with low NVIQ profile, indicates that children with autism can indeed display impaired language abilities in presence of spared nonverbal intelligence or spared language abilities in the presence of impaired nonverbal intelligence, a profile reminiscent of that found in Williams Syndrome (Mervis & Velleman 2011) and also in the language Savant *Christopher* (Smith & Tsimpli 1995). Specifically, concerning the existence of the ASD-LN with low NVIQ profile in both monolingual and bilingual children, our results support the few studies that have reported its existence in the literature (Joseph et al., 2002; Kjelgaard & Tager-Flusberg, 2001; Silleresi et al., 2018; Smith & Tsimpli 1995; Tuller et al., 2017) For many years, the assumption that low cognitive abilities necessarily entail low language abilities has been taken for granted. However, these results, along with the existence of profiles like those found in DLD and Williams Syndrome, reinforce the idea that language may constitute an independent module in the brain, even though this module clearly interfaces with other modules and central systems (see Chomsky, 1980; Fodor, 1985; Smith & Tsimpli, 1995). Furthermore, the fact that the ICD-11 classification makes explicit reference to the existence of two distinct profiles in nonverbal (or minimally verbal) children with ASD, one without intellectual impairment and one with intellectual impairment, seems to further corroborate the existence of a dissociation between language and cognitive (NV) abilities in this population.

Additional research is needed to test the replicability of the current findings and to address the following limitations. The number of participants in the current study was limited; a larger population sample, and in particular a larger sample of children with low NVIQ and of children with LI, should make it possible to better address the question of the number and relative prevalence of the profiles. Regarding the identification of profiles of abilities in ASD, we think that several pieces are still missing from the puzzle. Our work has proposed a step forward into identifying structural language / NV ability profiles in children with autism, but other factors which we were unable to investigate in this study, should be taken into consideration in future analyses, such as executive functions and the peaks and valleys of abilities which underlie performance on a wider array of NVIQ subtests. Finally, additional research is needed to investigate how profiles of language and intellectual abilities evolve from a longitudinal perspective (cfr. the idea of chronogeneity introduced by Georgiades et al., 2017).

N of words: 5434

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Tables

Table 1. Classification codes and description for the ICD-11 ASD subcategories

	Codes	Description
Verbal children with ASD	6A02.0	Autism spectrum disorder without disorder of intellectual development/functioning and with mild or no impairment in functional language
	6A02.1	Autism spectrum disorder with disorder of intellectual development/functioning and with mild or no impairment in functional language
	6A02.2	Autism spectrum disorder without disorder of intellectual development/functioning and with impaired functional language
	6A02.3	Autism spectrum disorder with disorder of intellectual development/functioning and with impaired functional language

Table 2. Participant characteristics - mean (SD) and minimum/maximum values

	Mean (SD)	**Range**
Age (y;m)	8 ;11 (1.7)	6;3 – 12;0
Severity of autism (calibrated scores for ADOS and global scores for CARS and ECA-R)		
CARS	27.5 (4.4)	19.5 – 38.5
ADOS severity score	5.89 (2.2)	2 – 10
ECA-R global score	25.8 (17.8)	2 – 68
NVIQ abilities (standard scores)†		
RPM	92.3 (15.3)	69 – 125
Block Design (PRI of WISC-IV) ‡	95.6 (18.9)	55 – 125
Matrix Reasoning (PRI of WISC-IV) ‡	92.5 (17)	60 – 120
Language abilities §		
NWR (% correct repetition)	79 (19)	0 – 100
SR (% correct repetition)	63 (31)	0 – 100

† The cut-off for NVIQ measures is 80 standard score.

‡ The scores for Block Design and Matrix Reasoning were collected for 43/51 children.

§ The repetition cut-off rate for monolingual children was established at 77% for SR and at 77% for NWR; for bilingual children at 75% for SR and at 77% for NWR. These rates correspond to high level of diagnostic accuracy for language impairment (Tuller et al., 2018).

Table 3. Variables contributing to principle components – correlation and *p*-values for Component 1 and Component 2 (the significance threshold after post-hoc correction – Bonferroni was $p = < .006$).

Component 1 (44.4%)	**Correlation**	***p*-value**
SR	.819	< .001
RPM	.820	< .001
NWR	.802	< .001
Matrix Reasoning	.798	< .001
Block Design	.286	.223
ADOS	-.335	.056
CARS	-.217	.224
ECAR	-.304	.085
Component 2 (16.3%)	**Correlation**	***p*-value**
Block Design	.764	< .001
Matrix Reasoning	.621	< .001
RPM	.303	.076
NWR	.404	.022
SR	.227	.198
CARS	.478	.010
ECAR	.335	.056
ADOS	-.034	.847

Table 4. The main characteristics (mean, SD), name and prevalence of the five profiles for both morphosyntactic/NV abilities and phonological/NV abilities

	SR (%)	RPM (standard score)	Block Design (standard score)	Matrix Reasoning (standard score)	Morphosyntactic / NVIQ ability profiles
Cluster 1 (*n* = 5)	**38 (24)**	**74 (4)**	**64 (8)**	**66 (5)**	ASD-LI with low NVIQ
Cluster 2 (*n* = 5)	83 (10)	**79 (9)**	**73 (8)**	83 (7)	ASD-LN with low NVIQ
Cluster 3 (*n* = 11)	**28 (17)**	87 (14)	102 (10)	92 (15)	ASD-LI with average NVIQ
Cluster 4 (*n* = 11)	88 (9)	92 (8)	101 (12)	95 (15)	ASD-LN with average NVIQ
Cluster 5 (*n* = 11)	90 (14)	111 (9)	106 (11)	108 (5)	ASD-LN with high NVIQ
	NWR (%)	RPM (standard score)	Block Design (standard score)	Matrix Reasoning (standard score)	Phonological / NVIQ ability profiles
Cluster 1 (*n* = 4)	**71 (24)**	**73 (4)**	**68 (12)**	**70 (5)**	ASD-LI with low NVIQ
Cluster 2 (*n* = 5)	91 (6)	**79 (8)**	**69 (8)**	**78 (13)**	ASD-LN with low NVIQ
Cluster 3 (*n* = 9)	**65 (13)**	86 (9)	104 (9)	95 (11)	ASD-LI with average NVIQ
Cluster 4 (*n* = 14)	90 (5)	92 (8)	100 (12)	93 (17)	ASD-LN with average NVIQ
Cluster 5 (*n* = 11)	91 (5)	111 (9)	106 (11)	108 (5)	ASD-LN with high NVIQ

Note :
Scores below the thresholds are in bold

Table 5. Individual scores of the 8 children evaluated via the EDEI-R psychometric test

Child code	SR (%)	NWR (%)	RPM (standard score)	NV score EDEI-R (standard score)	Morsyn/NV profile	Phono/NV profile
SIM	**40**	**62**	114	104	ASD-LI with average NVIQ	ASD-LI with average NVIQ
KEV	**33**	**28**	**78**	97	ASD-LI with average NVIQ	ASD-LI with average NVIQ
EVA	**33**	**38**	95	80	ASD-LI with average NVIQ	ASD-LI with average NVIQ
ROS	90	96	90	95	ASD-LN with average NVIQ	ASD-LN with average NVIQ
RIV Bilingual	**30**	**72**	103	103	ASD-LI with average NVIQ	ASD-LI with average NVIQ
MIM Bilingual	**0**	**0**	**78**	**79**	ASD-LI with low NVIQ	ASD-LI with low NVIQ
LCU Bilingual	**70**	78	110	104	ASD-LI with average NVIQ	ASD-LN with average NVIQ
YVA Bilingual	**50**	**74**	**69**	**30**	ASD-LI with low NVIQ	ASD-LI with low NVIQ

Note : Scores below the thresholds are in bold

Table 6. Prevalence of the five profiles for both morphosyntactic/NV abilities and phonological/NV abilities

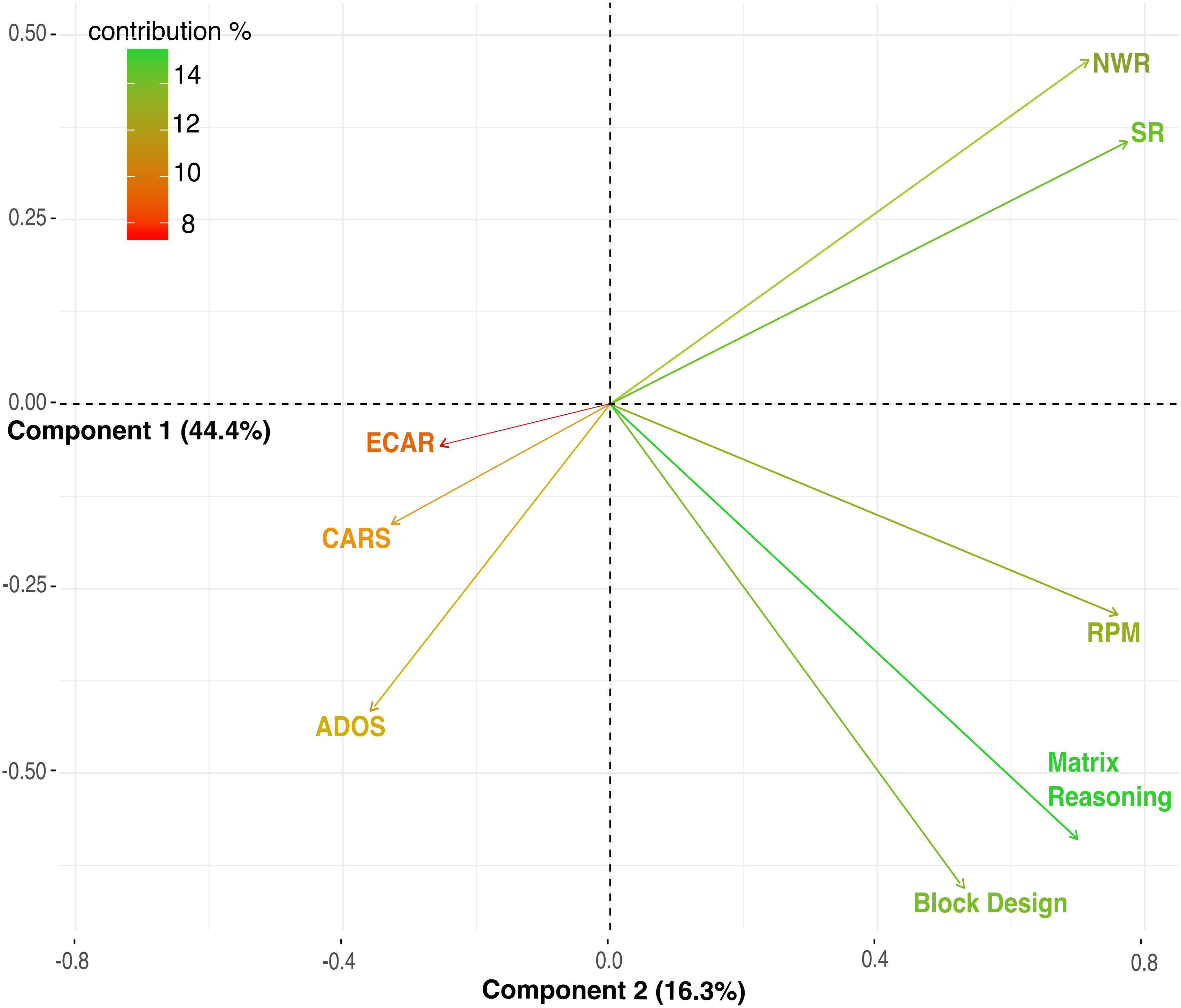
	Morphosyntactic/NV abilities	Phonological/NV abilities
ASD-LI with low NVIQ	14%	11%
ASD-LN with low NVIQ	10%	10%
ASD-LI with average NVIQ	33%	25.5%
ASD-LN with average NVIQ	23.5%	31%
ASD-LN with high NVIQ	21.5%	21.5%

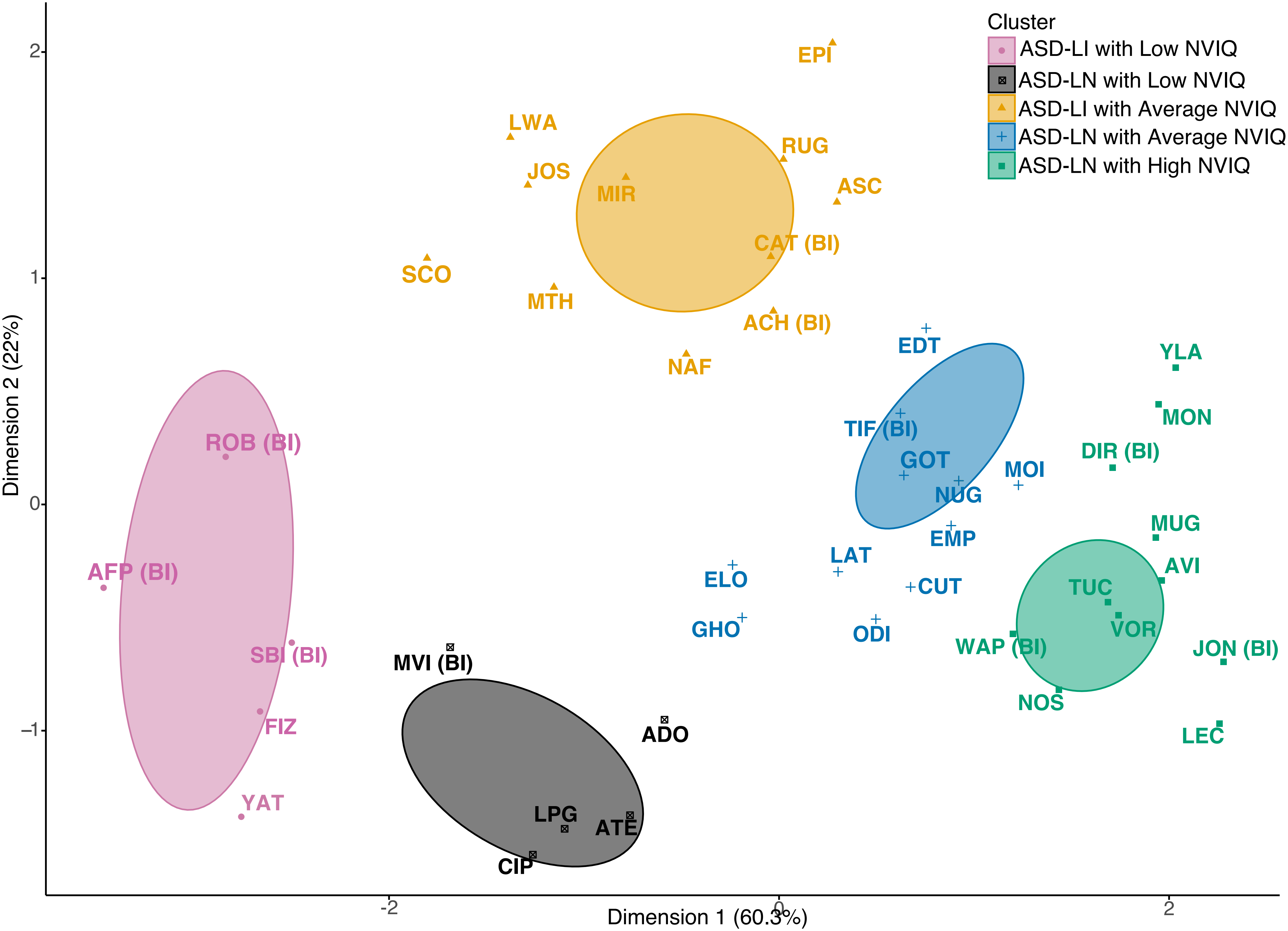
Figure Legends

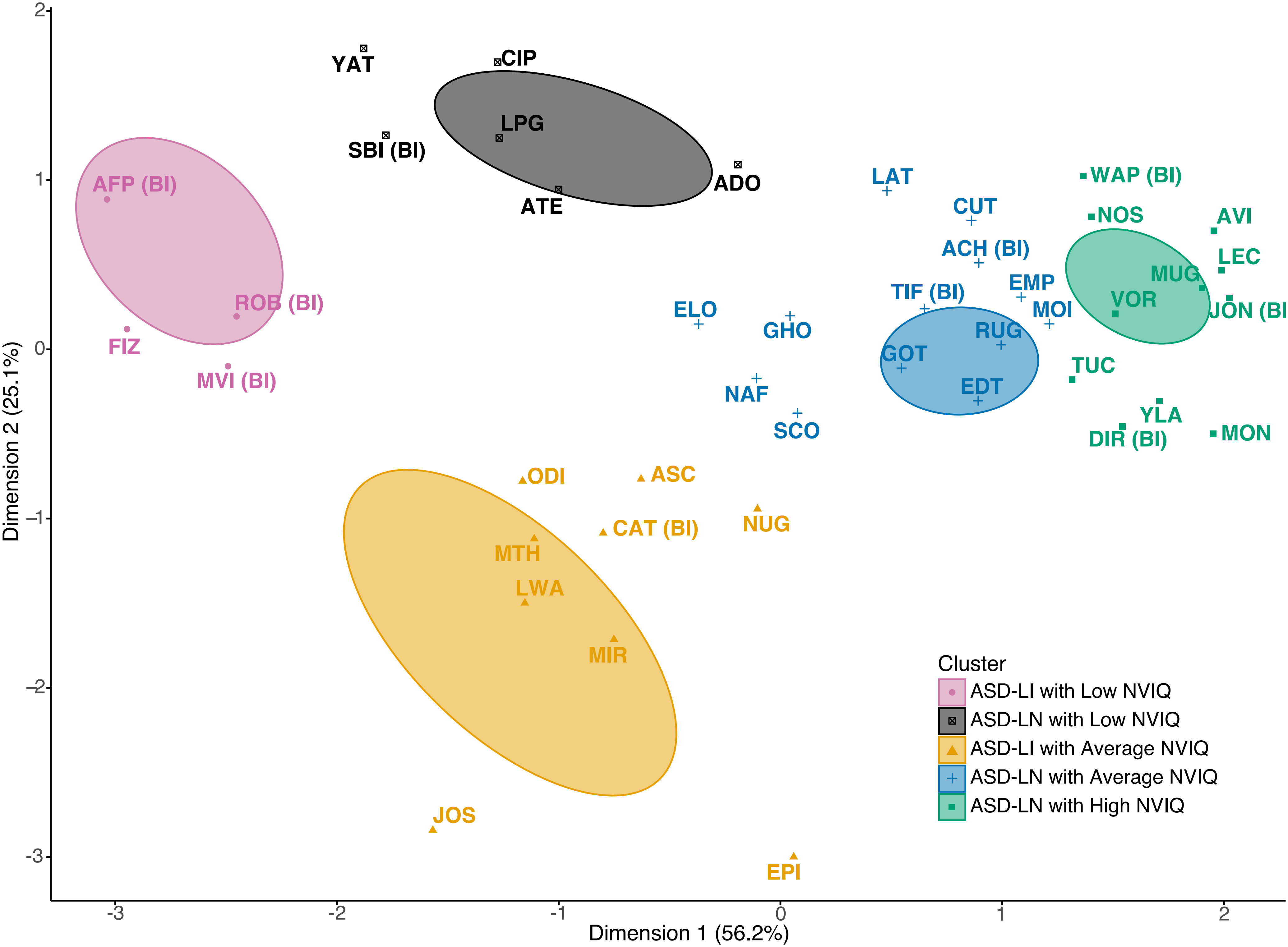
Figure 1. The PCA including all the parameters. The contribution bar highlights the weight (%) of each variable in explaining the variability in the data set. The left and bottom axes are showing normalized principal component scores.

Figure 2. Cluster analysis (K-means) for morphosyntactic/NV ability profiles on the measures of SR, Block Design, Matrix Reasoning and RPM. Children with bilingual exposure are indicated with (BI).

Figure 3. Cluster analysis (K-means) for phonologival/NV ability profiles on the measures of NWR, Block Design, Matrix Reasoning and RPM. Children with bilingual exposure are indicated with (BI).


contribution %
14
12
10
8
0.50
0.25
0.00
-0.25
-0.50
Component 1 (44.4%)
NWR
SR
ECAR
CARS
ADOS
RPM
Matrix
Reasoning
Block Design
-0.8
-0.4
0.0
0.4
0.8
Component 2 (16.3%)


Cluster
ASD-LI with Low NVIQ
ASD-LN with Low NVIQ
ASD-LI with Average NVIQ
ASD-LN with Average NVIQ
ASD-LN with High NVIQ
Dimension 2 (22%)
Dimension 1 (60.3%)
2
1
0
−1
-2
0
2
EPI
LWA
RUG
JOS
MIR
ASC
CAT (BI)
SCO
MTH
ACH (BI)
NAF
EDT
YLA
MON
TIF (BI)
GOT
DIR (BI)
MOI
NUG
ROB (BI)
EMP
MUG
LAT
AVI
AFP (BI)
ELO
CUT
TUC
GHO
ODI
VOR
WAP (BI)
JON (BI)
SBI (BI)
MVI (BI)
NOS
FIZ
ADO
LEC
YAT
LPG
ATE
CIP


YAT
CIP
LPG
SBI (BI)
ADO
ATE
AFP (BI)
ROB (BI)
FIZ
MVI (BI)
LAT
CUT
ACH (BI)
TIF (BI)
EMP
MOI
ELO
GHO
RUG
GOT
EDT
NAF
SCO
WAP (BI)
NOS
AVI
LEC
MUG
VOR
JON (BI
TUC
YLA
DIR (BI)
MON
ODI
ASC
CAT (BI)
NUG
MTH
LWA
MIR
JOS
EPI
Cluster
ASD-LI with Low NVIQ
ASD-LN with Low NVIQ
ASD-LI with Average NVIQ
ASD-LN with Average NVIQ
ASD-LN with High NVIQ
Dimension 2 (25.1%)
Dimension 1 (56.2%)
2
1
0
−1
−2
−3
−3
−2
−1
0
1
2