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Children with differing developmental trajectories of prelinguistic communication skills:

Language and working memory at age 5.

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Abstract

Purpose: This paper examines the developmental continuity from prelinguistic communication to kindergarten age in language and working memory capacity.

Method: Following our work outlining six groups of children with different trajectories of Early Communication Development (ECD, Määttä et al., 2012), we examined their later development by psychometric assessment. Ninety-one children first assessed at age 12 to 21 months completed a battery of language and working memory tests at age 5;3 (years; months).

Results: Two of the ECD groups previously identified as being at risk for language difficulties continued to show weaker performance at follow-up. The majority (79 %) of the children with compromised language skills at follow-up were identified on the basis of the ECD groups, but the number of false positives was high. The two at-risk groups also differed significantly from the typically developing groups in the measures tapping working memory capacity.

Conclusions: In line with the dimensional view of language impairment, the accumulation of early delays predicted the amount of later difficulties; however, at the individual level the prediction had rather low specificity. The results imply a strong link between language and working memory and call for further studies examining the early developmental interaction between language and memory.

Keywords: language impairment, working memory, early prediction, prelinguistic communication

Children with Differing Developmental Trajectories of Prelinguistic Communication

Skills: Language and Working Memory at Age 5

Language difficulties are one of the most common early developmental difficulties. Prevalence estimates are 19 % for early language delay (Nelson, Nygren, Walker, & Panoscha, 2006) and 7 % for specific language impairment (SLI) in kindergarten (Tomblin, Records, Buckwalter, Zhang, Smith, & O'Brien, 1997). Substantial variation exists in the progression of language performance both at early and later ages. For example about half of late talking toddlers appear to have caught up with their peers by age 5. If the language delay is still present at kindergarten age, 50 to 90 % of these children will continue to show language impairment throughout childhood and many go on to have related academic, behavioral, or psychiatric difficulties later on (for a review, see Hulme & Snowling, 2009). The outcome is generally better when the language difficulties are mild or very specific in form. However, even for children whose oral language delay seems to resolve by early school age, an increased risk for later mild deficits of language and academic difficulties has been reported (e.g., Hulme & Snowling, 2009; Rutter, 2008). In this study we followed the development of children who had differing developmental trajectories of prelinguistic communication at age 12 to 21 months and explored their language skills at age 5. The children's working memory capacity was also explored. Limited verbal working memory has been suggested to act as a risk marker for language impairment (Montgomery, Magimairaj, & Finney, 2010) implying that it might have a primary role in developmental language disorder and thus in the identification of children with persistent language impairment (Petruccelli, Bavin, & Bretherton, 2012).

Developmental Continuity of Early Language and Communication Delay

The heterogeneity in the outcomes of children with early language and communication delays makes early differentiation between normal variation and specific

impairments difficult. Outlining a dimensional view of language impairment, Rescorla (2002, 2005, 2009) argues against the dichotomy of impaired versus normal, suggesting instead that language ability should be regarded as a continuum along which children vary widely, from seriously impaired to extremely gifted. This dimensional view accounts in part for the stability of individual differences in language skills (e.g., Tomblin, Zhang, Buckwalter, & O'Brien, 2003) by its claim that the rank order of children, despite their level of performance, is partly determined by the endowment children are born with (Rescorla, 2002, 2005, 2009). This language endowment spectrum does not represent a unitary language skill, but a set of intercorrelated yet distinct skills that subservise language. This argument is consistent with the theories of Bates (2004; Bates, Thal, Finlay, & Clancy, 2002), who suggests that language ability emerges from the interactions of many early cognitive processes, such as speech sound perception and production, object recognition and categorization, imitation, joint reference, and intentionality. Thus, differential endowment postulates the heterogeneity of symptoms, as weak endowment can arise from weaknesses in any of the subskills that comprise language (Dollaghan, 2004; Rescorla, 2002, 2005, 2009).

Support for the dimensional view of language impairment comes from studies indicating that early delays are related to later language proficiency (Rescorla, 2009). It has consistently been shown that, as a group, children with a history of early language delay perform more weakly, though often within normal limits, than comparison children on a range of standardized language tests in kindergarten and at school age (Girolametto, Wiigs, Smyth, Weitzman, & Pearce, 2001; Rescorla, 2002; Roos & Ellis Weismer, 2008). As would be predicted by the dimensional view, some children with early language delays seem to show persistent but subtle language weaknesses that are not significant enough to be classified as clinical impairment. These subclinical language weaknesses might nevertheless

have a significant impact on later academic success, and thus merit early identification (Lyytinen, Eklund, & Lyytinen, 2005; Rescorla, 2002; Roos & Ellis Weismer, 2008).

Moreover, not all children with a history of early language delay catch up, but instead some of them go on to be diagnosed with SLI (e.g., Dale Price, Bishop, & Plomin, 2003). So far, no reliable and accurate means exists that would enable early identification of children who will later have clinically significant language impairment. For example, with regard to outcomes for late talkers, various potential predictors, such as level of expressive delay, receptive language, social engagement and joint attention, as well as gestures and symbolic play (e.g., Bates & Dick, 2002; Bruce, Kornfält, Radeborg, Hansson, & Nettelbladt, 2003; Dale et al., 2003; Rescorla & Goossens, 1992; Rescorla & Merrin, 1998), have been tested, but none of these have proven to have consistent predictive value. However, there are indications that the severity and multitude of early delays may serve as a guide (Ellis & Thal, 2008; Paul & Roth, 2011; Rescorla, 2009). Based on genetic studies of language, Bishop (2006) concludes that in SLI “development is compromised precisely because more than one cognitive process is disrupted” (p. 220), whereas a single area of deficit is rarely enough to seriously compromise language development. Thus, children showing multiple early delays, such as late talkers with concomitant receptive or social communication problems, are at a greater risk for developing language impairment (Paul & Roth, 2011; Rescorla 2009).

Examination of the composition of early skills over time is warranted on the basis of the three assumptions that (a) language ability develops through the interaction of many early skills (Bates, 2004; Rescorla, 2009), (b) more than one skill has to be disrupted in order for language to be seriously impaired (Bishop 2006), and (c) the predictive power of different early skills may change with age (Heimann, Strid, Smith, Tjus, Ulvund, & Meltzoff, 2006). By monitoring language development in infancy and toddlerhood by means of multifaceted and repeated assessments, it might be possible to identify typical patterns of development that

could lead to normal, compromised, or clinically impaired language skills. Correspondingly, in a study on late talkers, Desmarais, Sylvestre, Meyer, Bairati, and Rouleau (2010) suggest that it is possible to identify groups of children that vary along a continuum of early language and communication abilities and have differential outcome. Unfortunately, not many studies have used early developmental profiles to predict later language outcome. The few studies reported so far indicate that, at the group level, early communication delays lead to poorer language proficiency, but, at the individual level, at-risk children are not accurately identified (Dale et al., 2003; Määttä, Laakso, Tolvanen, Ahonen, & Aro, 2012; Ukoumunne et al., 2011).

Language and Working Memory of Children with Language Impairment

Children who present language impairment at kindergarten age show highly varied skill profiles (e.g., Asikainen, 2005). Compared to typically developing peers, children with language impairment have been shown to have smaller vocabularies (Hick, Botting, & Conti-Ramsden, 2005), to be slower and less accurate in naming tasks (Messer & Dockrell, 2006), to produce fewer overall responses and a lower percentage of valid responses in semantic fluency tasks (Weckerly, Wulfeck, & Reilly, 2001), to have slower performance and make more errors on tasks of rapid automatized naming (Katz, Curtiss, & Tallal, 1992), and to have limitations in working memory (Montgomery et al., 2010). On the other hand, not all children diagnosed with SLI show significant difficulties in standardized language tests; their average test scores may reach comparatively high, i.e. age-appropriate, levels despite their indisputable difficulties in language use in everyday situations (Asikainen, 2005; Conti-Ramsden & Botting, 1999).

To untangle the issue of heterogeneity, several attempts have been made to characterize the patterns of individual differences, that is, to distinguish different subgroups within SLI (for a review, see Tomblin, Zhang, Weiss, Catts, & Ellis Weismer, 2004). Conti-Ramsden and Botting (1999) reported a follow-up on six linguistic subgroups and found

stability in the patterns of difficulties, although the group membership of individual children varied from time to time. They concluded that there appears to be a limited number of linguistic skill profiles among which individual children can vary across developmental time. Conversely, Tomblin and colleagues (2004) argue against different qualitative subtypes and suggest that children vary mainly by the severity of impairment, pragmatic skills being the only truly segregating factor. Thus, the existing research has not yet reached a consensus regarding the dimension along which the children should be classified, and none of the existing groupings has received consistent empirical support.

Another line of research has focused on finding possible key difficulties, that is, risk markers that may help to distinguish the children at risk for the most persistent and substantial language impairments (Conti-Ramsden & Hesketh, 2003). Promising results have been obtained when examining tasks measuring verbal working memory capacity as this has been shown to be associated with various aspects of language, such as new word learning, mean length of utterance, complex sentence comprehension, comprehension of narratives, and performance in standardized language tests (for a review, see Montgomery et al., 2010).

The working memory model of Baddeley (2003; 2012) distinguishes between temporary, immediate short-term retention of unprocessed information (often referred to as short-term memory), and the temporary storage and recall of further processed material (working memory). The model consists of two separate subcomponents for verbal and visuospatial short-term storage, namely, the phonological loop and visuospatial sketchpad, and two working memory components, the central executive and episodic buffer, which are responsible for attentional control and the integration of representations from working memory, long-term memory and language processing systems (Baddeley, 2003, 2012). Research has indicated that a notable proportion of children with SLI have deficits in several components of the working memory model, that is, in both verbal short-term and working

memory, and a substantial minority also in visuospatial short-term storage (e.g., Archibald & Gathercole, 2006).

Two extensively studied working memory tasks, nonword repetition (NWR) and sentence repetition (SR) have been suggested to be risk markers for SLI (for a review, see Coady & Evans, 2008; and Vance, 2008). Both tasks impose a significant memory load, but each is considered to tap different components of the working memory model; NWR measures the functioning of the phonological loop, whereas SR is regarded as a measure of the episodic buffer due to the nature of the task involving the integration of information from phonological loop with long-term linguistic knowledge (Boyle, Lindell, & Kidd, 2013; Petruccelli et al., 2012). Both tasks have been shown to differentiate between children with language impairment and age- or language-matched children with typical development (Archibald & Joanisse, 2009; Conti-Ramsden & Hesketh, 2003). In addition, both have been argued to be rather sensitive indicators of residual language difficulties, even when the initial language difficulties have resolved (Conti-Ramsden, Botting, & Faragher, 2001; Thal, Miller, Carlson, & Vega, 2005).

Goals of the Present Study

In our previous study we identified six Early Communication Development (ECD) groups, three of which were regarded as having lower than average development in early communication skills and thus considered to be at risk for later language impairment (Määttä et al., 2012). A tendency towards early communication delays leading to an increased rate of parent-reported concerns about language development at the follow-up about three years later was detected (Määttä et al., 2012).

In this study, we followed the development of a subset of 91 children from the six ECD groups and explored their language skills and working memory capacity at age 5. Our aim now was to explore whether continuity prevails between the early communication

skills and psychometrically assessed later language outcome at both the group and individual levels. Based on the dimensional view of language impairment, we expected that the groups would retain their relative order, and that the individuals with multiple early risks would show poorer language skills. That is, the groups with average or above average prelinguistic development would show superior skills at follow-up compared to the groups showing slower early development, and that the groups showing early delays in more than one area of prelinguistic communication would present more impaired language at follow-up compared to those showing delay in only one prelinguistic skill. Another objective of this study was to consider the working memory capacity of the children in the different ECD groups. Given that memory functions have been shown to be associated with various components of language ability (e.g., Engel de Abreu, Gathercole, & Martin, 2011, Montgomery et al., 2010), we expected the ECD at-risk groups also to show limited working memory capacity.

Method

Participants

The participants of the present study represent a subset of a community-based sample collected in a longitudinal study of early language and communication development in the city of Jyväskylä, Central Finland (see Määttä et al., 2012). The participants were recruited through child health clinics, which are regularly attended by over 95% of Finnish parents and their children from birth to school age. Altogether, 508 children (50.2% boys, 49.8% girls) aged between 6 and 24 months participated. Data were collected every three months until the children were 24 months of age. Data from at least three measurement points were available for 67.9% of the participants. The total number of questionnaires filled in by parents depended on the age of their child at the time of completing the first questionnaire and on how many of the subsequent questionnaires they completed. Subgroups of the original 508 participants were followed after the early data collection

phase at 2 and 3 years of age (individual assessments), at the age of 4;7 (parental questionnaires), and at the age of 5;3 (an individual assessment). The early data and data from the age 5;3 individual assessment were used in the present study.

Early development data were collected with a parent questionnaire, the Infant-Toddler Checklist (ITC, Wetherby & Prizant, 2002). The questionnaire examines three composites of early language and communication skills covering various areas of development, such as social communication skills (Social), vocalizations and early expressive language (Speech), and understanding and object use (Symbolic). The Early Communication Development (ECD) groups were extracted from a subsample of 271 children (54.2% boys, 45.8% girls) from the original data using the three composites of the ITC. Data reduction was performed for statistical reasons to ensure the reliability of the developmental aspect of the analysis (for details, see Määttä et al., 2012).

The six ECD groups are depicted in Figure 1 (for more details, see Määttä et al., 2012). In the interpretation of the profiles, scoring below $-1SD$ was considered as an indicator of early risk rather than a clinically significant delay. Group 1 (Average, A) performed at an average level in each composite throughout the period of 12 to 21 months. Group 2 (Above Average, AA) also showed a stable profile, performing consistently above the mean. Group 3 (Average with fluctuating Social, A+So) showed an overall average performance with the exception of a temporary drop in the Social composite at age 18 months. Group 4 (Below Average with Symbolic Difficulties, BA+Sy) had Social and Speech skills within the age-range, although their performance was consistently at a markedly lower level than that of group 1 A especially in the Social composite. In addition their development in the Symbolic composite was compromised from age 18 months onward. Group 5 (Expressive difficulties, ED) showed clear difficulties in the Speech composite from age 15 months onward, whereas

the Social and Symbolic composites were on the average level. Group 6 (Broad Difficulties, BD) had a stable profile, showing markedly below average performance in each composite.

Insert Figure 1 about here.

Of the 271 children included in the ECD groups, 91 (50.5% boys, 49.5% girls) participated in the individual follow-up assessment at the age of 5;3. The participants included 68 children with full datasets from the previous assessment points and additional 23 children for whom the parents reported concerns about language and communication skills, hyperactivity, and/or executive functions at age 4;7. The ECD status was not known at the time of the follow-up and thus was not a criterion for inclusion. In terms of the ECD groups, the follow-up sample included 33% of group 1, 29% of group 2, and 35%, 40%, 25%, and 50% of groups 3, 4, 5, and 6, respectively. The children were administered a large battery of psychometric tests measuring language, memory, perception, attention, and executive functions. Here, the results of the language and working memory tests are reported.

All the families were Caucasian and all the children spoke Finnish as their native language. Parental education was classified using a 7-point scale ranging from a basic level ($0 = no\ vocational\ education$) to advanced educational training ($6 = higher\ level\ university\ degree$). There were no significant differences between the children who participated in the follow-up (P, $n = 91$) and those who did not (NP, $n = 180$) in either parental age (P: mother $M = 30.9$, $SD = 5.5$, father $M = 32.5$, $SD = 6.1$; NP: mother $M = 30.0$, $SD = 5.0$, father $M = 32.7$, $SD = 6.7$), education (P: mother $M = 3.8$, $SD = 1.6$, father $M = 3.6$, $SD = 1.5$; NP: mother $M = 3.6$, $SD = 1.5$, father $M = 3.3$, $SD = 1.5$), gender (percentage of males/females, P: 50.5 / 49.5; NP: 56.1 / 43.9) or early communication data (ITC score at 12 months, P: $M = 37.2$, $SD = 6.8$; NP: $M = 37.3$, $SD = 6.3$).

No significant differences were found in demographics between the ECD groups (range in group means of parental age: mothers 28.9 – 32.8, fathers 31.7 – 35.4; parent's education: mothers 3.2 – 4.0, fathers 3.0 – 3.8). The Block Design (BD) subtest of the WISC-III (Wechsler, 1999) was used as a rough estimate of nonverbal intelligence. The block design was chosen as it has been shown to have consistently high reliabilities and a high factor loading on Perceptual Organization, a factor related to nonverbal cognitive abilities (Keith & Witta, 1997). Attention was measured with the Inhibition: inhibition subtask of the NEPSY-II (Korkman, Kirk & Kemp, 2008), which assesses the ability to inhibit automatic responses in favor of novel responses. There were no significant differences between the ECD groups in nonverbal intelligence or inhibition (see Table 2 for means and standard deviations). One child (from Group 4) was reported as having a diagnosis of language impairment. However, the amount of children receiving speech and language therapy services was higher (7.7%) as diagnosis is not a criterion for being eligible for specialist services in Finland. Parents reported the use of these services for language-related difficulties (excluding articulation and stuttering problems) for 0 % (Group 1), 5 % (2), 0 % (3), 13 % (4), 17 % (5), and 33 % (6) of the children in the different ECD groups.

Measures at age 5;3

Language measures. The tasks were selected to measure a range of language-based skills that tap both expressive and receptive skills and different dimensions of language (such as verbal reasoning, lexical-semantic and syntactic knowledge, and verbal productivity), as suggested by Conti-Ramsden and Durkin (2012).

Verbal reasoning. Verbal abstract reasoning and conceptualization abilities were assessed with the Similarities (SI) subtest of the WPPSI-R (Wechsler, 1995). The test consists of three types of tasks. In the first task, the child is asked to select a picture compatible with a stimulus picture from an array of four pictures (6 items). In the second

task the child completes a sentence with an appropriate word (6 items) and in the third task the child is asked how two things are alike (8 items).

Receptive vocabulary. The Peabody Picture Vocabulary Test -Revised (PPVT-R; Dunn & Dunn, 1981) assesses the child's single-word receptive vocabulary. It consists of 30 words accompanied by pictures. The child hears a word and points to the picture that represents the word, choosing from an array of four black-and-white line drawings.

Receptive grammar. The Korpilahti Auditory Sentence Comprehension test, (SC; Korpilahti, 1996), a test of receptive grammar, assesses the child's ability to process semantic and syntactic information in sentences of increasing complexity, demanding greater verbal reasoning and auditory short-term memory. The child is read 30 sentences and asked after each sentence to choose, from three options, the picture that goes with the sentence.

Verbal productivity. The Verbal Fluency, Semantic categories test (VFS; NEPSY-II, Korkman, et al, 2008) assesses verbal productivity and vocabulary through the ability to generate words within specific semantic categories. The child is given a semantic category (animals, foods) and asked to produce as many words as possible in 60 seconds.

Rapid naming. In the task of Rapid Automated Naming (RAN; Ahonen, Tuovinen, & Leppäsaari, 2003; see also Denckla & Cutting, 1999) the child names an array of 50 pictures as fast as possible without errors. There are five different pictures (car, house, fish, pen, and ball) that alternate in random order.

Working memory measures. The tasks were selected to measure different subsystems of Baddeley's (2003, 2012) model of working memory. The division of tasks followed the conceptualizations of Archibald and Gathercole (2006), and Petruccelli and colleagues (2012).

Phonological loop. Two tasks were administered to assess auditory short-term memory, i.e. the functioning of the phonological loop of the working memory model. In the

Digit span (DS) subtest of the WISC-III (Wechsler, 1999), the child repeats a dictated series of digits that begins with two digits and increases in length with two trials at each length. The task includes two series, one forwards and the other backwards. The WISC-III offers only combined norms for the two parts of the task, and thus DS was analyzed as a whole. However, as the forwards part is regarded as tapping the phonological loop, and the backwards part as tapping both the phonological loop and the central executive (e.g. Vance, 2008), the parts were also standardized separately, using the sample mean and standard deviation.

The second task used to assess the functioning of the phonological loop was a task of Nonword repetition (NWR). In the Repetition of nonsense words test (NEPSY, Korkman, Kirk, & Kemp, 1997) the child imitates a series of nonwords of increasing length varying from one (“nas”) to six (“skrikoflunaflistrop”) syllables. The test consists of 16 nonwords that conform to the phonotactic rules of Finnish but are low in word-likeness and phonotactic frequency. In addition to auditory short-term memory, the task is regarded as tapping many language-related processes, such as speech perception, phonological encoding and assembly, and articulation (Coady & Evans, 2008).

Visuospatial sketchpad. The Corsi block task (CB, Corsi, 1972) assesses visuospatial short-term storage, that is, the visuospatial sketchpad. The examiner taps a sequence of identical spatially separated blocks and the child is asked to repeat the action. The sequences begin with two blocks and increase in length up to nine blocks.

Central Executive. The backwards digit recall part of the DS subtask of the WISC-III (Wechsler, 1999) was used as a measure of the central executive. The task was standardized using the sample mean and standard deviation, as the WISC-III does not offer separate norms for this part of the DS task.

Episodic buffer. The Sentence repetition (SR) test of the NEPSY-II (Korkman, et al., 2008) assesses the ability to repeat sentences of increasing complexity and length. The child is read 17 sentences and asked to recall each sentence verbatim immediately after it is presented. The task requires the integration of information from phonological short-term memory (such as verbatim recall of individual words and their order) with long-term linguistic knowledge (semantic and syntactic analysis by the language processing system) and it is thus regarded as measuring the episodic buffer which is responsible for storing chunks of such integrated information (Baddeley, 2000; Boyle, Lindell, & Kidd, 2013).

Analysis

In an earlier study (for details, see Määttä et al., 2012) *latent profile analysis* (LPA), a type of finite mixture analysis, was performed to analyze the repeated measures of early communication skills. The analysis was performed using the maximum likelihood with robust standard errors estimation method implemented in Mplus Version 5.1 (Muthén & Muthén, 1998-2007). This modeling is based on the idea that the observed data can represent subpopulations (i.e., latent classes) that can be identified and their parameters estimated (Muthén & Shedden, 1999; Muthén, 2001). Statistical fit information and substantive theory were used to decide the number of latent classes. The LPA resulted in a solution of six meaningful ECD groups that were clearly distinguishable both theoretically and based on estimates of their statistical quality, such as Entropy (.891) and Average Latent Class Posterior Probabilities (range .90-.99; Muthén & Muthén, 1998-2007).

We compared the six ECD groups on performance in each language and working memory test by performing Anovas with post hoc tests using the LSD method. Effect size was estimated by Partial Eta Squared. Due to the small group sizes and heterogeneity in group sizes and variations, the results were confirmed using the nonparametric Kruskal-Wallis Test. For the individual analysis, the children were divided

into two groups (difficulties/no difficulties) based on their performance in the follow-up language measures (SI, PPVT, SC, VFS) and parent report. The cut-off criterion for belonging to the “difficulties” group was performance at or below $-1 SD$ in at least two of the language measures and/or a parent reported diagnosis of language impairment. We compared the ECD groups along this dichotomy by means of crosstabulation and χ^2 test using Exact test. Effect size was estimated using Cramer’s V (Cramér, 1946). The analysis was performed using IBM’s SPSS Statistics for Windows, version 20.0.0.2.

We set the significance level at $p < .05$. Given the notably small number of subjects in some of the ECD groups, the results are presented without adjusting the p-value for multiple comparisons. While p-value adjustments reduce the risk of making type I errors (i.e., rejecting the null hypothesis when it is true), they increase the chance of making type II errors (i.e., failing to reject a null hypothesis when it is false), or necessitate an increase in sample size (Feise, 2002). The most widely used method, the Bonferroni correction, is criticized for being overly conservative, especially for variables that are intercorrelated (Zhang, Quan, Ng, & Stepanavage, 1997), such as the measures of language and working memory in this study.

Results

Pearson correlations for the whole sample were computed between the follow-up language and working memory measures (Table 1). The data indicated shared variance across these age 5;3 measures with the exception of RAN, which showed only one significant correlation of $-.24$ ($p = .027$) with VFS. Sixteen out of the remaining 21 correlations were significant (range $.23$ to $.58$), with effect sizes ranging from small to large (Cohen, 1992). The correlations were higher among the working memory measures than among the language measures, the correlations of which, despite being significant, were rather low, indicating that in part the tests measure different aspects of language.

Insert Table 1 about here.

Language performance of the ECD groups

We compared the performance of the six ECD groups in each language measure (SI, PPVT, SC, and WFS) to ascertain to what extent continuity exists between the early developmental profiles and follow-up language skills. The profiles of language performance for each of the ECD groups are depicted on the left in Figure 2. Table 2 presents the means and standard deviations of the *z*-scores for each test by group. As the standard deviations indicate, marked variation was observed in all the language measures within each group. Group comparisons were executed with one-way ANOVA and confirmed with Kruskal-Wallis Test. No significant between-group differences in any of the language measures were found. There was a trend for groups 4 and 6 to have the lowest means, but the differences failed to reach significance, possibly due to the small group sizes and rather large individual variation within the groups.

Insert Table 2 about here.

To compare the performance of individual children, we then divided the children into two groups (difficulties/no-difficulties) using a criterion of performing at or below $-1 SD$ in at least two of the language measures (SI, PPVT, SC, WFS) ($n = 13$) and/or having a parent-reported diagnosis of language impairment ($n = 1$). The crosstabulation of the ECD groups and the difficulties dichotomy revealed associations between the ECD grouping and the difficulty status of the children, as shown in Table 3. The chi-square test was statistically significant, $\chi^2(5) = 18.154, p = .004$, with a medium effect size (Cramer's V

= .45, Cramér, 1946). The adjusted residuals showed significantly more children than expected in the difficulties group; these children came mostly from the two ECD at-risk groups 4 and 6 (adj.res. = 3.0 and 2.4), along with significantly fewer children than expected from group 1 (adj.res. 2.2).

All in all, based on the cut-off criteria, 14 (15.4 %) children had compromised language skills. Eleven (78.6 %) of these 14 children came from ECD groups 4 and 6, the remaining three (21.4 %) coming from groups 1 and 2. The *z*-scores for each language and working memory measure for these 14 children are presented in Table 4. The children showed highly varied and extensive deficiencies in both their language and working memory ability.

Insert Table 3 about here.

Insert Table 4 about here.

Working memory performance of the ECD groups

As with the language measures, the between-group comparisons for working memory (DS – total, forwards and backwards, NWR, SR, and CS) were executed with one-way ANOVA and confirmed with Kruskal-Wallis Test. The profiles of working memory performance for each of the ECD groups are depicted on the right side of Figure 2, and the means and standard deviations of the *z*-scores for each test by group in Table 2. Significant group differences in performance were found in Digit span (total), (DS, $F(5,84) = 2.550, p = .034, \eta_p^2 = .132; \chi^2(5) = 13.311, p = .021$), Digit span forwards (DSf, $F(5,84) = 2.351, p = .048, \eta_p^2 = .123; \chi^2(5) = 12.719, p = .026$), and Sentence repetition (SR, $F(5,84) = 3.621, p =$

.005, $\eta_p^2 = .177$; $\chi^2(5) = 13.853$, $p = .017$). The post hoc tests, using the LSD method, indicated that, in DS and DSf, group 4 differed significantly from groups 1 ($p = .006$, and $p = .032$), 2 ($p = .045$, *n.s* for DSf), and 3 ($p = .013$, $p = .006$), and that group 6 differed from group 3 ($p = .050$, $p = .021$). In SR, groups 4 and 6 differed significantly (range $p = .005 - .022$) from the three typically developing groups (1, 2, and 3). In both measures, the two at-risk groups 4 and 6 showed weaker performance. The analysis failed to reach significance in Digit span backwards (DSb, $F(5,83) = 2.105$, $p = .073$, $\eta_p^2 = .113$; $\chi^2(5) = 10.103$, $p = .072$), Nonword repetition (NWR, $F(5,82) = 2.126$, $p = .070$, $\eta_p^2 = .115$; $\chi^2(5) = 9.140$, $p = .104$) and Corsi Span (CS, $F(5,84) = 2.288$, $p = .053$, $\eta_p^2 = .120$; $\chi^2(5) = 8.784$, $p = .118$). Also in these tasks, groups 4 and 6 showed the lowest scores.

Discussion

The purpose of the present study was to investigate language skills and working memory capacity of kindergarten-age children first studied at the age of 12 to 21 months. Following our earlier work outlining different developmental trajectories of prelinguistic communication, we examined the children's language and working memory abilities with psychometric tests at age 5;3. At the group level, there were no significant differences in the performance in the language measures used in the study. However, on the individual level, the children who showed below average performance in more than one area of prelinguistic development more often had compromised language skills at follow-up. They also showed considerably weaker working memory capacity at follow-up than peers with no or only a single early difficulty.

In our previous study (Määttä et al., 2012), we identified six groups of Early Communication Development (ECD) based on parent report on children's prelinguistic skills between ages 12 to 21 months in three relevant domains: (1) social communication (Social), (2) vocalizations and early expressive language (Speech), and (3) understanding and object

use (Symbolic). Three of the ECD groups were identified as being at risk for language difficulties on the basis of their below average performance, each showing a different combination of weaknesses: (a) the group 4 (Below average with symbolic difficulties, BA+Sy) showed slow development in Symbolic skills, and to some extent in Social skills; (b) the group 5 (Expressive difficulties, ED) in Speech skills; and (c) the group 6 (Broad difficulties, BD) in all three domains of prelinguistic communication. The remaining three groups 1 (Average, A), 2 (Above average, AA) and 3 (Average with fluctuating social skills, A+So) were considered to represent varieties of typical development (Määttä et al., 2012).

The at-risk groups 4 and 6 with the poorest early communication skills also showed the poorest language performance at follow-up. The between-group comparisons on the language measures did not reach significance, but these two groups tended to have the lowest means in these measures, and at the individual level more often showed compromised language skills. The findings are well in line with the dimensional view of language impairment (Rescorla, 2009), according to which children with a weaker endowment, as indicated by multiple early delays, have higher risk for later language difficulties.

In both groups 4 and 6, the children showed slower development compared to peers in the Social and Symbolic composites. It is noteworthy that the children in group 4 did not show delay in early expressive language, which has rather consistently been reported as an early characteristic of children with later language impairment (Hulme & Snowling, 2009). These findings are consistent with those of previous studies indicating that social communication, receptive skills, and symbolic play skills measured very early predict later communication and language skills even better than expressive skills (Chiat & Roy, 2008; Watt, Wetherby, & Shumway, 2006). The role of comprehension in early parent/child interaction has led Dale (2012) to suggest that “comprehension even more than production is likely to be at the center of the process of language acquisition” (p. 595).

The difference between groups 4 and 6 was in the extent of their early delays and in their early expressive skills. In group 6 the level of early performance was consistently lower in all three early composites, thereby placing the group at the biggest theoretical risk for language impairment. Consistent with this, group 6 had the lowest means in all the follow-up language measures at the group level, and at the individual level showed more often compromised language skills (50 % compared to 35 % in group 4). However, the differences between groups 4 and 6 at kindergarten-age were not as clear cut as might have been expected. One possibility is that the difficulties experienced by the children in group 6 are not specific to language, but rather reflect a more general overall level of cognition that is lower than that of their peers, but nonetheless age-appropriate. The lowest group means in the control variables, Block Design and Inhibition, offer tentative support for this speculation; however, for more conclusive inferences a larger sample size is required.

The third at-risk group, group 5, showed slow early development in expressive language with otherwise typical social and symbolic skills. As a group, these children performed as well as the typically developing groups at follow-up. The inferences in the existing literature regarding so called late talkers are somewhat conflicting. The dimensional view of language impairment suggests that early expressive language delay may reflect a predisposition to slower language acquisition, and thus it has been hypothesized that these children will show slightly poorer language skills, though often within normal limits, compared to peers (e.g., Rescorla, 2009). In turn, other researchers suggest that for children who are delayed only in early expressive language there seems to be no reason for serious concern (Lyytinen, Poikkeus, Laakso, Eklund, & Lyytinen, 2001; Wetherby & Prizant, 2002). The present results for group 5 are consistent with the latter view in that slow development in early expressive language without other concomitant difficulties did not seem to place these children at risk for later language impairment. However, in our previous study, parents

reported language-related concerns for over 40% of these children at the age of four years and seven months (Määttä et al., 2012).

There are several possibilities for the discrepancy between our results from parent reports and the children's test performance regarding group 5. First, it is possible that slow development in early expressive skills has affected some aspect of communication that we cannot tap into in a one-on-one testing situation with psychometric tests. For example, a delay in the development of late talkers' social-conversational skills has been reported (Bonifacio, Girolametto, Bulligan, Callegari, Vignola, & Zocconi, 2007). Second, there might be certain characteristics of the child, such as temperament, or of the parent-child relationship that sustain parental concerns. For example, late talkers have been found to be rated by parents as more withdrawn and less compliant, and as showing less acceptable characteristics and more negative emotions (Caulfield, Fischel, DeBaryshe, & Whitehurst, 1989; Irwin, Carter, & Biggs-Gowan, 2002; Kubicek & Emde, 2012; Paul & Kellogg, 1997).

Large variability was detected in the language variables both within the ECD groups and in the skill profiles of individual children with compromised language skills. No clear patterns of difficulties emerged among the children; instead, each child showed a unique combination of language skills and difficulties. The skill profiles of children with language impairment have been shown to be highly varied (Asikainen, 2005) and so far no single measure has been shown to be consistently impaired within the group of children with compromised language skills. This accords with the notion of Bishop (2006) that there is no single crucial deficit that leads to compromised language development, but instead multiple deficits underlie language impairment. This individual variability of language skills and weaknesses, in addition to small group sizes, might explain the non-significant differences in the group comparisons on language skills in our study.

The role of verbal working memory in language performance, evident in our study, is consistent with a great deal of earlier research (e.g., Montgomery et al., 2010; Vance, 2008). Among the tasks measuring the phonological loop, significant between-group differences were found in forward Digit span (DSf), and the differences approached significance in Nonword repetition (NWR). These group differences indicated that the at-risk groups 4 and 6 performed weaker than the groups with no early risk. The results support the findings of previous studies showing that limitations in phonological working memory capacity frequently co-occur with impaired language skills (e.g., Archibald & Gathercole, 2006). However, perhaps due to possible differences in the task or scoring, our results failed to replicate earlier findings that NWR, in particular, is deficient in children with impaired language (Conti-Ramsden & Hesketh, 2003), and that NWR is an indicator of residual language difficulties when the initial difficulties have resolved (Conti-Ramsden et al., 2001; Thal et al., 2005). In our visuospatial sketchpad task, Corsi span (CS), the between-group differences failed by a small margin to reach significance. However, the results are parallel to previous findings that in a minority of children with language impairment the memory deficits are not limited to verbal memory (Archibald & Gathercole, 2006).

In the present study the backwards section of the DS measure (WISC-III, Wechsler, 1999) was used to assess the central executive component of the working memory model. Research has shown that children with language impairment show poor performance on central executive tasks (e.g., Archibald & Gathercole, 2006). In our study, however, the between-group differences failed to reach significance on the task. Reasons for this might be the lack of formal norms for the task and the relatively young age of the children. Our observations on the data supported those of Petruccelli and colleagues (2012), who found that backwards digit recall was difficult for all their sample of children age 5, and concluded that the task was not a good discriminatory tool at this age.

The episodic buffer component of the working memory model was measured with Sentence repetition (SR) a task that has been suggested to be a particularly sensitive marker of language impairment (Archibald & Joanisse, 2009; Petruccelli et al., 2012). Consistent with these previous findings, the groups 4 and 6 performed significantly more poorly than the typically developing groups. At the individual level, SR was the most difficult task among the memory measures (9/14 children scored below $-1SD$). The difficulties in SR co-occurred with various other language-related difficulties, as was shown both by the high correlations between SR and the language measures and by the individual children's skill profiles. It has been suggested that SR reflects the interaction between memory and language, as it relies on both verbal working memory and linguistic skills, such as speech processing and language knowledge (Archibald & Joanisse, 2009; Vance, 2008).

Strengths and weaknesses

The purpose of this study was to examine the continuity of at-risk development from the prelinguistic stage to kindergarten-age language and working memory performance. Few studies have examined the developmental risk profiles of language and communication development starting from the prelinguistic period. The examination of various aspects of language and communication at the prelinguistic stage and the inclusion of working memory measures at follow-up are clear strengths of the present study. The complex nature of language requires that both multiple dimensions of language and measures of working memory be used in the assessment (Conti-Ramsden & Durkin, 2012). In addition, the use of a rather large community-based sample, early and repeated initial assessments, and a lengthy follow-up period are assets of the present study.

A word of caution is warranted when interpreting and generalizing the results. Despite the large initial sample, some of the groups were rather small. The small statistical power due to small group sizes is also reflected in the effect sizes that were, for the group

comparisons, rather small. Thus, interpretations of the outcome concerning the smallest groups should be regarded as directional, pending replication with larger samples.

Moreover, there were some limitations in the set of language measures used in this study.

The lack of a measure of morphosyntax was a clear shortcoming of the study, as children with language impairment have often been shown to have difficulties with inflectional morphology (Kunnari et al., 2011). In addition, the use of spontaneous language samples (Asikainen, 2005; Conti-Ramsden & Durkin, 2012) and oral narratives (Marini, Tavano, & Fabbro, 2008) in evaluating children's language skills has been recommended, as it seems that standardized language tests are not systematically able to identify all children with language impairment (e.g. Asikainen, 2005). It would also have been worthwhile to assess working memory at an earlier age as this might have clarified the interplay between language and working memory development.

It is important to bear in mind that the early profiles represent average paths of prelinguistic communication, not exact paths for each individual. At the individual level, we were able to attain rather high sensitivity, as the majority (79 %) of the children with compromised language skills at follow-up were identified on the basis of their early at-risk profile. However, our specificity was weak: only 31 % of the children in the at-risk groups 4, 5, and 6 showed compromised language skills at age 5;3. Thus, there were a large number of false positives. That said, it is noteworthy that all in all 38 % of our sample belonged to one of the three ECD at-risk groups. In a community-based sample, such a high percentage of children could not be expected to show later language impairment. The prevalence of SLI at kindergarten age has been reported to be 7 % (Tomblin et al., 1997). In our study, the percentage of children with compromised language skills was 15 %, owing to our inclusion criteria, which had been set so that also children with minor language difficulties would be identified. Unfortunately, with the measures used in this study, we were not able to determine

which children meet clinical criteria for SLI.

Clinical implications and conclusions

Our results support the rationale for early screening of language and communication difficulties as the majority of children with later difficulties already showed risk attributes in the second year of their life. The risk for later difficulties was strongest if the child showed slowness in multiple areas of early communication development, especially combined with symbolic delay. This, together with our results of the interplay between language and working memory, suggests that early screening should be multifaceted, that is, to include multiple areas of prelinguistic skills along with possible precursors of working memory. Consistent with the conclusions of Ukoumunne and colleagues (2011), our low specificity suggests that the heterogeneity within the specified risk trajectories confounds their ability to accurately identify children with persistent language difficulties. An early risk status should rather be considered as an indicator for a need for further, more frequent and intensive, surveillance of development. An essential goal for future studies is to identify additional attributes or risk factors that are associated with the specific risk trajectories.

Our results suggest that a notable proportion of children with prelinguistic communication delays show poorer language skills, and especially more limited working memory capacity, in their later development than peers without difficulties in early development. The results provide support for the dimensional view of language impairment in that the number of early communication delays indicated a higher risk for later difficulties. In addition, the results endorse the view that language difficulties can have different origins, of which late language emergence is but one, and not necessarily sufficient by itself to compromise language development. The role of working memory in language development seems to be essential, and thus longitudinal studies exploring the developmental interaction between memory and language functions are called for.

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Table 1.

Correlations between the Follow-Up Language and Working Memory Measures

	SI	PPVT	SC	VFS	RAN	DS	NWR	SR
SI								
PPVT	.26*							
SC	.24*	.35***						
VFS	.33**	.11	.24*					
RAN	.00	-.12	-.11	-.24*				
DS	.15	.12	.36***	.03	-.21			
NWR	.37***	.24*	.15	.23*	-.11	.30***		
SR	.47***	.33**	.34***	.34***	-.11	.58***	.54***	
CB	.20	.15	.30**	.16	-.10	.30**	.22*	.41***

Note. SI = WPPSI Similarities; PPVT = Peabody Picture Vocabulary Test; SC = Sentence

Comprehension; SR = Sentence Repetition; NWR = Nonword Repetition; WFS= Word Fluency – Semantic categories; RAN = Rapid Automatized Naming – Objects; DS = Digit Span; CB = Corsi Block task.

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 2.

Descriptive Statistics of the ECD Groups by Follow-Up Measures

Measure	ECD group										Group comparisons			
	1. A		2. AA		3. A+So		4. BA+Sy		5. ED		6. BD		F	Post hoc
	n	M (SD)	n	M (SD)	n	M (SD)	n	M (SD)	n	M (SD)	n	M (SD)		
SI	28	0.92 (0.82)	19	0.68 (1.00)	7	1.14 (0.47)	23	0.38 (1.14)	5	1.00 (1.11)	6	0.11 (0.75)	1.70	
PPVT	29	0.05 (0.87)	20	0.16 (1.10)	7	0.02 (0.51)	23	-0.20 (1.00)	5	0.61(0.97)	6	-0.51 (1.59)	1.00	
SC	29	0.01 (1.48)	20	-0.27 (1.31)	7	-0.07 (1.72)	23	-0.20 (1.26)	6	0.39 (0.82)	6	-1.23 (1.49)	1.04	
WFS	27	-0.02 (1.13)	20	0.43 (0.87)	7	0.57 (0.92)	22	-0.41 (1.26)	6	0.00 (1.05)	6	-0.44 (1.34)	1.78	
RAN	27	-0.26 (1.14)	20	0.38 (0.77)	7	0.35 (0.94)	22	-0.06 (0.90)	5	-0.01 (0.93)	6	-0.25 (1.35)	1.23	
DS	29	0.48 (1.05)	20	0.32 (0.78)	7	0.76 (0.63)	22	-0.27 (0.89)	6	0.39 (1.02)	6	-0.28 (1.2)	2.55*	4 < 1, 2, 3; 6 < 3
DSf	29	0.14 (1.22)	20	0.13 (0.79)	7	0.80 (0.58)	22	-0.52 (1.16)	6	-0.19 (1.25)	6	-0.61 (1.11)	2.35*	4 < 1, 3; 6 < 3
DSb	29	0.29 (1.00)	20	-0.04 (0.91)	7	0.19 (0.82)	21	-0.47 (0.77)	6	0.33 (0.79)	6	-0.44 (1.35)	2.11	
NWR	28	0.47 (0.99)	20	0.42 (0.77)	7	0.43 (0.71)	22	-0.33 (1.18)	6	0.27 (1.23)	6	-0.06 (0.65)	2.13	
SR	28	0.33 (1.03)	20	0.27 (0.75)	7	0.81 (0.69)	23	-0.52 (1.33)	6	-0.22 (1.09)	6	-0.89 (1.20)	3.62**	4, 6 < 1, 2, 3
CB	28	-0.06 (0.43)	20	-0.09 (0.44)	7	0.34 (0.57)	23	-0.33 (0.71)	6	0.20 (0.48)	6	-0.29 (0.62)	2.29	
BID	29	0.54 (1.02)	20	0.42 (0.82)	7	0.76 (0.71)	22	0.39 (1.08)	5	0.67 (0.78)	6	-0.39 (0.80)	1.21	
Inh	28	0.27 (0.14)	20	0.17 (0.83)	7	0.57 (0.29)	22	0.22 (0.18)	4	0.08 (0.37)	6	-0.61 (0.22)	1.67	

Note. SI = WPPSI Similarities; PPVT = Peabody Picture Vocabulary Test; SC = Sentence Comprehension; WFS= Word Fluency – Semantic categories; RAN = Rapid Automatized Naming – Objects; DS = Digit Span; NWR = Nonword Repetition; SR = Sentence Repetition; CB = Corsi Block task; LMC = Language and Verbal Memory Composite; BID = Block Design; Inh = Inhibition ECD group = Early Communication Development group; A = Average; AA = Above average; A+So = Average with fluctuating social skills; BA+Sy = Below average with symbolic difficulties; ED = Expressive difficulties; BD = Broad difficulties.

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 3.

A Crosstabulation of the ECD Groups and Difficulties at Follow-Up

Difficulties at 5;3

ECD group	Yes			No		
	n	%	Adj.Res.	n	%	Adj.Res.
1. A (n=29)	1	3.4	-2.2	28	96.6	2.2
2. AA (n=20)	2	10	-0.8	18	90	0.8
3. A+So (n= 7)	0	0	-1.2	7	100	1.2
4. BA + Sy (n= 23)	8	34.8	3.0	15	65.2	-3.0
5. ED (n=6)	0	0	-1.1	6	100	1.1
6. BD (n=6)	3	50	2.4	3	50	-2.4

Note. Adjusted residuals that have an absolute value over 1.96 are considered to be

significant. ECD group = Early Communication Development group; A = Average; AA =

Above average; A+So = Average with fluctuating social skills; BA+Sy = Below average with

symbolic difficulties; ED = Expressive difficulties; BD = Broad difficulties.

Table 4.

Descriptive Data of the 14 Individuals with Compromised Language Skills at Follow-Up

Child	Gender	ECD Group	SI	PPVT ^a	SC	WFS	DS	DSf ^a	DSb ^a	NWR	SR	CB	RAN ^a	BID	Inh
1	Boy	1 A	1.67	0.39	-2.52	-2.00	-1.00	-0.75	-1.46	0.33	-1.00	-0.59	-2.79	-0.33	-0.67
2	Boy	2 AA	-2.33	0.39	-1.55	0.67	0.00	-0.75	0.08	0.33	0.00	0.59	0.37	0.33	-1.00
3	Girl	2 AA	1.33	-3.29	-2.19	-0.33	0.00	0.08	-0.69	1.00	0.33	-0.59	0.24	0.00	0.33
4	Boy	4 BA+Sy	-1.67	-1.87	-1.87	-2.67	-1.33	-1.58	-1.46	-0.67	-3.00	-0.59	0.67	0.00	-0.33
5	Boy	4 BA+Sy	-1.33	-1.03	-2.84	-2.33	-2.67	-4.08	-	-2.33	-3.00	-1.18	-0.37	-2.33	-
6	Boy	4 BA+Sy	0.00	-1.31	-0.58	-1.67	-1.33	-1.58	-1.46	-2.00	-3.00	-1.18	-0.02	0.67	0.67
7	Boy	4 BA+Sy	1.67	-1.87	-0.90	-1.33	0.00	0.08	-0.69	-0.67	0.67	-1.18	-2.88	-2.00	0.67
8	Girl	4 Ba+Sy	-0.33	-1.03	-2.84	-0.33	0.00	0.92	-1.46	-1.33	-0.67	0.00	-0.93	1.67	1.00
9	Girl	4 BA+Sy	-1.33	-0.74	-0.90	-2.33	0.00	-0.75	0.08	-2.67	-1.00	0.00	0.41	0.33	1.33
10	Girl	4 BA+Sy	1.33	-1.31	-1.23	-0.33	0.33	0.08	0.08	0.67	-0.33	-1.18	0.24	1.00	-1.00
11	Girl	4 BA+Sy	-1.33	-0.74	0.39	1.33	-1.00	-0.75	-1.46	-0.67	-3.00	-2.35	0.28	0.00	0.33
12	Boy	6 BD	-0.67	-0.74	-1.87	-1.00	0.67	0.08	0.85	-0.67	-2.33	0.00	-0.41	-0.33	0.00
13	Boy	6 BD	0.33	-2.72	-3.48	0.00	-1.33	-1.58	-1.46	0.00	-2.00	-0.59	-0.15	-1.33	-1.00
14	Boy	6 BD	0.00	0.10	-1.87	-1.00	-1.33	-1.58	-1.46	0.33	-1.00	0.00	-0.05	0.67	-1.33

Note. ECD group = Early Communication Development group; SI = WPPSI Similarities; PPVT = Peabody Picture Vocabulary Test; SC =

Sentence Comprehension; WFS= Word Fluency – Semantic categories; DS = Digit Span; DSf = Digit Span forward; DSb = Digit Span

backward; NWR = Nonword Repetition; SR = Sentence Repetition; CB = Corsi Block task; RAN = Rapid Automatized Naming – Objects; BD =

Block Design; Inh = Inhibition.

a = Standardized using the sample mean and standard deviation

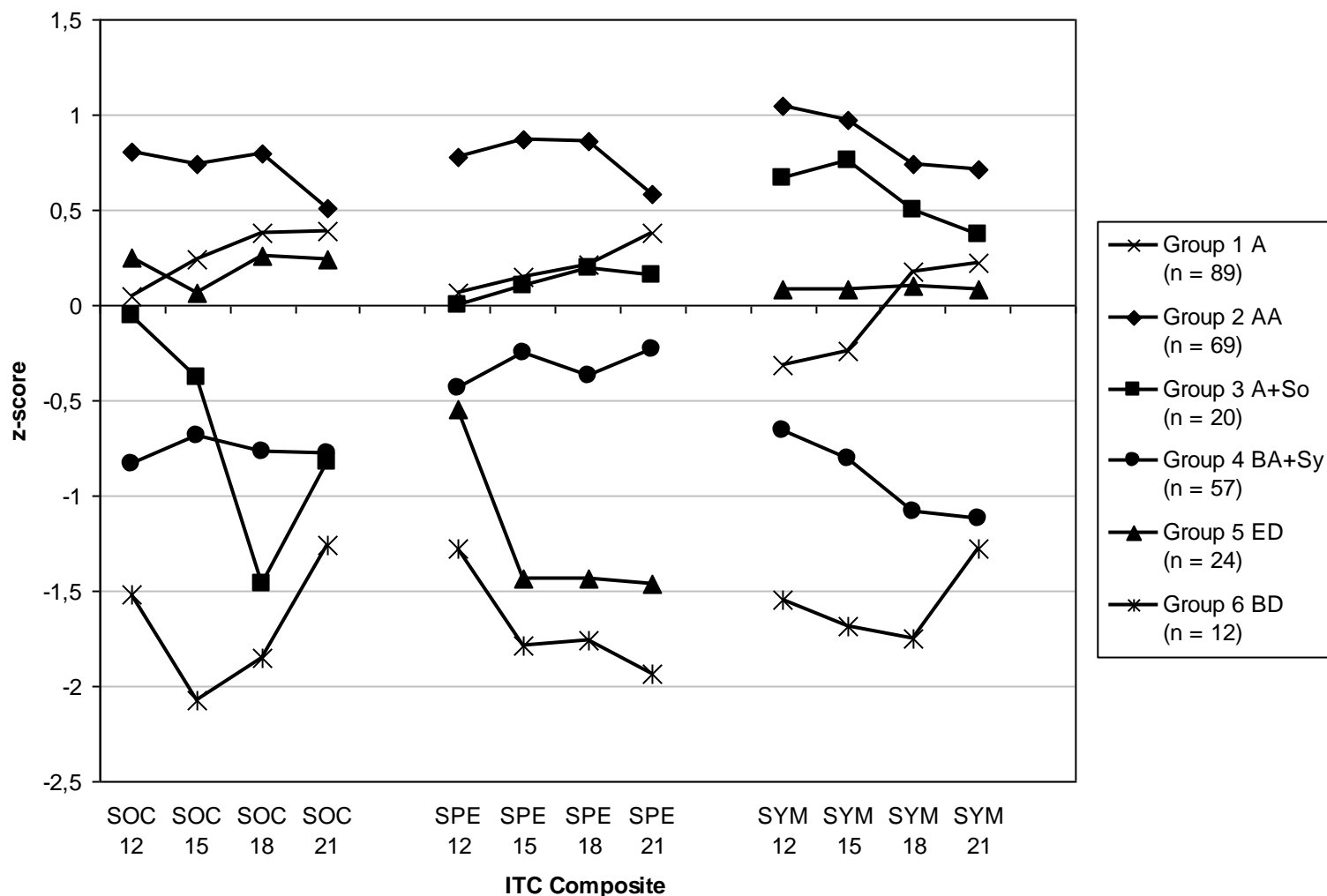


Figure 1. The profiles of the Early Communication Development (ECD) groups. Profiles are based on the standardized estimated means. Standardization was done using the sample means and standard deviations of each age stage. ITC = Infant-Toddler Checklist; SOC = Social composite of the ITC; SPE = Speech composite of the ITC; SYM = Symbolic composite of the ITC; A = Average; AA = Above average; A+So = Average with fluctuating social skills; BA+Sy = Below average with symbolic difficulties; ED = Expressive difficulties; BD = Broad difficulties. Figure originally printed in Määttä et al. (2012).

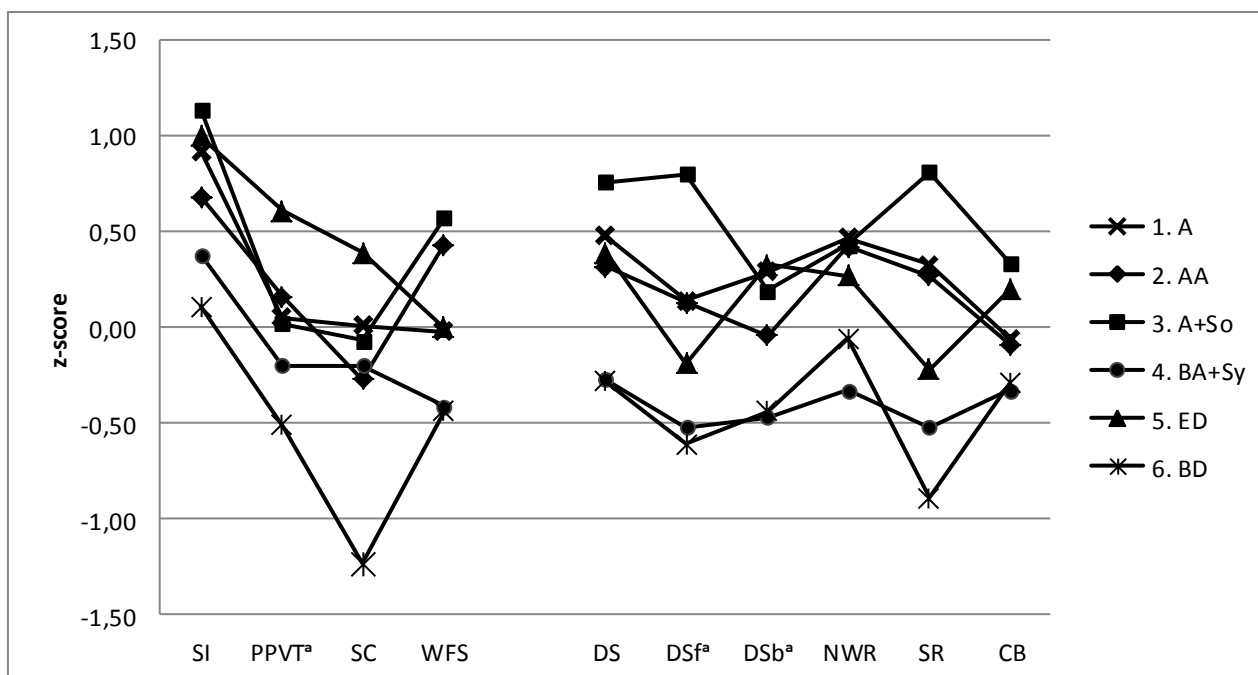


Figure 2. The profiles of language and working memory performance of the ECD groups. A = Average; AA = Above average; A+So = Average with fluctuating social skills; BA+Sy = Below average with symbolic difficulties; ED = Expressive difficulties; BD = Broad difficulties. SI = WPPSI Similarities; PPVT = Peabody Picture Vocabulary Test; SC = Sentence Comprehension; WFS= Word Fluency – Semantic categories; DS = Digit Span; DSf = Digit Span forward; DSb = Digit Span backward; NWR = Nonword Repetition; SR = Sentence Repetition; CB = Corsi Block task.

a = Standardized using the sample mean and standard deviation