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Forward and backward digit span difficulties in children with specific learning disorder

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Abstract

This study examined performance in the forward and backward digit span task of the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV) in a large group of children with specific learning disorder (SLD) as compared with a group of typically developing children matched for age and sex. Our results further support the hypothesis that the intellectual difficulties of children with SLD involve working memory in the forward digit span task to a greater extent than in the backward digit span task. The correlation of the two spans with a General Ability Index (GAI) was similar in SLD, and smaller in magnitude than in typically developing children. Despite a GAI within normal range, children with SLD had difficulty with both digit span tasks, but more so for forward span. This pattern was similar for different SLD profiles with clinical diagnoses of dyslexia and mixed disorder, but the impairments were more severe in the latter. Age differences were also investigated, demonstrating larger span impairment in older children with SLD than in younger.

Keywords: Digit span; Wechsler intelligence scale for children–fourth edition; general ability index; children with specific learning disorder; working memory.

Highlights

- Forward and backward versions of memory span tasks involve different processes in typically developing and SLD children.
- Forward and backward recall relate differently to intelligence in the two groups.
- Children with dyslexia or mixed SLD showed the same patterns, but the latter group was more severely impaired.

Forward and backward digit span difficulties in children with specific learning disorder

Children with specific learning disorder (SLD) are usually poor achievers specifically in reading or writing, or calculation, but not in terms of their overall cognitive abilities. A discrepancy between an average intelligence and an impaired academic performance is no longer a defining criterion for the diagnosis of SLD (American Psychiatric Association 2013), although children with SLD generally have a full-scale IQ in the normal range. Full-scale IQ scores obtained with a battery of intelligence tests are the result of a combination of different subtests that measure different underlying factors. Based on the administration of the Wechsler intelligence scale for children (WISC) battery, it has been demonstrated that children with SLD do badly in working memory (WM) and processing speed subtests by comparison with typically developing children (TDC), whereas they perform well in subtests measuring verbal comprehension and perceptual reasoning (Cornoldi, Giofrè, Orsini, & Pezzuti, 2014). These findings support the assumption that general intelligence is not impaired in children with SLD. Not usually being impaired in the WISC reading comprehension and perceptual reasoning indexes, they are consequently not impaired in terms of the General Ability Index (GAI) obtained from the above two indexes, and the GAI is a good proxy of intelligence (Saklofske, Prifitera, Weiss, Rolfhus, & Zhu, 2005).

The fact that children with SLD have low scores in the WISC working memory index is consistent with a large body of literature showing an impairment in WM tasks in association with learning disorders. For example, a recent meta-analysis found a mean effect size of 0.71 in verbal short-term memory (STM) tasks when comparing poor and good readers (Melby-Lervåg, Lyster, & Hulme, 2012). The generality of this effect has been questioned, however, and it has been argued that it applies mainly to the English language, which is highly opaque (i.e., the phoneme–grapheme correspondence is not straightforward) and substantially different from other languages (e.g., Italian, in which phoneme–grapheme correspondence is straightforward) that have a greater degree of correspondence between the written and spoken forms of words (van der Sluis, van der Leij, & de Jong, 2005). It has also been noted that weaknesses in STM functions (which are related to the articulatory loop) and in WM functions (which are related to the central executive) contribute differently to the academic difficulties of individuals with learning disabilities, suggesting that these deficits are differentiated (Swanson, 1994).

The WISC's digit span subtest represents a very interesting case for examining the WM difficulties of children with SLD. The digit span subtest was included in all the latest versions of the WISC battery and in all its various international adaptations. Digit span has often been considered in studies examining STM performance in children with SLD, recording a standardized difference between SLD and TDC groups ranging from .65 to .71 (Giofrè & Cornoldi, 2015; Styck & Watkins, 2014), resembling the figure reported by Melby-Lervag and coauthors (2012) for all STM measures. But research conducted to date has not systematically investigated the potential differences between the two classical versions (forward and backward) of the digit span task, both of which are included in the WISC battery. The two versions seem to measure partly different components of WM, judging also from the fact that the two versions of the digit span task correlate differently with intelligence (Cornoldi, Orsini, Cianci, Giofrè, & Pezzuti, 2013). This distinction is also supported by neuroanatomical data indicating that the brain regions involved in performing the two digit span tasks differ to some degree (Rossi et al., 2013).

The two versions of the digit span task have also been typically related to different aspects of WM. It has been suggested, for example, that forward digit span is associated with the STM component, and backward digit span with the WM component (e.g., Alloway, Gathercole, Kirkwood, & Elliott, 2009). In a similar vein, Baddeley's (1986) model distinguished between the articulatory loop devoted to the immediate serial recall of phonological strings and the central executive responsible for maintaining and manipulating information. This model (here called tripartite) represents the most classical model and further developments of the model (Baddeley, 2000) have maintained the distinction between three components, that is a modality-independent component and modality-dependent verbal and visuospatial components of STM. A different approach (modality-independent model) distinguishes between a storage component (typically characterized as a STM component) and a processing component, and it suggests that WM processing capacity is limited by controlled attention (Engle, Tuholski, Laughlin, & Conway, 1999). As far as span is concerned, based on the tripartite model digit span is considered a measure of the articulatory loop, and backward digit span is thought to measure the central executive (e.g., Alloway, Gathercole, Willis, & Adams, 2004), whereas this distinction is less clear in the modality-independent model (Rosen & Engle, 1997).

Other formulations of working memory do not rigidly assume a perfect STM and WM differentiation. For example, Cornoldi and Vecchi (2003) suggest that tasks should be collocated along a vertical continuum (from passive to active) based on their executive control requirement, and according to this formulation forwards and backwards spans are distinguished. The digit span forward requires a very limited amount of executive control and is considered “passive”, whereas other tasks involving double request and/or control for irrelevant information, such as the listening span task, requiring a large amount of executive resources, are considered more “active”. Other tasks that require a larger amount of executive resources than passive tasks but a smaller amount than the most active tasks, such as the backward digit span, are allocated in between active and passive tasks. According to this theory, the passive-active continuum has important implications for the study of the relationship between WM and intelligence as the relationship increases in correspondence with increases in the degree of required active control. In fact Cornoldi and coauthors (2013) demonstrated that the correlation between WM measures and the measure of general ability obtained with the WISC is low in the case of the forward span, medium in the case of the backward span and higher in the case of other more active measures.

While there is a consensus on the distinction between forward and backward digit span in typical development, the implications of the distinction for children with SLD seem complex and the results are unclear. Some studies have reported children with SLD having similar difficulties in different WM tests. In particular, similar difficulties in the two versions of the digit span task were also reported in studies comparing children with SLD and TDC (MacKinnon McQuarrie, Siegel, Perry, & Weinberg, 2014). Also, Wang and Gathercole (2013) found pervasive deficits in simple and complex span tasks in children with reading difficulties. Further, they found that the difference between children with or without SLD in complex span tasks remained significant even after controlling for simple span. This effect was modality independent and included both verbal and spatial tasks and it was concluded that WM problems in children with reading difficulties may reflect a core deficit in the central executive component (Wang & Gathercole, 2013).

If children with SLD present a specific weakness in the “executive” component of WM and are more severely impaired in the backward than in the forward version of the digit span task, they should also present general intellectual weaknesses, due to the relationship between the executive component of WM and intelligence (Cornoldi & Giofrè, 2014) and the higher relationship that a general ability measure has with the backward version of the digit span than with the forward version (Cornoldi et al., 2013). Instead, children with SLD have intelligence within the normal range, but specific impairments in some processing measures (American Psychiatric Association, 2013), including aspects of WM (Swanson, 1994). In fact has been suggested that the difficulty experienced by children with SLD in WM tasks reflects a specific problem unrelated to their general intellectual level and executive functioning (Giofrè & Cornoldi, 2015). It may therefore be that children with SLD have impairments in basic STM functioning that relate to their phonological difficulties but not in the executive control of phonological information. This hypothesis would produce the predictions that children with SLD by comparison with TDC present deficits in both forward and backward digit spans, due to their poor phonological short-term memory, whereas their higher intellectual abilities remain preserved. As a consequence these deficits would be more severe in the case of the forward version of digit span, directly assessing phonological short-term memory, than in the case of the backward version, also involving an executive component.

We explored these issues in the present study, taking advantage of the systematic administration of the Wechsler Intelligence Scale for Children–Fourth Edition (WISC–IV) battery to children with a clinical diagnosis of SLD at an Italian center specializing in the study of SLD.

The scores obtained by these children in the forward and backward versions of the digit span task were correlated with their overall scores in the main WISC indexes and were compared with the scores obtained by a sample of typically developing children with no diagnosed learning disorders, matched precisely for age and gender, randomly selected from a Italian standardization sample. We studied these two groups to test two hypotheses, that: (a) Italian children with SLD have a poor performance in the digit span subtests, with more evident impairments in the forward version; and that (b) because children with SLD have an average overall intelligence and specific phonological memory weaknesses, they reveal a weaker relationship between span measures and general intelligence than in TDC, especially in the case of the backward span version.

We also considered the possibility of different subtypes of SLD coinciding with a different performance in digit span tasks. This hypothesis was suggested by Rudel and Denckla (1974), who suggested that a poor forward digit span might be associated with learning dysfunctions (mainly relating to the left hemisphere), while a poor backward digit span could be associated with the right hemisphere. Differences in WM performance by type of difficulty were reported in Dutch children by van der Sluis et al. (2005), who found a poor backward digit span only in the case of children with combined difficulties in both reading and arithmetic. De Weerdt, Desoete and Roeyers (2013) also found some differences in children's WM depending on whether they had reading and/or mathematical disabilities. Other studies on Anglophone children found no clear differences associated with different SLD subtypes (see Swanson, 1993), however, and an authoritative source as the Diagnostic and Statistical Manual of Mental Disorders–Fifth Edition (DSM-5; 2013) argues that the profiles of SLD subtypes probably largely overlap.

Finally, we also considered age effects. The development of STM and executive processing capabilities in children with SLD may parallel the growth in their reading and math performance, as suggested in the literature supporting the notion that the executive system's level of development underlies performance in reading and math measures (e.g., Jerman, Reynolds, & Swanson, 2012).

Children with SLD may have different developmental trajectories in their digit span from TDC, and their growth pattern may also differ between forward and backward digit span.

Method

Participants

The present study included 318 children with a clinical diagnosis of learning disorder certified in accordance with Italian law 170 by the Public Health Service (AUSL of Ferrara, Italy). All the children were assessed thoroughly by an expert clinician, meeting all the requirements for a clinical diagnosis of SLD, which include a performance below 2 standard deviations or the 5th percentile in standardized tests on reading decoding or spelling, or calculation, and they were classified using the International Classification of Diseases–10th (ICD-10; World Health Organization, 1992) coding system. For the purposes of the present study, we collected information on children aged between 7 and 14 years who underwent a WISC-IV assessment on at least the 10 core subtests, with results recorded separately for forward and backward digit span, and who were clinically diagnosed as cases of SLD[1]. These children were compared with a group of TDC matched for gender and age (in months), whose data were drawn from the Italian WISC-IV standardization sample (Orsini, Pezzuti, & Picone, 2012). The two groups (SLD and controls) had exactly the same numbers of males and females (females = 42.8%), and were perfectly matched for age in months (M_{age} = 10.25 [SD = 2.11]) as each child of the SLD group was individually paired to a TDC with the same age.

Instrument

The children were assessed with the recently published Italian adaptation of the WISC-IV (Orsini et al., 2012), which retains the Full-Scale IQ and the four main indexes, plus two additional indexes (General Ability and Cognitive Proficiency). The Italian WISC–IV test manual reports that internal consistencies, test-retest and inter-rater stability, and standard errors of measurement are comparable with those of the English version (Wechsler, 2003).

For the purposes of the present study, we separately examined the scores obtained in the forward digit span task (which measures the capacity to recall digits in their order of presentation) and the backward digit span task (which measures the capacity to recall digits in reverse order). We also calculated the Full-Scale IQ (FSIQ) from the sum of the 10 subtests, and the four main indexes (Perceptual Reasoning; Verbal Comprehension; Working Memory; and Processing Speed). We then calculated the scores for the two additional indexes, that is, the General Ability Index (GAI) obtained from the Verbal Comprehension (VC) and Perceptual Reasoning (PR) indexes, and the Cognitive Proficiency Index (CPI) obtained from the Working Memory (WM) and Processing Speed (PS) indexes.

Results

To compare dependent correlations we used the updated version of Steiger's Z_H formula (Hoerger, 2013). The R program (R Core Team, 2014) was used with the "lme4" package (Bates, Mächler, Bolker, & Walker, 2015) for the regressions, the "effects" package (Fox & Hong, 2009) for the graphs, and the package "pbkrtest" (Halekoh & Højsgaard, 2014) for calculating the *p*-value.

Table 1 shows the correlations, means and standard deviations obtained by the SLD and the TDC groups in the WISC-IV main and additional indexes, and the raw and standardized scores in the forward and backward digit span tasks. The standardized scores obtained by the children with SLD were average for the GAI, which includes the PR and VC indexes, but below average for the CPI, which includes the WM and PS indexes (Table 1).

In particular, Table 1 shows that children with SLD performed poorly on both memory span tasks, but worse in the forward (8.67 vs. 7.15) than in the backward version (6.78 vs. 5.97), with a large effect size in the former case (Cohen's d = 0.84) and a medium effect size in the latter (Cohen's $d = 0.54$), using raw scores[2]. It is worth adding that the correlation between the GAI and the forward ($r = .10$) and backward (r = .25) versions of the digit span task differed significantly in the TDC ($Z_H = -2.55$, $p = .011$), being statistically greater for backward than for forward digit span. For control purposes, we also ran analyses with the FSIQ, obtaining much the same result ($Z_H = -2.44$, $p = .014$). Conversely, the correlations were very similar (and lower in magnitude) in the SLD group (.15 and .10 for the forward and backward digit span tasks, respectively) and did not differ statistically from one another vis-à-vis the GAI ($Z_H = 0.79$, $p = .43$) or the FSIQ ($Z_H = 0.74$, $p = .46$).[3]

Table 1 about here

To examine whether the two groups of children differed significantly in digit span measures, and whether the difference changed with the type of digit span being tested, we performed a 2 group (SLD and control) × 2 digit span (forward and backward) mixed analysis of variance (ANOVA). Using the raw scores, the results showed significant main effects of digit span, $F(1,634) = 447.39$, $p < .001$, $\eta^2_p = .414$, and of group, $F(1,634) = 113.23$, $p < .001$, $\eta^2_p = .152$, and a significant interaction between group and digit span, $F(1,634) = 23.46$, $p < .001$, $\eta^2_p = .036$. We also performed a post hoc with a Bonferroni correction, which showed that the difference between the forward and the backward version of the digit span was larger in the controls group ($M_{diff} = 1.98$, $p < .05$) than in the SLD group ($M_{diff} = 1.60$, $p < .05$). This different pattern was also evident when effects due to the range of scores were considered by examining the standardized scores for the two digit spans. As shown in Table 1, the SLD group performed less well in both digit span tasks, but the backward version proved comparatively less difficult for the SLD group.[4]

We also compared the two subgroups of children most strongly represented among the children with SLD--that is those diagnosed with dyslexia (F81.0 in the ICD system adopted by the clinical service, n = 82 cases), and those with a mixed disorder (F81.3, n = 155), who had math problems associated with their reading or spelling difficulties. When we ran a 2 group (dyslexia and mixed) × 2 digit span (forward and backward) mixed ANOVA on the standardized scores, we found an effect of group, $F(1,235) = 15.99$, $p < .001$, $\eta^2_p = .064$, with the mixed group performing less well overall (M = 7.72) than the dyslexia group (8.75), and of digit span, $F(1,235) = 12.91$, $p < .001$, $\eta^2_p = .052$, with a worse forward span performance (7.87 and 8.59 for forward and backward digit span, respectively), but the interaction was not significant, $F(1,235) < 0.001$, $p = .994$, $\eta^2_p < .001$.[5]

Finally, to examine whether the effects were influenced by the children's age, we ran an analysis on digit span (forward and backward), group (TDC and SLD), and age (in months). Figure 1 shows that the scores obtained in the two versions of the digit span task followed a similar trend, but the differences between the groups tended to become more pronounced with older age in the case of forward digit span.

Figure 1 about here

Discussion

The present study on a large sample of children diagnosed with SLD found further support for the hypothesis of a general WM difficulty in these children, even if they speak a mainly "transparent" language like Italian. In fact, we found that Italian children with SLD (including those who only had reading difficulties) performed poorly in digit span tasks, with much the same effect size as reported elsewhere in the literature (Melby-Lervåg et al., 2012). Our finding would go to show that the problem remains the same for transparent languages as for opaque languages like English.

We also found that the WM impairment in children with SLD was more severe for forward than for backward digit span. Though these children had difficulty with both versions of the task, the difference between their performance and that of controls was greater in the forward digit span task. This finding is consistent with the impression that the two versions of the task measure two partly different components of WM (Rossi et al., 2013), and that SLD relates more to dysfunctions of the component represented by phonological STM than to dysfunctions in executive WM (e.g., Swanson, 1999). The fact that backward digit span was impaired as well in our children with SLD could be interpreted in the light of the hypothesis that WM failings in children with SLD involve its executive components too (Wang & Gathercole, 2013), but also with reference to the hypothesis that their impairment concerns the maintenance component, not the control component involved in backward digit span tasks.

An important result of the present study concerns the relationship between the digit spans and general intelligence, which differed between children with SLD and TDC. A characteristic feature of children with SLD lies in their having an average overall intelligence and specific WM failings, and we found that: (a) the relationship between digit span and general intelligence (as measured by the GAI) is weaker in children with SLD than in TDC; and (b), results obtained in the two versions of the digit span task are more similar in their correlation with the GAI in the case of SLD. In fact, the relationship between digit span and GAI is stronger for the backward than for the forward version in TDC, whereas in children with SLD the relationship is generally weaker and does not differ significantly between the backward and forward versions of the task. These findings are in line with the hypothesis that intelligence is organized differently in TDC and SLD children (Giofrè & Cornoldi, 2015). Even if the differences in the correlations among the TDC versus the SLD groups may actually seem not large (.10 and .25 in TDC versus .15 and .10 in SLD), however, this small difference in the correlation pattern may be particularly relevant for explaining the observation that the overall *g*-content of these tasks at the latent level is reduced in the case of SLD (Giofrè & Cornoldi, 2015). In fact, differences in these tasks may be related to the task-specific variance (or error) and not to differences in the underlying *g*-factor (i.e., in intelligence).

In the present study, we took advantage of our large dataset to examine other related issues. In particular, we attempted to distinguish between different types of learning disability, finding that the pattern of results remains much the same in children with a reading disorder (dyslexia) or a mixed SLD, and this is consistent with others' findings of a similar profile in SLD, with no differences between subgroups with the condition (e.g., Swanson, 1993). It is worth mentioning, however, that our dyslexic subgroup obtained higher mean scores in both versions of the digit span task, confirming that dyslexic children's generally less severe academic failings imply a greater span (van der Sluis et al., 2005). It is also worth adding that the material used to measure span included digits, so it may be that children with a mixed SLD performed less well because of their additional difficulties with basic numerical processing (Landerl, Bevan, & Butterworth, 2004). Future studies should follow up these findings, including more children with a "pure" mathematical disability profile, for example (an analysis that was impossible because of the small number of such cases in our sample and their heterogeneity), to examine other hypotheses advanced in the literature (De Weerdt et al., 2013).

As for the effects of age, the difference between our TDC and the children with SLD tended to increase with age. The curve charting improvements in the forward and backward versions of the digit span task in later stages of development was steeper for the TDC and was much the same for the two versions of the task, whereas this improvement was less evident in the children with SLD, who showed little difference in digit span performance with older age, and in the forward version of the task the older children with SLD became even more impaired. This issue could be better explored using a longitudinal design. Therefore, future research is warranted to address this point--for example considering this problem at the latent level with a grow curve modeling approach based on repeated observation collected at different time points on the same children.

In conclusion, this study has important theoretical and clinical implications. On the theoretical side, we found that forward and backward digit span performance relies on partly distinct WM components. The relationships between the two types of digit span and between digit span and intelligence reveal different patterns in TDC and children with SLD. These findings cast doubts on the general applicability of theories of intelligence that assume a central role for working memory (Cornoldi & Giofrè, 2014; Giofrè & Cornoldi, 2015). Our results also have clinical implications, confirming that children with SLD have crucial deficits in WM and that these deficits particularly affect phonological short-term memory. It is worth emphasizing that the diagnosis of SLD is limited in Italy to children who have poor reading decoding, spelling and calculation skills and is not applied to children who have poor reading comprehension, written expression and mathematical reasoning skills. In the latter cases, an opposite pattern may be observed, with greater weaknesses in controlled WM than in phonological short-term memory (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998). Differences between the present report and other studies (Wang & Gathercole, 2013) showing a substantial impairment in executive processing in children with SLD could therefore be due to group differences. Another important clinical implication of the present study concerns the fact that using WM tasks as a proxy of intelligence does not seem to be particularly appropriate in the case of SLD. Based on our results we can hypothesize that children with SLD have a slower developmental trajectory for WM than for TDC, and this has implications on the use of the full-scale IQ with cases of SLD. Since WM is included in the full-scale IQ of the WISC-IV, children with SLD may show an intellectual impairment as they grow older not because they are becoming less intelligent, but because they have a different WM developmental trajectory from TDC.

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Footnotes

[1] Based on the classification of SLD adopted in Italy, in the light of Italian law 170 (2010) and using the ICD-10, the sample included: 82 cases of F81.0 (specific reading disorder); 4 cases of F81.1 (specific spelling disorder); 7 cases of F81.2 (specific disorder of arithmetical skills); 155 cases of F81.3 (mixed disorder of scholastic skills); 8 cases of F81.8 (other developmental disorders of scholastic skills); 3 cases of F81.9 (developmental disorder of scholastic skills, unspecified); and 59 children with two or more of the above diagnoses within the F81 category.

[2] A similar effect size was obtained using the standardized scores (Cohen's d = 0.87 and 0.60 respectively for the forward and backward digit span task).

[3] These results were very similar also using standardized scores, with not-significant difference in the correlations between the forward and backward span in the SLD group (GAI: ZH = 0.35, p = .729; FSIQ: ZH = –0.03, p = .974), and with a significant difference in the control group (GAI: ZH = –3.08, p = .002; FSIQ: ZH = –3.04, p = .002).

[4] These analyses were also very similar using the span scores, which corresponded to the maximum number-items correctly recalled in forward and reverse order. When the span scores were analyzed, the ANOVA showed a significant main effect of group, F (1, 634) = 128.31, p < .001, η^2_p = .128, and of digit span, F (1, 634) = 1612.28, p < .001, η^2_p = .718, and a significant interaction, F (1, 634) = 19.91, p < .001, η^2_p = .030.

[5] These analyses were very similar using the span scores too. When the span scores were analyzed, the ANOVA showed a significant main effect of group, F (1, 235) = 9.84, p = .002, η^2_p = .040, and of digit span, F (1, 235) = 499.30, p < .001, η^2_p = .680, while the interaction was not significant, F (1, 235) = 2.35, p = .127, η^2_p = .010.

Table 1

Correlations, means, and standard deviations in the standardized scores for the WISC indexes, and in both the raw and standardized scores for the forward and backward digit span task, in children with SLD and controls.

	VCI	PRI	WMI	PSI	FSIQ	GAI	CPI	FDS-RS	BDS-RS	FDS-SS	BDS-SS	M	SD
VCI	-	.398**	.308**	.022	.746**	.857**	.216**	.148**	.020	.250**	.142*	98.86	13.93
PRI	.559**	-	.279**	.232**	.763**	.807**	.346**	.103	.156**	.110*	.193**	102.78	13.31
WMI	.354**	.378**	-	.099	.578**	.352**	.701**	.580**	.430**	.658**	.572**	88.29	12.40
PSI	.285**	.347**	.265**	-	.454**	.144**	.760**	-.011	.081	-.005	.106	93.22	13.73
FSIQ	.804**	.822**	.645**	.608**	-	.900**	.693**	.271**	.223**	.350**	.352**	95.47	11.57
GAI	.879**	.877**	.422**	.368**	.922**	-	.331**	.148**	.095	.215**	.192**	100.82	12.78
CPI	.400**	.454**	.787**	.803**	.786**	.495**	-	.359**	.342**	.413**	.452**	88.41	12.09
FDS-RS	.076	.079	.575**	.049	.236**	.100	.388**	-	.276**	.890**	.170**	7.15	1.44
BDS-RS	.219**	.223**	.598**	.095	.371**	.247**	.432**	.452**	-	.122*	.819**	5.97	1.23
FDS-SS	.112*	.106	.646**	.056	.283**	.136*	.436**	.903**	.311**	-	.263**	7.90	2.54
BDS-SS	.286**	.299**	.667**	.145**	.460**	.327**	.505**	.303**	.886**	.341**	-	8.46	2.32
M	101.78	100.26	100.90	98.75	100.69	101.20	99.70	8.67	6.78	10.26	10.00		
SD	14.13	15.02	14.42	14.60	14.34	14.63	14.50	2.10	1.72	2.85	2.82		

Note. WISC = Wechsler Intelligence Scale for Children; SLD = specific learning disorder; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; FSIQ = Full-Scale IQ; GAI = General Ability Index; CPI = Cognitive Proficiency Index; FDS–RS = Forward Digit Span, raw score; BDS–RS = Backward Digit Span, raw score; FDS–SS = Forward Digit Span, standardized score; BDS–SS = Backward Digit Span, standardized score; M = mean; SD = standard deviation. Correlations: Control group below and SLD group above the diagonal; M and SD: Control group at the bottom and SLD group on the right.

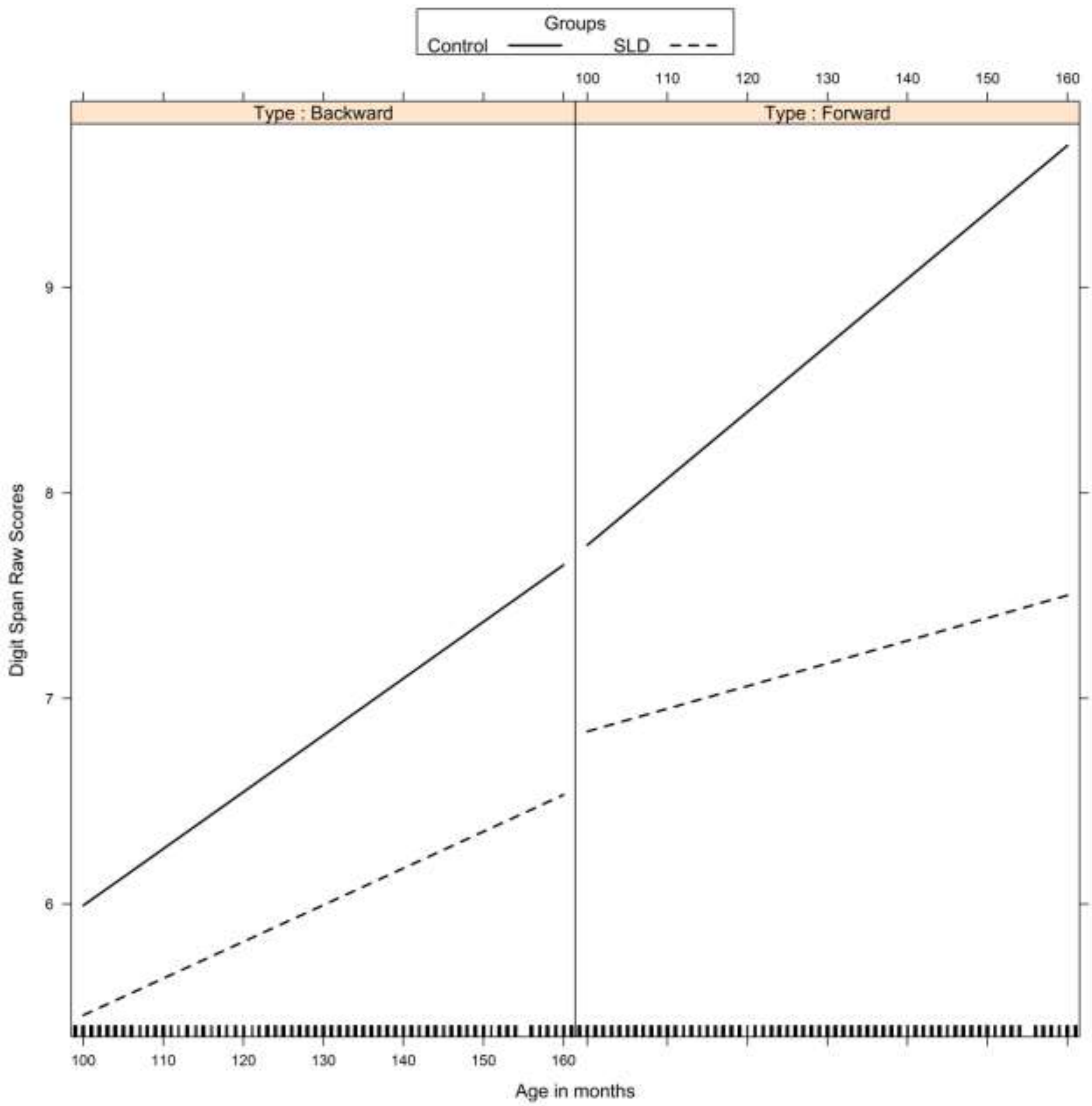

Figure 1. Relationship between group and backward and forward digit span (raw scores) by age (in months). SLD = specific learning disorder. The three -way interaction of Group × Span × Age is statistically significant, $t = -2.00$, $p = .045$, as well as the interaction of Group × Age, $t = -1.98$, $p = .047$, the effect of span, $t = 2.37$, $p = .018$, and the effect of age, $t = 7.95$, $p < .001$; other effects were not statistically significant. Note that these are regression parameters and, when significant, only the three -way interaction should be interpreted and considered.