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Working memory performance and executive function behaviors in young children with SLI

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ABSTRACT

The present study compared the performances of young children with specific language impairment (SLI) to that of typically developing (TD) children on cognitive measures of working memory (WM) and behavioral ratings of executive functions (EF). The Automated Working Memory Assessment was administered to 58 children with SLI and 58 TD children aged 4 and 5 years. Additionally, parents completed the Behavior Rating Inventory of Executive Function – Preschool Version. The results showed the SLI group to perform significantly worse than the TD group on both cognitive and behavioral measures of WM. The deficits in WM performance were not restricted to the verbal domain, but also affected visuospatial WM. The deficits in EF behaviors included problems with inhibition, shifting, emotional control, and planning/organization. The patterns of associations between WM performance and EF behaviors differed for the SLI versus TD groups. WM performance significantly discriminated between young children with SLI and TD, with 89% of the children classified correctly. The data indicate domain general impairments in WM and problems in EF behaviors in young children with SLI. Attention should thus be paid to WM – both verbal and visuospatial – and EF in clinical practice. Implications for assessment and remediation were discussed.

1. Introduction

There is growing evidence that besides linguistic factors, non-linguistic factors may contribute to the problems associated with specific language impairment (SLI) (Bishop, 2006; Montgomery, 2010). One factor that has been implicated is working memory (WM) (Archibald & Gathercole, 2006a; Lum, Conti-Ramsden, Page, & Ullman, 2011; Montgomery, 2010). More recently, limitations on other executive functions (EF) have also been shown in children with SLI (Henry, Messer, & Nash, 2011; Im-Bolter, Johnson, & Pascual-Leone, 2006). Evaluation of WM and EF may thus contribute to assessment of children and early identification of SLI (Conti-Ramsden & Durkin, 2012; Petrucelli, Bavin, & Bretherton, 2012). Early identification of SLI and determination of the child's strengths and weaknesses can then facilitate intervention. However, most previous studies focused on the role of WM and EF in school-aged children with SLI, and research in preschool children is still very limited. In the present study, we therefore addressed the role of WM and EF in young children with SLI. We examined whether the performances on the different components of WM and behavioral ratings of EF differed significantly for young children with SLI versus TD peers.

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1.1. SLI and working memory

The acquisition of language is a major milestone in children's development. While the development of most children's language unfolds automatically, other children show marked problems or delays. A diagnosis of specific language impairment (SLI) is made when language problems are encountered and can be characterized as a failure to make normal progress without further evidence of underlying intellectual, neurological, social, or emotional impairment (Bishop, 2002, 2006). SLI can affect different linguistic domains including phonological, morphological, lexical and grammatical domains. The language profile of children with SLI often changes with age and development; changes can occur both within and across linguistic domains (Bishop, 2006; Leonard, 1998). SLI is a persistent disorder that affects language abilities in childhood and adolescence, or even into adulthood (Brizzolara et al., 2011; McKinley & Larson, 1989). Children with SLI are also at risk for less successful academic outcomes as well as behavioral, emotional, and social difficulties (Conti-Ramsden, Durkin, Simkin, & Knox, 2009; St Clair, Pickles, Durkin, & Conti-Ramsden, 2011).

WM refers to the structures and processes used to temporarily store and manipulate information. The conceptualization that has been mostly used in research on children with SLI is the multicomponent WM model of Baddeley (Baddeley & Hitch, 1974; Baddeley, 2003). In this model, a central executive (CE) system is assumed to be linked to three subsystems: the phonological loop, the visuospatial sketchpad, and the episodic buffer. The CE is responsible for the coordination and control of activities in WM. This system has limited attentional capacity and thus requires attentional control. The phonological loop and visuospatial sketchpad are so-called "slave" systems and responsible for the temporary storage of verbal and visuospatial information, respectively. The episodic buffer is a relatively recent addition to the model and assumed to involve the binding of information from multiple sources together into chunks (Baddeley, 2003). Other conceptualizations of WM concentrate more specifically on the executive and attentional aspects. For instance, Engle, Tuholski, Laughin, and Conway (1999) have suggested that WM capacity is limited by the ability to control attention and that this ability might, in fact, entirely explain the individual differences observed in WM. In the Embedded-Processes model of Courage and Cowan (2009), WM is assumed to reflect the activation of information that is in the focus of attention from long-term memory.

Strong links have been found between WM limitations and SLI (Archibald & Gathercole, 2006a; Bishop, 2006; Montgomery, 2010). The evidence nevertheless suggests that the WM problems exhibited by children with SLI are diverse and may involve different components of the WM system (Montgomery, 2010). The functioning of the storage components can be assessed using tasks that require the serial recall of information. Verbal versions require the retention of words, digits, or letters; the visuospatial versions require the retention of visual patterns or figures. The functioning of the CE component of the WM system can be assessed using tasks that require significant processing activity in addition to storage (i.e., complex memory span tasks). In one common complex listening span task, for example, the child must make a judgment about the meaning of each sentence in a series of sentences but also remember the last word of each sentence in the order of the sentences presented.

A widely accepted account of the deficits associated with SLI is the so-called phonological storage deficit hypothesis (Archibald & Gathercole, 2007; Baddeley, 2003; Bishop, 1996; Coady & Evans, 2008; Gathercole & Baddeley, 1990) and the underlying assumption that a specific deficit in the temporary storage of novel phonological information underlies SLI. In young children with SLI, deficits in verbal storage are widely reported in studies of nonword repetition (i.e., the repetition of unfamiliar or nonexistent words that thus require phonological processing on the part of the respondent) and digit recall (Conti-Ramsden, 2003; Gray, 2003, 2006; Horohov & Oetting, 2004). Between 3 and 6 years of age, children with SLI perform significantly worse than age-matched peers on both such tasks. Nonword repetition performance is even hypothesized to be a reliable marker of SLI in young children. It differentiates between children with and without SLI from the age of 2;06 (years;months) with good results in terms of sensitivity, specificity, and overall accuracy (Chiat & Roy, 2007; Gray, 2003, 2006).

In addition to these constraints on verbal storage, substantial deficits have been reported for verbal CE. Children with SLI consistently show relatively more impairments on verbal complex memory span tasks that combine verbal storage with either verbal or visuospatial processing than on straightforward verbal storage tasks (Archibald & Gathercole, 2006b; Briscoe & Rankin, 2007). It is suggested that deficits in verbal storage, twinned with general processing limitations, underlie the SLI impairments on verbal complex memory span tasks (Archibald & Gathercole, 2006b). However, some controversy exists about the nature of the processing limitations of children with SLI. Some authors assume that these limitations are caused by slower processing, the so-called generalized slowing hypothesis (Kail, 1994). This hypothesis is supported by several studies showing children with SLI to have slower reaction times both in verbal and visuospatial tasks (Miller, Kail, Leonard, & Tomblin, 2001; Schul, Stiles, Wulfeck, & Towsend, 2004; Tallal & Piercy, 1973). Other findings indicate however that children with SLI especially struggle under conditions of high processing loads, indicating reduced processing capacity (Ellis Weismer, 1996; Fazio, 1998; Hoffman & Gillam, 2004: Montgomery, 2002).

In contrast to the verbal domain, the visuospatial domain of WM has been less extensively investigated in children with SLI and the results are ambiguous at best (Alloway & Archibald, 2008; Archibald & Gathercole, 2006a; Montgomery, 2010). Despite this ambiguity and the lack of consensus regarding the role of visuospatial WM in the speech and language of children with SLI, several authors continue to assume that the WM deficits are limited to the verbal domain. This is because children with SLI and their TD peers have been found to perform similarly on visuospatial storage and CE tasks (Archibald & Gathercole, 2006a, 2006b; Baird, Dworzynski, Slonims, & Simonoff, 2009; Lum et al., 2011; Riccio, Cash, & Cohen, 2007; Williams, Stott, Goodyer, & Sahakian, 2000). In contrast, the results of several other studies and a recent meta-analysis have yielded evidence suggesting that the WM deficit of children with SLI may extend to the visuospatial domain (Vugs, Cuperus, Hendriks, & Verhoeven, 2013). In young children with SLI, significant group differences have been reported for children with SLI versus TD children on a variety of visuospatial storage tasks, including pattern recognition memory, paired associates learning, pattern recall, picture recognition, and localization recall but not for spatial recognition (Bavin, Wilson, Maruff, & Sleeman, 2005; Hick, Botting, & Conti-Ramsden, 2005; Menezes, Takiuchi, & Befi-Lopes, 2007; Nickisch & Von Kries, 2009). Longitudinal research by Hick et al. (2005) has further shown the performance of children with SLI (aged 3;03–4;05 years) on a pattern-recall task to develop slower than the performance of TD peers. Research on visuospatial CE has shown young children with SLI to perform significantly worse than TD peers on several tasks, including a spatial span task, space visualization task, and position-in-space task but not a spatial WM search task (Bavin et al., 2005; Marton, 2008).

If children with SLI also exhibit deficits in the visuospatial domain of WM, this suggests that their impairments are not restricted to language or verbal information. It would implicate more general limitations, thus challenging the specificity of SLI. Based on a twin study, Bishop (1994) also questioned the specificity of SLI as they found that SLI is not genetically distinct from less specific disorders where language impairments occur in the context of non-verbal limitations. A further domain-general account of SLI is provided by Ullman and Pierpont (2005), who propose that SLI is characterized by abnormal development of brain structures that constitute the procedural memory brain system (procedural deficit hypothesis). This memory system serves both linguistic and non-linguistic functions, but is particularly important in the acquisition of grammar.

Finally, the episodic buffer or third subsystem assumed to compose the Baddeley's multicomponent WM model has been examined using sentence repetition tasks. Sentence repetition requires the integration of phonological information with semantic and syntactic information. Poor performance for children with SLI (compared to TD peers) on this task has been reported in several studies (Archibald & Joanisse, 2009; Petrucelli et al., 2012; Redmond, Thompson, & Goldstein, 2011). However, research on the episodic buffer of young children with SLI is limited.

Petrucelli et al. (2012) were among the first to examine the WM of young children with SLI in a multimodal context and thus using measures of the different components of WM. When they compared the performance of 5-year-old children with SLI on measures of the phonological loop, visuospatial sketchpad, central executive, and episodic buffer to that of TD children and late talkers, the children with SLI showed significantly poorer performance for the phonological loop and episodic buffer but not for the other components of WM.

1.2. SLI and executive functions

Executive function is a multidimensional construct that subsumes the processes responsible for purposeful, goal-directed behavior. EF is implicated in not only cognitive processes but also emotional responses and behavioral actions (Gioia, Isquith, & Guy, 2001; Miyake & Shah, 1999). Although some uncertainties remain about the *exact* components of EF, frequently postulated components are: inhibition, shifting, planning, fluency, and WM (Huizinga, Dolan, & van der Molen, 2006; Miyake et al., 2000). These inter-related processes function together to provide an integrated, supervisory control system (Stuss & Alexander, 2000).

Besides limitations in WM, significant group differences have been reported between children with SLI versus TD children on tasks of the following components of EF: inhibition, planning, and fluency. Limitations in EF shown by the children with SLI were not confined to verbal EF tasks, but also occurred for some nonverbal EF tasks. However, not all components of EF have been equally extensively studied and in some cases results are still somewhat contradictory. *Inhibition* refers to the ability to stop ongoing responses. Compared to their TD peers, children with SLI demonstrate reduced inhibition of prepotent responses in several studies (Bishop & Norbury, 2005b; Finneran, Francis, & Leonard, 2009; Im-Bolter et al., 2006; Marton, Kelmenson, & Pinkhasova, 2007). However, limitations in inhibition have not been confirmed by all studies investigating children with SLI. The study of Noterdaeme, Amorosa, Mildenberger, Sitter, and Minow (2001) for instance showed children with SLI to perform comparable to their TD peers on a go-no go task. A possible explanation for this finding might be that the inhibition task used in this study required inhibition of less dominant or automatic responses than the tasks used in other studies. *Planning* is the ability to plan and organize activities and is typically measured using problem-solving tasks. Difficulties with planning have been found in children with SLI on Towers tests and a Sorting test (Henry et al., 2011; Marton, 2008). *Fluency* refers to the ability to generate new responses. In a recent study, children with SLI obtained significantly lower scores on both verbal and non-verbal fluency tests compared to their TD peers (Henry et al., 2011). Deficits in non-verbal fluency have not been consequently found in all studies, however. For instance, the study of Bishop and Norbury (2005a) showed the performance of children with SLI not to differ from that of TD children on two tasks of non-verbal fluency.

In contrast to the reported group differences on tasks of inhibition, planning and fluency, no group differences have been found on tasks of shifting. *Shifting* is the ability to switch the focus of attention between different activities. Children with SLI and their TD peers have been found to perform similarly on several shifting tasks, including the Trailmaking test and set-shifting tasks (Dibbets, Bakker, & Jolles, 2006; Henry et al., 2011; Im-Bolter et al., 2006).

In addition to cognitive tasks, behavioral rating scales are often used to investigate EF in daily life (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Gioia et al., 2001). Hughes, Turkstra, and Wulffeck (2009) compared the parental and self-ratings of EF for adolescents with SLI versus TD adolescents, and found more negative ratings of EF in general for the SLI group compared to the TD group with half of the parents of adolescents with SLI rating their child's EF abilities in the clinically impaired range. More recently, Wittke, Spaulding, and Schechtman (2013) studied executive functioning of preschool children with SLI. The results showed that the EF of children with SLI, aged 3–5 years, were rated significantly worse than those of their TD peers by both parents and teachers.

1.3. Assessment of WM and EF in young children

Although some studies investigated the role of the storage components of WM in young children with SLI, research on the other components of WM and EF in this age group is still very scarce. In general, the exploration of EF in young children has been minimal for long time. One reason for the limited number of studies is, that until recently, little was known about the development of EF in preschool children. However, in recent years it has been shown that the prefrontal cortex – the region of the brain that plays an important role in EF – undergoes enormous neurodevelopmental changes between the age of 3 and 6 years (Garon, Bryson, & Smith, 2008; Luciana & Nelson, 1998). Different components of EF show different developmental trajectories. The basic components of EF (i.e., inhibition and WM) emerge during the first years of life. The ability to keep simple information in mind (i.e., WM) is present before the age of 6 months, for example (Courage & Cowan, 2009; Garon et al., 2008). The underlying structure of Baddeley's multicomponent WM model is in place by about the age of 4 years with related but separable components (Alloway, Gathercole, & Pickering, 2006; Gathercole, Pickering, Ambridge, & Wearing (2004)). Between 3 and 5 years of age, spurts in children's inhibition and WM have been observed and other components of EF such as planning and shifting can be seen to start developing at this time (Best, Miller, & Jones, 2009; De Luca & Leventer, 2008; Diamond, 1990; Epsy, 2004).

The majority of tasks used to study EF have been designed for use with adults and have thus not been suited for use with young children who may encounter problems with the instructions to start with. More recently, developmentally-sensitive tasks have been created and research on the WM and EF of young children has thus increased (Alloway et al., 2006; Diamond, 1990). The verbal storage component of WM can now be reliably measured by the age of 2 years, for example, using nonword repetition tasks (Chiat & Roy, 2007, 2008). Alloway (2007) recently developed the Automated Working Memory Assessment (AWMA) to assess the different components of WM from the age of 4 years.

More general in the field of EF research is the question of the ecological validity of the EF tasks that are used. Standardized cognitive measures of EF have been widely criticized as not being sufficiently sensitive to the multidimensional nature of EF in daily life (Anderson et al., 2002; Chaytor, Schmitter-Edgecombe, & Burr, 2006). This is obviously an issue for the assessment of young children who are known to behave differently in unfamiliar contexts. That is, obtaining representative behaviors in clinical or research settings can be a major problem. To gain ecologically valid information on children's EF, it is thus suggested that information should be collected in different contexts and from different sources – including caregiver behavioral ratings of EF (Gioia et al., 2001). In a recent review of the assessment of language development in preschool children, Conti-Ramsden and Durkin (2012) indeed advocate adoption of a multi-method, multi-informant approach. They also assert that information from caregivers may provide a more accurate assessment of young children's language problems. For the assessment of EF behavior in young children, Gioia, Andrews, and Isquith (2003) developed the Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P). This questionnaire was one of the first to provide developmentally appropriate methods to assess the multidimensional nature of the EF construct in young children. Research has shown it to be a reliable and valid measure of everyday EF (Mahone & Hoffman, 2007).

1.4. Present study

Given that research on the EF of young children with SLI is limited and that only a few studies have compared WM performance for young children with SLI versus TD children, the role of WM and EF in young children with SLI is not clear. In the present study, we therefore compared the WM performances and behavioral ratings of EF of young children with SLI to that of TD children. More specifically, we administered a battery of WM tests to assess the different components of the WM system according to Baddeley's WM model. Additionally, we collected parental ratings of behaviors requiring a range of executive functions. We did this with children with SLI and TD children in the age range of 4- to-5 years. Our specific research questions were as follows.

(1) Do WM performance and/or behavioral ratings of EF differ significantly for young children with SLI versus TD peers?
(2) Do the performances on the different components of WM and behavioral ratings of EF correlate significantly for children with SLI and/or TD children?
(3) Does WM performance discriminate between children with SLI and TD children?

2. Methods

2.1. Participants

A total of 116 children aged 4- to 5-years participated in this study: 58 children with SLI (42 boys and 16 girls) and 58 age-matched TD peers (32 boys and 26 girls). The mean age of the children with SLI was 4;09 (SD = 7.41 months, range 4;0–5;11). The mean age of the TD peers was 4;11 (SD = 6.78 months, range 4;01–5;11). All of the children had average intelligence (85

Table 1
Descriptive statistics for nonverbal intelligence and language measures.

Measure	SLI (n = 58, 42 boys)		TD (n = 58, 32 boys)	
	Mean	SD	Mean	SD
Age	57.03	7.41	59.44	6.78
Non-verbal IQ (SON-R 2½-7)	107.24	12.74	112.12	15.68
PPVT-III-NL	90.86	14.86	107.05	10.37
Reynell	84.17	12.38	112.13	12.54
Schlichting WQ	79.14	12.59	–	–
Schlichting ZQ	78.66	8.81	–	–

Note: SLI = specific language impairment; TD = typically developing children; n = number of included children; SD = standard deviation; PPVT-III-NL = Peabody Picture Vocabulary Test-III-NL; WQ and ZQ Schlichting = word and sentence development Schlichting Test for Language Production.

or more on a nonverbal intelligence test, SON-R 2½-7) and were native speakers of Dutch (Tellegen & Laros, 1998). Any children with a diagnosed hearing impairment, neurological disorder, ADD/ADHD, or autism spectrum disorder were excluded.

The children in the SLI group were recruited from special language units (n = 52) or from special education schools (n = 6) in the Netherlands. All of them were receiving daily support for their speech or language problems. Diagnosis was based on extensive clinical and psychometric assessment by speech and language pathologists; persistent difficulties specific to language were shown in all cases. For most of the children, recent results for measures of language and nonverbal intelligence were available via their personal files. These results were included in the current study only when they were no more than 6-month old. Otherwise, assessment was repeated. Participants were included in our study when they performed 1.25 SDs or more below the mean on at least two language measures, following Tomblin (1996). The language measures included the *Peabody Picture Vocabulary Test-III-NL* (Dunn & Dunn, 1997; Schlichting, 2005), the *Reynell Developmental Language Scales* (Reynell & Gruber, 1990; van Eldik et al., 2004), and tests of word and sentence development from the *Schlichting Test for Language Production* (Schlichting et al., 2003). The Dutch versions of these tests have all been normed. The SLI group means for expressive language were about 1.5 SDs below the standardized mean; 76% of the children with SLI performed 1.25 SDs below the mean on one of the expressive language measures; 62% performed 1.25 SDs below the mean on one of the receptive language measures; and 45% scored more than 1.25 SDs below the mean on three or more language measures.

The children in the control group were recruited from three middle-class schools in the Netherlands. The language measures examined for the control group were the *Peabody Picture Vocabulary Test-III-NL* (Dunn & Dunn, 1997; Schlichting, 2005) and the *Reynell Developmental Language Scales* (Reynell & Gruber, 1990; van Eldik et al., 2004). All of the control children performed in the normal range on both of these tests.

The SLI and control groups did not differ significantly with regard to age (ANOVA $F(1,114) = 3.64$, $p = .059$), nonverbal intelligence (ANOVA $F(1,114) = 3.58$, $p = .061$), or gender (Chi-square test χ^2 (1, $n = 116$) = 3.73, $p = .053$). The descriptive statistics for the two groups of children are presented in Table 1. One-way analyses of variance (ANOVAs) confirmed that the SLI group had significantly lower scores on the language measures than the control group (PPVT-III-NL $F(1,114) = 46.29$, $p < .001$; Reynell $F(1, 114) = 189.67$, $p < .001$).

2.2. Procedure

All children were tested individually in a quiet room at their school or in a clinic. Written consent was obtained for participation in the present study from the parents of all children. Assessment took anywhere from two to four 45-min sessions, depending on the availability of the selected language and nonverbal intelligence measures in the children's personal files. A short break was taken halfway through each session. In addition to the measures for nonverbal intelligence and language listed above, all of the children were administered the Dutch translation of the *Automated Working Memory Assessment (AWMA)* (Alloway, 2007). All of their parents completed the Dutch translation of the *Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P)* (Gioia et al., 2003; van der Heijden van der, Suurland, Sonneville, & de Swaab, 2012).

The AWMA was administered on a laptop. To start, the experimenter explained the task to the child. Next, practice trials were administered in which feedback was provided by the computer. If necessary, the experimenter repeated the practice items and thereby made sure that the child understood the task instructions. After the practice trials, all of the children were able to perform the trials individually without the help of the experimenter. All of the children completed the test battery, also in the order recommended. Nine of the parent questionnaires were not returned (6 for the SLI group; 3 for the control group).

2.3. Cognitive measures of WM

The AWMA (Alloway, 2007) is an automated, computerized assessment battery suitable for use with respondents who are 4–22 years of age. The AWMA has been validated and measures the different components of Baddeley's WM model (Gathercole & Pickering, 2000). The assessment battery includes twelve subtests which form four nonoverlapping composite scores that include three subtests of verbal storage, verbal CE, visuospatial storage, and visuospatial CE, respectively. The storage measures tap into the phonological loop or visuospatial sketchpad, depending on the nature of the information to be remembered. For the CE measures, the children must simultaneously store and process information. The processing activity is assumed to tap into the central executive component of the WM model.

Testing follows the same span procedure in all subtests. Following a practice session, a maximum of six sequences of increasing lengths are presented. The length of the sequences are increased by one after the child has correctly recalled four sequences of a particular length with a maximum of seven items for the CE tasks and nine items for the storage tasks. Testing is stopped when three sequences of a particular length are not recalled correctly. The children respond by pointing to the answer of their choice on the screen or by saying it aloud. The experimenter then imports their choice into the computer program.

2.3.1. Verbal storage

In the Digit recall task, the child must recall a sequence of digits in the right order. The digits can range from one to nine and are spoken at a rate of one digit per second. The sequences are randomly generated and no digits are repeated.

In the Word recall task, the child must recall a sequence of words in the right order. The words are monosyllabic, spoken at a rate of one syllable per second, and no words are repeated. When a substitution reflects the child's habitual articulation pattern for a phoneme, credit is given for the substitution and the recall of the item judged to be correct.

In the Nonword recall task, the child must recall a sequence of nonwords in the right order. These nonwords are composed of the same phonemes as the words from the Word recall task. The nonwords are monosyllabic, spoken at a rate of one syllable per second, and no nonwords are repeated. As in the Word recall test, when a substitution reflects the child's habitual articulation pattern for a phoneme, credit is given for the substitution.

2.3.2. Verbal CE

In the Listening span task, the child is presented short sentences. The child must then judge whether the content of the sentence is correct (by saying "true" or "false") and remember the last word of the sentence. The number of sentences increases in length and the child must then recall the last words of the sentences in the correct serial order. The sentences have a simple subject-verb-object order and contain early developing vocabulary.

In the Counting recall task, the child first views red dots and blue triangles arranged in a box on the screen. The child is instructed to count the red dots, say the number aloud, and remember the total number of dots. After trials requiring the child to count the number of red dots, they must recall the number of red dots in the correct serial order.

The Backward digit recall task is the same as the Digit recall task except that the child must now recall the sequence of digits in the reverse order.

2.3.3. Visuospatial storage

In the Dot matrix task, a sequence of red dots is presented on a 4 × 5 grid. All of the dots appear in the grid for 2 s. The dots then disappear and the child must point to the position of each dot in the same serial order as presented.

In the Mazes memory task, a maze with a path drawn through it is presented to the child for 3 s. The same maze is then presented to the child without the path and the child must then draw the path of the line on the computer screen. Maze complexity is increased with the addition of more walls to the maze.

In the Block recall task, the child is presented a board with 9 randomly located cubes. A series of the tubes is then pointed to with an arrow. Thereafter, the child must point to the cubes in the same order.

2.3.4. Visuospatial CE

In the Odd-one-out task, a horizontal row of 3 boxes with a complex shape in each of them is shown to the child. The child must point to the shape that does not resemble the others. After trials in which the child identifies the odd shape, three blank boxes appear. The child is asked to point to the position of the boxes that contained the odd shapes in the correct serial order.

In the Mr. X task, the child is presented two Mr. X figures. The one on the left is wearing a yellow hat; the one on the right a blue hat. The figures are otherwise the same. Each Mr. X also has a ball in his hand, and the child must judge whether both figures have the ball in the same hand or not. In addition, the child must remember the position of the ball held by the figure with the blue hat (i.e., the figure on the right); the ball rotates to six possible positions in a circle. After trials in which the child must judge whether the ball is in the same hand or not, the Mr. X figures disappear and a circle of six dots appears. This circle reflects the possible positions of the ball. The child is asked to point to the position of the dots in the same as presented for Mr. X.

In the Spatial span task, two identical shapes are presented to the child with a red dot above the right shape. The child must judge whether the two shapes are in normal or mirror image and to remember the location of the dot. The position of the dot rotates to one of three positions of a triangle. After trials requiring the child to judge the similarity of the shapes, they disappear and a triangle of three dots reflecting the possible positions of the previous dots appears. The child must point to the positions of the previous dots in the right order.

2.4. Behavioral measures of EF

The BRIEF-P is a standardized rating scale for parents and teachers designed to measure executive function behaviors of children aged 2–5 years old (Gioia et al., 2003; van der Heijden et al., 2012). The scale contains 63 items within five nonoverlapping theoretically and empirically derived clinical scales that measure different aspects of executive functioning: inhibition, shifting, emotional control, working memory, and planning/organization. The five clinical scales form three broader indexes of inhibitory self-control, flexibility, and emergent metacognition. An overall global EF score (i.e., global executive composite) is also calculated.

3. Results

3.1. Group comparisons

The descriptive statistics for the cognitive measures of WM (AWMA) and behavioral measures of EF (BRIEF-P) are shown in Table 2. Performance of the SLI and TD groups were compared in multivariate analyses of variance (MANOVAs) and follow-up analyses of variance (ANOVAs). In addition, effect sizes were computed. The effect-size (*d*) is the difference between the mean of the control group and the SLI group divided by the pooled sample standard deviation. Effect sizes are considered small for $d = .20$, medium for $d = .50$, and large for $d = .80$ (Cohen, 1988).

The SLI group performed significantly worse than the TD group on the cognitive measures of WM. We first conducted MANOVA investigating group differences on the four composite scores (i.e., verbal storage, verbal CE, visuospatial storage, and visuospatial CE) showed a significant overall group effect: Wilks' $\Lambda = .37$, $F(1,114) = 48.16$, $p < .001$, $\eta^2 = .63$. Follow-up ANOVAs were next conducted. Using the Bonferroni method, which divides the level of significance by the number of dependent variables, each ANOVA was tested at the .013 level. The outcomes for all four of the univariate comparisons were significant: verbal storage $F(1,114) = 161.70$, $p < .001$; verbal CE $F(1,114) = 127.13$, $p < .001$; visuospatial storage $F(1,114) = 74.97$, $p < .001$; visuospatial CE $F(1,114) = 58.57$, $p < .001$. The average effect size for the composite scores was $d = 1.89$. The largest composite effect size was found for verbal storage ($d = 2.38$).

Secondly, MANOVA investigating the group differences on the individual subtest scores also revealed a significant overall group effect: Wilks' $\Lambda = .31$, $F(1,114) = 19.51$, $p < .001$, $\eta^2 = .70$. All of the follow-up univariate ANOVAs (at .004 level) were significant: digit recall $F(1,114) = 91.78$, $p < .001$; word recall $F(1,114) = 145.58$, $p < .001$; nonword recall $F(1,114) = 72.29$, $p < .001$; listening recall $F(1,114) = 141.33$, $p < .001$; counting recall $F(1,114) = 77.51$, $p < .001$; backward digit recall $F(1,114) = 29.16$, $p < .001$; dot matrix $F(1,114) = 53.64$, $p < .001$; mazes memory $F(1,114) = 58.61$, $p < .001$; block recall $F(1,114) = 31.77$, $p < .001$; odd-one-out $F(1,114) = 27.17$, $p < .001$; mister X $F(1,114) = 30.51$, $p < .001$; and spatial recall $F(1,114) = 29.48$, $p < .001$. The average effect size for the differences between the performance of children with SLI and TD children on the individual subtests was $d = 1.45$. The largest effect size was observed for word recall ($d = 2.26$).

To control that intelligence, gender and age were not mediating performance on the cognitive measures of WM, multivariate analyses of covariance (MANCOVAs) and follow-up analyses of covariance (ANCOVAs) were next conducted for

Table 2
Descriptive statistics for cognitive WM performance (AWMA) and EF behaviors (BRIEF-P).

	SLI		TD		*F*	*d*
	M	SD	*M*	SD		
AWMA						
Verbal storage: composite score	85.33	13.03	113.59	10.80	161.70	2.38
Digit recall	74.45	15.02	97.03	9.83	91.78	1.79
Word recall	92.81	11.31	115.76	9.04	145.58	2.26
Nonword recall	98.24	12.92	118.62	12.90	72.29	1.59
Verbal CE: composite score	89.59	9.38	113.31	12.99	127.13	2.11
Listening recall	98.09	11.32	122.68	10.96	141.33	2.23
Counting recall	87.63	11.25	109.69	15.40	77.51	1.65
Backward digit recall	89.88	7.86	101.21	13.91	29.16	1.01
Visuospatial storage: composite score	89.38	12.03	109.81	13.35	74.97	1.62
Dot matrix	89.79	13.68	109.07	14.65	53.64	1.37
Mazes memory	93.85	11.05	110.09	11.79	58.61	1.43
Block recall	91.24	11.67	104.89	14.29	31.77	1.06
Visuospatial CE: composite score	95.74	13.84	115.14	13.45	58.57	1.43
Odd-one-out	96.07	16.01	113.69	20.16	27.17	.98
Mister X	94.29	13.09	110.59	18.26	30.51	1.03
Spatial recall	99.22	12.76	114.10	16.51	29.48	1.02
BRIEF-P						
Global executive composite	59.92	14.52	48.48	10.47	22.44	.92
Inhibition	58.89	12.69	49.91	12.04	14.38	0.73
Shifting	54.81	11.49	46.41	6.31	22.70	.92
Emotional control	54.83	15.65	47.80	11.26	27.02	.52
Working memory	63.94	14.54	50.84	11.69	27.02	1.01
Planning/organization	55.23	13.72	46.54	10.49	13.90	.72

Note: SLI = specific language impairment; TD = typically developing children; *M* = mean; SD = standard deviation; *F* = ANOVA statistics; *d* = effect size; AWMA = Automated Working Memory Assessment; BRIEF-P = Behavior Rating Inventory of Executive Function – Preschool Version.

both the composite and individual subtest scores; nonverbal intelligence (IQ SON-R), gender and age were entered as covariates. Both the overall group effect on the composite scores (Wilks' $\Lambda = .39$, $F(1,114) = 43.17$, $p < .001$, $\eta^2 = .62$) and the univariate group effects for each of the composite scores at the .013 level (verbal storage $F(1,114) = 137.72$, $p < .001$; verbal CE $F(1,114) = 112.73$, $p < .001$; visuospatial storage $F(1,114) = 60.78$, $p < .001$; visuospatial CE $F(1,114) = 46.65$, $p < .001$) remained significant.

For the individual subtests, the overall group effect remained significant in the MANCOVA (Wilks' $\Lambda = .33$, $F(1,114) = 17.55$, $p < .001$, $\eta^2 = .68$). And once again, all of the univariate ANCOVAs also showed significant group effects: digit recall $F(1,114) = 75.73$, $p < .001$; word recall $F(1,114) = 120.54$, $p < .001$; nonword recall $F(1,114) = 65.23$, $p < .001$; listening recall $F(1,114) = 116.01$, $p < .001$; counting recall $F(1,114) = 72.00$, $p < .001$; backward digit recall $F(1,114) = 18.73$, $p < .001$; dot matrix $F(1,114) = 39.26$, $p < .001$; mazes memory $F(1,114) = 48.99$, $p < .001$; block recall $F(1,114) = 23.36$, $p < .001$; odd-one-out $F(1,114) = 18.98$, $p < .001$; mister X $F(1,114) = 24.93$, $p < .001$; and spatial recall $F(1,114) = 20.70$, $p < .001$. The results indicate that even when intelligence, gender and age were taken into account, the SLI group performed significantly worse than the TD group on all the components of WM.

For the BRIEF-P behavioral measure of EF, an ANOVA investigating the group differences on the overall global EF score (i.e., global executive composite) revealed a significantly higher global EF score for the SLI group than for the control group: $F(1,107) = 22.44$, $p = .002$. This indicates more problems in EF behaviors in the SLI group compared to the TD group.

MANOVAs investigating the group differences on the clinical scales of inhibition, shifting, emotional control, working memory, and planning/organization revealed a significant overall group effect: Wilks' $\Lambda = .86$, $F(1,107) = 3.42$, $p = .007$, $\eta^2 = .140$. Follow-up univariate ANOVAs showed significant group differences for all of the five clinical scales at a .01 level: inhibition $F(1,107) = 14.38$, $p < .001$; shifting $F(1,107) = 22.70$, $p < .001$; emotional control $F(1,107) = 27.02$ $p < .001$; working memory $F1,107) = 27.02$, $p < .001$; planning/organization $F(1,107) = 13.90$, $p < .001$). The average effect size for the differences among the clinical scales was $d = .78$. The largest effect size was found for the clinical scale of working memory ($d = 1.01$). These results show the parents of children with SLI to report significantly more problems on all of the behavioral measure of EF compared to the parents of TD children, with medium to large effect sizes.

3.2. Relations between WM performance and behavioral ratings of EF

To explore the relations between the performances on the different components of WM and behavioral measures of EF for the SLI and TD groups of children, the correlations were computed between the WM composite scores from the AWMA, the overall global EF score from the BRIEF-P, and the clinical scales from the BRIEF-P (see Table 3). The correlations for the SLI group are displayed first and those for the TD group second.

For the SLI group, low correlations were generally found between the different components of WM and behavioral ratings of EF ($r = -.004$ to $r = -.284$). Only the correlation between the AWMA composite score of verbal storage and the BRIEF-P clinical scale of shifting was found to be significant.

For the TD group, the correlations varied between $r = .004$ and $r = -.364$. The AWMA composite score of verbal CE significantly correlated with the BRIEF-P overall global EF score ($r = -.341$) and the clinical scales of inhibition ($r = -.348$), working memory ($r = -.364$), and planning/organization ($r = -.312$). The highest correlation was between the verbal CE composite score and the clinical scale of working memory. The AWMA composite score of visuospatial CE significantly correlated with the BRIEF-P overall global EF score ($r = -.339$) and the clinical scales of inhibition ($r = -.303$), working memory ($r = -.348$), and planning/organization ($r = -.338$). The highest correlation was between the visuospatial CE composite score and the clinical scale of working memory.

3.3. Identifying SLI

Given that the measures of WM performance produced significant group differences with large effect sizes, we next explored if these measures could discriminate between young children with SLI and TD children. For this purpose, a discriminant analysis was conducted to determine whether performance on the composite scores from the AWMA (i.e., verbal storage, verbal CE, visuospatial storage, and visuospatial CE) could predict group membership. We also conducted a

Table 3
Correlation between cognitive WM performance (AWMA) and EF behaviors (BRIEF-P).

	Verbal storage	Verbal CE	Visuospatial storage	Visuospatial CE
Inhibition	.110/−.066	.027/−.348**	−.026/−.244	−.006/−.303*
Shifting	−.284*/−.107	−.010/−.192	−.004/−.101	−.110/.004
Emotional control	−.021/−.090	−.040/−.092	−.021/−.116	.060/−.117
Working memory	−.229/−.192	−.134/−.364**	−.270/−.251	−.101/−.348**
Planning/organization	−.246/−.150	−.044/−.312*	−.217/−.122	−.184/−.338*
Global executive composite	−.166/−.144	−.059/−.341*	−.151/−.246	−.071/−.339*

Note: Correlations for SLI group displayed first; correlations for TD group displayed second.

* $p < 05$.

** $p < .01$.

Table 4
Classification of children as SLI or TD in discriminant function analysis.

Variable entered	Correctly classified SLI	Correctly classified TD	Sensitivity	Specificity	LR+
Composite scores AWMA	52 (89.7%)	51 (87.9%)	88.1%	89.5%	8.4
PPVT-III-R	39 (67.2%)	49 (84.5%)	81.2%	72.1%	2.9
Reynell	51 (87.9%)	52 (89.7%)	89.5%	88.1%	7.5

Note: LR+ = positive likelihood ratio; PPVT-III-R = Peabody Picture Vocabulary Test-III-NL.

discriminant analysis to determine whether performance on the two language measures included in this study (i.e., PPVT-III-NL and Reynell) predicted group membership, to facilitate comparison. The results are presented in Table 4.

The first discriminant analysis explored the use of the four AWMA composite scores (entered together) as a classification function. The overall Wilks's lambda was significant, $\Lambda = .37$, χ^2 (4, $n = 116$) = 112.71, $p < .001$. This shows the predictors to differentiate between the SLI and TD group. Based on this function, 90% of the children in our sample were correctly classified as SLI and 88% correctly classified as TD. Using the leave-one-out method (cross-validation) to assess how well this classification procedure would predict in a new sample, 88% of the children were next correctly classified as SLI and 86% correctly classified as TD. The sensitivity of this function is 88%, and the specificity is 90%. The positive likelihood ratio is 8.4, indicating that children with SLI are over 8 times more likely to have greater problems with WM performance than their TD peers.

The second discriminant analyses explored the use of the two language measures as classification functions. The Wilks's lambdas for both language measures were significant: PPVT-III-NL, $\Lambda = .71$, χ^2 (1, $n = 116$) = 33.68, $p < .001$; Reynell $\Lambda = .38$, χ^2 (1, $n = 116$) = 111.20, $p < .001$. These results show both of the language measures to successfully differentiate between the two groups of children. Based on the PPVT-III-NL, 67% of the children in our sample were correctly classified as SLI and 85% correctly classified as TD. Based on the Reynell, these percentages were 88% and 90%, respectively. For the PPVT-III-NL, the sensitivity is 81%; the specificity is 72%; and the positive likelihood ratio is 2.9. For the Reynell, the sensitivity is 90%; the specificity is 88%; and the positive likelihood ratio is 7.5. The percentage of children correctly classified by the composite scores from the AWMA is comparable to the percentage of children correctly classified by the language measures.

In Table 5, we present the within-groups correlations between the predictors and the discriminant function of the AWMA composite scores as well as the standardized weights for this function. Verbal storage shows the strongest association with the discriminant function, followed by verbal CE, visuospatial storage, and visuospatial CE.

4. Discussion

The purpose of this study was to determine if the performances of young children with SLI differ from that of TD children in terms of WM performance and EF behaviors. We also asked how the performances on the different components of WM and behavioral ratings of EF interrelate for children with SLI versus TD children and whether assessment that includes measures of WM performance discriminates between children with SLI and TD children?

With regard to our first question, namely whether WM performance and/or ratings of EF differ significantly for young children with SLI versus TD peers, we found children with SLI to perform significantly below their TD peers on all components of WM, including verbal storage, verbal CE, visuospatial storage, and visuospatial CE. The effect sizes for the different components all were large (varying from $d = 1.43$ to $d = 2.38$). We also calculated the effect sizes for the language measures included in this study, the PPVT-III-NL and Reynell, for comparison and found the effect sizes to be comparable to those for the measures of WM ($d = 1.27$ and $d = 2.26$, respectively). Taken together, these findings replicate previous findings showing clear impairments in verbal storage and verbal CE in children with SLI (Archibald & Gathercole, 2006b, 2007; Coady & Evans, 2008; Gray, 2003; Montgomery, 2010). Reduced performance on visuospatial storage and visuospatial CE tasks has also been reported in most previous studies examining these in *young* children with SLI (Bavin et al., 2005; Hick et al., 2005; Marton, 2008; Menezes et al., 2007). However, age-appropriate performance on visuospatial storage and visuospatial CE tasks has been shown in older children with SLI (Alloway & Archibald, 2008; Archibald & Gathercole, 2006a, 2006b; Baird et al., 2009; Lum et al., 2011; Riccio et al., 2007; Williams et al., 2000). Additionally, a recent study showed this to also be the case for young children with SLI (Petrucelli et al., 2012). The data on impairments in the visuospatial domain of WM in children with SLI are still not clear, thus.

Table 5
Correlations and standardized coefficients of composite scores AWMA with discriminant functions.

Predictors	Correlation coefficients with discriminant functions	Standardized coefficients for discriminant functions
Verbal storage	.90	.65
Verbal CE	.80	.39
Visuospatial storage	.62	.14
Visuospatial CE	.54	.02

Behavioral ratings of EF showed the parents of the young children with SLI to report significantly more problems relative to the parents of the TD children in our study. These included problems with inhibition, shifting, emotional control, WM, and planning/organization. The effect sizes for the differences between the children with SLI and the TD children were medium to large on average (range of $d = .44$ to $d = 1.01$). The largest effect size for ratings of EF were found for WM. These results are in line with the results of Hughes et al. (2009) who found adolescents with SLI and their parents to report impaired EF behaviors during daily life.

Our second research question concerned the intercorrelations between performances on the different components of WM and behavioral ratings of EF for children with SLI versus TD children. The intercorrelations differed for the two groups of children. In the TD group, both verbal CE *and* visuospatial CE performance significantly correlated with behavioral ratings of EF in daily life. More specifically, both verbal CE and visuospatial CE performance correlated with the behavioral ratings of inhibition, WM and planning/organization in the TD group. In contrast, in the SLI group, consistently low correlations were found for all of the components of WM with the ratings of EF in daily life; only the correlation between verbal storage performance and the behavioral rating of shifting proved significant. This pattern of findings suggests that the associations between WM performance and EF behaviors are less consistent and non-specific in young children with SLI compared to their TD peers. However, in general, limited correlations between the BRIEF and cognitive measures of EF, including WM, have also been reported in previous studies for both TD children and other clinical groups (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Mahone & Hoffman, 2007; Vriezen & Pigott, 2002). It is suggested that this findings are due to the lack of ecological validity of standardized cognitive measures of WM and EF (Anderson et al., 2002; Chaytor et al., 2006).

Our final research question was whether WM performance could adequately discriminate between young children with SLI versus TD peers. The composite scores from the AWMA, which measured the different components of WM, differentiated between the SLI and TD groups with 90% of the children in our sample correctly classified as SLI and 88% correctly classified as TD. The percentage of children classified correctly by the AWMA composite scores was comparable to the percentage classified correctly by the two language measures in the present study. Sensitivity and specificity were both high (i.e., 88% and 90%). The verbal storage component of WM demonstrated the strongest relationship with the discriminant function, followed by verbal CE, visuospatial storage, and then visuospatial CE. These results suggest that assessment of the cognitive measures of WM can help identify young children with SLI but that it is not sufficient on its own for accurate classification.

Taken together, the results of our study show that young children with SLI perform significantly below their TD peers on both cognitive and behavioral measures of WM. In addition to constraints on WM, the deficits in EF behaviors include problems with inhibition, shifting, emotional control, and planning/organization. The observed deficits in WM performance involved all the components of WM and were not restricted to the verbal domain; the visuospatial domain of WM was affected as well. Our results also show the patterns of associations between WM performance and EF behaviors to differ for children with SLI versus those with typical language development. Furthermore, WM performance and particularly verbal storage can adequately discriminate between young children with SLI versus typical language development.

Although consensus on the involvement of the visuospatial WM in SLI has not been found across studies to date, the current findings clearly suggest that *both* the verbal and visuospatial domains of WM are affected in young children with SLI. Stated more generally, this outcome suggests that SLI in young children may be associated with domain general impairments of WM. The impairments seem not to be completely specific to language or the processing of strictly verbal information.

Alternative explanations for this outcome are nevertheless available. One frequently offered explanation is that the visuospatial WM system may be intact but that the control of this system by the language system is problematic. This explanation hinges on whether the performance of the children on visuospatial WM tasks possibly reflects verbal mediation of visuospatial information, or genuinely reflects their visuospatial storage and processing, as we have assumed. Some experts have hypothesized that children with SLI indeed show *inefficient* verbal coding during visuospatial WM tasks (Archibald & Gathercole, 2006b; Gillam, Cowan, & Marler, 1998). Due to their language problems, they may rely more on visual encoding when actually phonological codes are preferable or use less efficient verbal strategies. But such an explanation in terms of inefficient verbal coding is not likely to hold for the young children in our study because it is known that verbal coding does not emerge until around the age of seven (Gathercole, Adams, & Hitch, 1994). An alternative explanation of the domain general impairments of WM in young children with SLI must thus be sought.

Another possibility is that the visuospatial WM impairments of young children with SLI are a reflection of more general limitations on executive and attentional control. This view is in line with accounts of WM that highlight the notion of limited executive and attentional resources (Courage & Cowan, 2009; Engle et al., 1999). Such a limitation can be expected to manifest itself on any task with a high processing load. Stated differently, young children with SLI can be expected to adequately process single bits of information but encounter problems when more complex information must be processed (Ellis Weismer, 1996; Fazio, 1998; Hoffman & Gillam, 2004; Marton & Schwartz, 2003; Montgomery, 2000, 2002). It is known that executive and attentional control greatly influence children's WM performance, and there is evidence for a stronger association between executive and attention processes and visuospatial WM than between these processes and verbal WM (Busch et al., 2005; Marton, 2008; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001).

The current finding of problems with EF together with previous documentation of attentional impairments in young children with SLI support the explanation of domain general WM impairments in terms of limitations on executive and attentional control (Finneran et al., 2009; Spaulding, Plante, & Vance, 2008). This explanation nevertheless calls for further documentation of the exact roles of EF and attentional control in the WM performance – both verbal and visuospatial. The development of EF and attentional control over time should be documented, for example. These factors were, after all, still developing in the children included in the present study. The present findings cannot rule out that it only concerned delays in the development of these capacities. If factors like EF and attentional control are implicated, it might be specific to young children with SLI and thus not hold for older children.

Understandably, there has not been much research conducted on WM and EF of young children with SLI to date. The present study is one of the first to clearly document the WM performances and EF behaviors of young children with SLI. We used a validated and standardized test to assess the different components of WM. This multimodal approach permitted a more reliable assessment of each component than reliance on any single measure (Archibald & Gathercole, 2006a). Our study is also unique in the inclusion of behavioral ratings of EF. One possible limitation on the present study is that we did not include cognitive measures of EF. This is thus a potentially valuable direction for future research on young children with SLI. Several studies in older children with SLI have indeed revealed impairments on cognitive measures of EF, including inhibition, planning, updating, and fluency (Henry et al., 2011; Im-Bolter et al., 2006; Marton, 2008). Another possible limitation is that measures of the functioning of the episodic buffer component of WM were not included in the present study. The inclusion of such information might nevertheless be of value as impairments in this component of WM in young children with SLI have recently been reported (Petrucelli et al., 2012). Continued research on the cognitive and behavioral aspects of WM and EF of young children with SLI will provide greater insight into the relationships between linguistic and cognitive factors in language impairment.

In closing, the present findings have some potential implications for the assessment and treatment of young children with language problems. Although SLI can be reliably identified in preschool children, its diagnosis in clinical practice is sometimes difficult due to substantial variation in the range of normal language development (Conti-Ramsden & Durkin, 2012; Ellis Weismer & Evans, 2002). The present results suggest that WM measures, and particularly verbal WM measures, could be a valuable addition for the identification of young children with SLI. Furthermore, evaluation of WM and EF in young children with SLI can create more detailed profiles of the strengths and weaknesses of these children. Given the present finding of limitations on different components of WM, including the verbal and visuospatial domain, examination of WM within a multimodal approach is recommended. The WM deficits of young children experiencing language problems may not be restricted to verbal WM, and it is obviously important to know if the problems being experienced by the child are also visuospatial. In order to assure ecological validity and complement information gleaned from cognitive measures, the addition of parental ratings of the child's EF during daily life is recommended. More generally, the present findings indicate that the AWMA and BRIEF-P are efficient measures for detecting WM and EF limitations in young children.

For remediation, it is recommended that interventions should not focus on language alone but also address strategies used by the child to store and process both verbal and visuospatial information. It is also recommended that the adverse effects of impaired WM and EF be minimized during teaching and remediation by taking task demands (i.e., task complexity, amount of material, and possible distractors) into account. While the use of visual support is already a common support strategy for intervention with children with SLI, the current findings suggest that young children with SLI might not benefit as much from visual support as typically developing children do. This means that only certain types of visual support may be suited for use with young children with SLI, namely: simple visual information that does not exceed the child's WM capacity. In language impaired children with clear impairment of WM and/or EF, WM or EF training may be relevant (Klingberg, Forssberg, & Westerberg, 2002; Prins et al., 2010). Finally, these clinical implications may be particularly important for those children showing limited response to traditional language intervention. Taking into account WM and EF in young children with SLI can create more detailed profiles of the strengths and weaknesses of these children and thus determine suitable interventions.

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