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## EXECUTIVE FUNCTION PROFILES IN CHILDREN WITH AND WITHOUT SPECIFIC LANGUAGE IMPAIRMENT

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### Abstract

We present findings from a study that focused on specific executive functions (EF) in children with and without specific language impairment (SLI). We analyzed performance patterns and EF profiles (spatial working memory, inhibition control, and sustained attention) in school-age SLI children and two control groups: age-matched and language matched. Our main research goal was to identify those EFs that show a weakness in children with SLI. Our specific aims were to: (1) examine whether the EF problems in children with SLI are domain-general; (2) examine whether deficits in EF in children with SLI can be explained by the general slowness hypothesis or by an overall delay in development; (3) compare EF profiles to examine whether children with SLI show a distinct pattern of performance from their peers. Our findings showed different EF profiles for the groups. We observed differences in performance patterns related to age (e.g., reaction time in response inhibition) and differences related to language status (e.g., sensitivity to interference). The findings show interesting associations in EFs that play a crucial role in language processing.

### Keywords

Language impairment; Spatial working memory; Sustained attention; Inhibition control; School age children

### I. Introduction

Executive functions play a critical role in language processing and working memory performance across age groups and populations (Engle, Kane, Tuholski 1999). Executive function is an umbrella term referring to task switching abilities (Towse, Hitch, & Hutton 1998), controlled attention (Barrouillet & Camos 2001; Engle *et al.* 1999), inhibition of

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irrelevant information (Hasher & Zacks 1988), simultaneous processing (Engle 2002), avoiding distraction and focusing on task-relevant thoughts, (Miyake *et al.* 2000), developing goals, holding these goals in active memory, and monitoring performance to achieve goals (Stuss 1992). Research on the relationship between executive functions and language processing in children is limited, but there is evidence that tasks involving language processing, such as sentence comprehension, are highly influenced by executive functions (Mazuka, Jincho, & Oishi 2009). The present study examined executive functions in school-age children with and without specific language impairment (SLI).

Specific language impairment is a neurodevelopmental disorder affecting about 6–7% of kindergarten children in the United States (Tomblin *et al.* 1997). Children with SLI perform more poorly than their peers on working memory tasks involving various executive functions (Ellis Weismer, Evans, & Hesketh 1999; Marton & Schwartz 2003; Montgomery 2000). Many children with SLI perform complex linguistic and cognitive tasks at a slower rate and with different performance patterns than typically developing children (Im-Bolter, Johnson, & Pascual-Leone 2006; Marton 2008; Miller, Kail, Leonard, & Tomblin 2001; Montgomery & Leonard 1998). A deficit in executive functions may account, at least in part, for these difficulties but there are few studies on specific executive functions in school-age children with SLI. Thus, the nature of this deficit is not clear.

## II. Executive functions: variations in inhibition, attention control and working memory

There is no widely accepted model of executive functions in the literature, in part, because executive functions are manifested by their impact on other cognitive processes such as domain-free attentional capacity (Miyake *et al.* 2000). Some executive functions that are likely to be involved in complex cognitive processes and language processing have been extensively studied and are relatively well defined. These more precisely circumscribed executive functions include, but are not limited to, monitoring and updating information, inhibiting irrelevant and distracting information, sustaining attention, switching/set-shifting, and actively maintaining information to pursue goals.

One executive function commonly studied in children and adults is inhibition. Inhibition control involves temporal delays in response and resistance to interference (Barkley 1997; Friedman & Miyake 2004). Inhibition control may reduce the level of activation of a strong response when a weaker or equivalent, but contextually more appropriate, reaction is needed (Anderson 2003). It can prevent perseveration in task performance through the suppression of irrelevant information.

Studies in children with neurodevelopmental disorders often examine inhibition as a unitary construct, but more experimentally oriented studies suggest that it is an umbrella term. Although there are different views among researchers regarding the subtypes of inhibition, most agree that resistance to interference should be distinguished from prepotent response inhibition (Friedman & Miyake 2004; Wilson & Kipp 1998). Inhibition of a prepotent response refers to the active suppression of materials in working memory. To guide performance, for example on a language task, working memory is utilized to formulate plans

and retain the goals and intentions of different actions (Barkley 1997). Therefore, when there is a delay in response, the contents of working memory need to be protected from both external interfering stimuli and from internal intruding memory representations. Resistance to distractor interference protects the contents of working memory from being distorted or disrupted by external interfering stimuli (Friedman & Miyake 2004). Resistance to proactive interference protects the contents of working memory from internal stimuli, such as traces of information from previous actions and memory intrusions from previously relevant material. These components of inhibition show differences in their developmental trajectories. The ability to inhibit a prepotent response develops earlier than resistance to interference. While response inhibition develops rapidly during the preschool years, interference control continues to develop through around sixth grade (Bjorklund & Harnishfeger 1990). Other developmental data on complex executive functions show that the best fitting model of problem solving involves both working memory and inhibition control in children between 2–6 years of age. In younger children, inhibition had a larger impact on problem solving than working memory, whereas in older children working memory was a stronger contributor than inhibition (Senn, Espy, & Kaufmann 2004).

It is important to note, however, that variations in working memory and in language processing are further influenced by individual abilities in attention control (Engle, Tuholski, Laughlin, & Conway 1999). Attention control, particularly sustained attention, is strongly associated with language learning and information processing because one needs to attend to speech input and to relevant information over time in order to process any linguistic material (Cowan *et al.* 2005; Engle 2002). Findings from experimental studies provide strong evidence for close links among working memory capacity, language comprehension, and attention control. Working memory plays an important role in language comprehension during acquisition because it allows children to analyze and to verify the structural properties of the language to which they are exposed. In older children and in adults, working memory is critical for processing language because linguistic units need to be related across words and syllables over time (Caplan & Waters 1999; Gathercole 2006). Individuals with higher and lower working memory capacity show similar engagement in selective visual focus, but the latter group shows difficulty in maintaining that selective focus over time. Thus, individuals with low working memory capacity show a weakness in sustained attention (Poole & Kane 2009).

### III. Executive functions in children with SLI

It has been hypothesized that the working memory difficulties (e.g., in listening span tasks) demonstrated by children with SLI are highly influenced by weaknesses in inhibition and attention control. Children with SLI failed to exhibit primacy and recency effects in linguistic span tasks (Ellis Weismer *et al.* 1999; Marton & Schwartz 2003; Marton, Schwartz, Farkas, & Katsnelson 2006). There was no difference in recall accuracy across word positions (list-initial, middle, and final items) in children with SLI, which result might reflect poor resistance to both distractor and proactive interference. Inhibiting lexical items that were the focus of previous searches was a difficult task for these children, particularly in contexts with more interfering stimuli. This may have contributed to the high number of perseverative errors seen in children with SLI across various verbal working memory tasks

(Ellis Weismer *et al.* 1999; Marton, Kelmenson, & Pinkhasova 2007; Marton & Schwartz 2003).

In a more recent study, Spaulding (2010) examined preschool-age children's resistance to distractor interference and their ability to inhibit a prepotent response. Participants included children with and without language impairment. Children with SLI performed more poorly than their peers in interference control across modalities (nonverbal auditory, linguistic, and visual). These children also had more difficulty suppressing prepotent responses. The author concluded that children with SLI show a deficit in suppressing both irrelevant and contradictory information. Given that the different inhibition sub-components mature at different times during development it was an important goal of the current study to examine response inhibition and resistance to interference in school-age children with SLI. In studying the role of executive functions in information processing in children with SLI, Im-Bolter and her colleagues (2006) also found that these children perform more poorly than their age-matched peers in inhibition, working memory, and attention control. The deficits in executive functions were related to children's language competence. Yet, it is less clear whether their attention deficit is modality-specific or general.

The findings on sustained attention in preschool-age children with SLI indicate a domain general deficit, although the outcomes on visual sustained attention are somewhat contradictory. Children with SLI performed more poorly than typically developing children in auditory sustained selective attention tasks when the attention load was high (Spaulding, Plante, & Vance 2008). Although these children's accuracy rate was lower than that of their peers, their speed of processing was comparable to that of controls. Their performance on the visual sustained attention task was also similar to that of the age-matched children. These findings are in line with the results of Noterdaeme, Amorosa, Mildemberger, Sitter, & Minow (2001). In a comparative study of executive functions in children with SLI, autism, and controls, the authors found a significant group effect in auditory sustained attention but not in visual sustained attention.

In contrast to these outcomes, Finneran, Francis, and Leonard (2009) showed that children with SLI were significantly less accurate on visual sustained attention than the control group. The children with SLI showed a greater decrement over time than the controls, but similarly to the results of Spaulding and colleagues, their reaction time data did not differ from the age-matched children. Although the participants' ages in the Spaulding and Finneran studies were similar, the tasks of visual sustained attention were different. The authors used different stimuli and procedures. These methodological differences may explain the inconsistent findings in accuracy on visual sustained attention.

The literature on executive functions in children with SLI indicates deficits in specific functions, but some of the results are inconsistent. The amount of literature is limited and there are some methodological issues in a number of studies. Numerous studies employed neuropsychological tasks that measured more than one executive function. These test results reflected global scores that were difficult to interpret. The number of participants in the SLI groups was typically small. The inclusion criteria for the SLI groups were not always clear, and were inconsistent across studies. The age ranges were often broad and there are very

few studies on specific executive functions in school-age children. Although the developmental literature on executive functions is also somewhat inconsistent, there is evidence that sustained attention and inhibition remain immature below 8 years of age (De Luca *et al.* 2003; Luciana & Nelson 1998). Although memory span continues to improve beyond this age, resistance to nonspecific interference is already mature around 8–10 years (Hale, Bronik, & Fry 1997). To overcome some of the limitations in the literature, we selected norm-referenced tasks that have been shown to target specific executive functions; we excluded participants with overlapping disorders; and we included two control groups in the present study. The overarching goal of this study was to determine in which EFs children with SLI demonstrate weaknesses. Based on previous findings in the literature, we tested the following hypotheses:

1. The working memory deficit in children with SLI is not limited to the verbal domain. These children show a general deficit in working memory that is reflected by their smaller visuo-spatial span than that of the children with typical language development.
2. Children with SLI exhibit poor performance in inhibition control, however, not in all sub-components of inhibition because inhibition control is not a unitary construct. The different sub-components, such as inhibition of a prepotent response and resistance to interference, do not develop at the same rate or at the same age therefore are not equally vulnerable. Children with SLI will perform similarly to the age-matched children in response inhibition but not in resistance to interference, as the latter skill develops later.
3. Children with SLI show difficulty in sustained attention tasks. Although the literature is inconsistent regarding the sustained attention skills of children with SLI, our previous findings suggest a weakness in this area.
4. The group differences between children with SLI and typical language development cannot be explained by a general slowness hypothesis or by an overall delay in development. Children with SLI are not slower than their peers in every executive function task and their baseline reaction time measures are comparable to those of the age-matched control group. A general developmental delay is not an adequate explanation as children with SLI perform similarly to the younger, language-matched group (showing a delay) on certain tasks, but differ from both language- and age-matched groups on others.
5. The two control groups show significant differences on most measures, indicating an age effect because there is a dynamic development in executive functions during the school years.

## IV. Methods

### Participants

Sixty-six children participated in the study, with 22 children in each of three groups: (1) children with SLI, (2) age-matched children with typical language development (TLD-A), and (3) language-matched children with typical language development (TLD-L). All

participants used English as their primary language, passed a hearing screening, and showed no symptoms of intellectual disability or other developmental disorders (e.g., Attention Deficit Disorder, Autism Spectrum Disorder). Descriptive statistics for all participants can be found in Table 1.

The first group consisted of children with SLI (age-range: 10;0–14;2 years) who had been diagnosed by a speech-language pathologist as having language impairment. Inclusion in the SLI group was dependent on the participant scoring at least 1.25 SD below the mean on at least one of the following standardized measures: the Core Language composite score of the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel, Wiig, & Secord 2003), the Expressive One-Word Picture Vocabulary Test (EOWPVT; Brownell 2000), or the Test for Reception of Grammar, Second Edition (TROG-2; Bishop 2003). Each child scored in the normal range (standard score > 85) on the Test of Nonverbal Intelligence, Third Edition (TONI-3; Brown, Sherbenon, & Johnsen 1997).

The 22 children in the second group exhibited typical language development and served as an age-matched comparison group (age-range: 8;3–14;9 years). Their scores on the CELF-4 Core Language composite, the EOWPVT, and the TROG-2 were 85 and above. Additionally, TLD-A children scored in the normal range on the TONI-3.

A group of 22 younger children (age-range: 8;0–13.5), also with typically developing language, served as a language-matched control group. These children were matched to the SLI group based on their performance on the *Recalling Sentences* subtest of the CELF-4 (+/– 3 raw scores). All children in this group scored above 85 on the CELF-4 Core Language composite, the EOWPVT, and the TROG-2. Additionally, TLD-L children scored in the normal range on the TONI-3.

### Procedures and Stimuli

As part of a larger study of the executive function abilities of children with SLI, four subtests of the Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition Ltd 2006) and a basic computerized nonverbal vigilance task were administered. Parental permission for participation was obtained in writing from parents/guardians; participants also gave their assent and were told they could opt out at any time. Five tasks were presented on a high-resolution touch-screen monitor under computer control and took approximately 45 minutes to complete. Scoring was automatically computed by the programs. To test our specific hypotheses regarding SLI children's domain general working memory limitation and their proposed weakness in inhibition and sustained attention, the following four CANTAB subtests were administered: Spatial Span task (SSP), Stop Signal Task (SST), Delayed Matching to Sample task (DMS), and Rapid Visual Information Processing task (RVP). The CANTAB tests have previously been described in detail (e.g., Luciana 2003; Robbins *et al.* 1994) and therefore are described here briefly.

The SSP task, modeled after the Corsi block task, examines spatial working memory by measuring participants' ability to remember the order in which visual stimuli are presented. Nine white squares on the monitor changed color in a variable sequence; participants then replicated the order in which the squares changed color. Sequence length increased

progressively from two squares to nine squares. The task included three possible sequences at each sequence length, however, once participants passed a sequence at a given length, they progressed immediately to the next length. The test was terminated when participants failed to recall the order of color change on all three trials at a given sequence length. Performance was measured by recording the longest sequence recalled correctly.

The SST assesses inhibition of prepotent responses by measuring the ability to suppress a relatively automatic response in the presence of an auditory cue. Participants were instructed to press a button to indicate the direction of a visual stimulus (left-pointing or right-pointing arrow) on the computer screen, but to withhold this response upon hearing an auditory beep signal. The stop signal delay was adjusted using a staircase procedure, where correct answers increased the delay (making the task more difficult) and incorrect answers decreased the delay. Participants completed 5 blocks of 64 trials each.

The DMS task assessed participants' ability to recognize a complex visual design after a delay of 0, 4, or 12 seconds. Participants were shown a target pattern and, after the delay interval, were required to touch the matching design, given a set of four options. The simultaneous condition was used to test resistance to distractor interference. Interference was created through the use of distractors in the response set: one with the same color pattern but different shape from the target, and another with the same shape but different color pattern from the target. After 3 practice trials, participants completed 40 counterbalanced test trials: 10 simultaneous and 10 with each of the delay intervals.

The RVP task evaluates visual sustained attention by requiring the detection of target sequences in a stream of continuous numbers. Digits were presented in a pseudo-random order on a computer screen at a rate of 100/min. Participants had to detect and respond as quickly as possible via button press upon consecutive presentation of the three-digit target sequence (e.g., 3–5–7). There was an initial practice phase, followed by a three-minute experimental phase.

A task of nonverbal vigilance was utilized as a baseline reaction time measure. In this task, children were instructed to keep a start button pressed down and release it when a central fixation point appeared. Then, after a random interval (between 1–3 seconds), a circular target was displayed on either the left or right side of the monitor. Participants were required to press a selection button on the side corresponding to the displayed stimulus as fast as they could upon seeing the target. The task included ten trials.

## V. Results

One-way ANOVA was employed to study the group differences and post-hoc analyses were used to explain any main effects found in the ANOVA. TONI scores were used as a covariate (ANCOVA) in order to control for the group differences in nonverbal IQ. The existing group differences remained after using ANCOVA so those additional results are not reported here. To better understand the developmental trajectories of executive functions and the contribution of language status, regression analyses were performed including SLI and control groups (without group distinction within TLD because age was examined as a

factor in the analysis). The dependent variables for all tasks were accuracy and latency/ reaction time (RT). Effect sizes are reported for main effects. The results section is organized by each hypothesis, but the effect of age (i.e., hypothesis 5) is described under each hypothesis.

**Hypothesis 1**—The SSP task examined visuo-spatial WM skills. The ANOVA showed a main effect for group on span length (Table 2), with the age matched group showing better performance than the other two groups: TLD-A and SLI,  $t(42) = 2.48, p = .016$ , TLD-L and TLD-A,  $t(42) = -3.75, p < .001$ . The SLI and TLD-L groups performed similarly,  $t(42) = -1.27, p = .209$ . There was no difference in latency among the groups. The regression data revealed that both age and language status were significant variables predicting spatial span, however, there was no interaction between the variables (see Table 3 and Figure 1).

**Hypothesis 2**—The Stop Signal Task was used to study the inhibition of prepotent responses. The ANOVA results did not show a main effect for group in accuracy or reaction time (Table 2). The Stop Signal Reaction Time (SSRT), an estimate of the latency of the stop process determined by the difference between the go stimulus and the stop stimulus at which the participant is able to successfully inhibit their response on 50% of trials, was calculated for each participant. The ANOVA results showed a main effect for group on the SSRT measure, with children in the TLD-L group being significantly slower than participants in the TLD-A group,  $t(42) = 3.18, p = .002$ . However, no significant difference in performance was found between SLI and TLD-L groups,  $t(42) = 1.67, p = .1$ , or between SLI and TLD-A groups,  $t(42) = -1.51, p = .135$ . The results from the regression analysis confirmed the effect of age as a significant predictor of SSRT but not language status. There was no interaction between the variables (see Table 3 and Figure 1).

Resistance to interference was measured with the DMS task. All accuracy data were near ceiling for the simultaneous condition. For the delayed condition, the ANOVA showed a main effect for group in accuracy (Table 2), with significant differences between TLD-L and SLI,  $t(42) = -2.05, p = .045$ , and between TLD-L and-TLD-A,  $t(42) = -3.24, p = .002$ . Performance of the SLI group was comparable to that of TLD-A children,  $t(42) = 1.19, p = .239$ . The latency results did not show any significant differences among groups in the delayed condition, but there was a main effect of group on latency for the simultaneous condition. The results from post-hoc analyses showed an effect of language status based on differences between SLI and TLD-A,  $t(42) = -3.29, p = .002$ , and between SLI and TLD-L,  $t(42) = -2.16, p = .034$ . Performance of the younger TLD-L group was similar to the older TLD-A group, showing no effect of age,  $t(42) = 1.13, p = .262$ . This simultaneous condition reflected a distractor interference context. Children with SLI showed slower processing than both the age matched and younger, language-matched children. The results from the regression analysis confirmed the ANOVA results: language status was a significant predictor of latency performance in the simultaneous condition. Moreover, there was a significant age by language status interaction, showing different developmental changes over time between TLD and SLI groups. The latency difference between children with SLI and TLD was larger at the earlier stage of development, but got smaller with increasing age (see Table 3 and Figure 1).



**Hypothesis 3**—Sustained attention was assessed by the RVP task. The ANOVA results showed a main effect for group in overall accuracy (i.e., total hits) approaching significance. Post-hoc analyses revealed a difference between the TLD-A and TLD-L groups,  $t(42) = -2.41, p = .019$ , but there was no difference between the SLI and TLD-L groups,  $t(42) = -.87, p = .388$ , and between the SLI and TLD-A groups,  $t(42) = 1.54, p = .128$ . Similarly, there was a main effect for group in the number of total correct rejections, with a significant difference between TLD-A and TLD-L children,  $t(42) = -3.73, p < .001$ . The SLI group also performed less accurately than the TLD-A group in correct rejections,  $t(42) = 2.98, p = .004$ , but there was no significant difference between the SLI and the TLD-L groups,  $t(42) = -0.74, p = .459$ . Analysis of the false alarm data did not reveal any significant difference among groups. The results from the regression analysis corroborated the findings of the ANOVA by showing an age effect in the number of total hits. Furthermore, there was an interaction between language status and age. The difference in performance between the groups of children with SLI and TLD decreased with increasing age (see Table 3 and Figure 1).

**Hypothesis 4**—The ANOVA for the baseline nonverbal vigilance task showed a main effect for group in response time (Table 2). Post-hoc analysis was performed to examine differences among the three groups: TLD-L and SLI groups,  $t(42) = 3.09, p = .003$ , and between TLD-L and TLD-A children,  $t(42) = 3.19, p = .002$ . This analysis reflected an age effect, with the younger TLD-L children showing increased RTs in comparison to the TLD-A and SLI groups. There was no difference in performance between the SLI and TLD-A groups,  $t(42) = -0.10, p = .921$ . Based on this finding, the children with SLI did not show slowness compared to their age-matched peers.

## VI. Discussion

The goal of the present study was to examine performance on specific executive functions that have been associated with language processing in the literature in children with SLI (e.g., Im-Bolter *et al.* 2006; Mazuka *et al.* 2009). Our central hypothesis was that children with SLI show weaknesses in executive functions and that their overall performance pattern differs from both age-matched and language-matched controls. To test our specific hypotheses, we used four tasks from the CANTAB cognitive test battery (Spatial Span, Stop Signal, Delayed Matching to Sample, and Rapid Information Processing) and a baseline non-verbal vigilance task that was developed in our laboratory. We selected the CANTAB tasks for our study because they provide a reliable measure of executive functions across age groups (Luciana 2003).

First, we proposed that the working memory deficit in children with SLI is not limited to the verbal domain. The literature shows some contradictory findings regarding this question. In the current study, we hypothesized that children with SLI would perform more poorly than the older, age-matched children with TLD on a spatial working memory task. This hypothesis was supported by the findings of the current study, which showed smaller spatial span in children with SLI compared to age-matched controls. The spatial span of the children with SLI was similar to that of the younger language-matched group. This latter group also differed from the age-matched controls. The age effect in working memory span

is well documented in the literature (e.g., Luciana 2003; Myerson, Emery, White, & Hale 2003). Although the children with SLI differed in their spatial span from the age-matched group, their speed of processing was similar. The children with SLI did not perform more slowly than the other two groups of typically developing children in spatial working memory. These findings of smaller spatial span are consistent with our previous accuracy data on visuo-spatial working memory in children with SLI (Marton 2008) and with the outcomes of Bavin and colleagues (2005). These authors also reported that children with SLI were not slower but were less accurate in recalling visuo-spatial patterns than typically developing children.

In addition to differences in working memory, we expected to observe weaknesses in certain aspects of inhibition and attention control in children with SLI. We did not propose a general deficit in inhibition control because inhibition is a multi-component construct and its sub-components show different developmental patterns. We expected that children with SLI would perform similarly to their peers on earlier developing components, such as inhibition of a prepotent response, but that they would show more difficulty on tasks involving interference control. This hypothesis was based on several earlier findings. Our previous results showed that children with SLI are more easily distracted by interfering items than their peers (Marton *et al.* 2007). These children produced many perseverative errors in various tasks, under different conditions (Marton, 2008, 2009; Marton *et al.* 2007). Furthermore, resistance to interference develops later than response inhibition in typically developing children (Ridderinkhof, Band, & Logan 1999). These age-related changes in sensitivity to interference have a great impact on performance in various cognitive tasks including working memory and language processing (Bjorklund & Harnishfeger 1990; Dempster & Corkill 1999).

The results of the present study supported our hypotheses. Children with SLI performed more poorly than the typically developing participants in some, but not all, inhibition tasks. The results on the Stop Signal task indicated no difference between the SLI and age-matched groups in response inhibition. Thus, the children with SLI were not slower than their peers. The results revealed only an age effect that was expected based on the literature. In contrast to response inhibition, resistance to distractor interference (simultaneous condition in the DMS task) showed differences across groups. Children with SLI performed more slowly than both the age-matched controls and the younger, language-matched participants. Although the task was not too demanding on interference control because the younger typically developing children performed as well as the older ones, the children with SLI clearly exhibited difficulties. Their speed of processing was much slower than that of the children in both control groups. The results of the regression analysis revealed that this deficit in children with SLI was more prominent in younger children, with a smaller difference in performance between the children with SLI and the controls at an older age. Further research is needed to better understand the nature of the deficit of resisting interference in children with SLI. More specific experimental manipulations in well-designed tasks may show us the conditions and contexts that have the largest effect on these children's sensitivity to interference.

The visual sustained attention data (RVP task) were somewhat mixed, depending on the outcome measure we examined. The results from the number of hits only showed an age-effect. The children with SLI performed similarly to the age-matched controls but the younger children performed less accurately than the older ones. A different pattern emerged for the number of correct rejections. In this aspect, the children with SLI differed from the age-matched controls and performed similarly to the younger typically developing participants. The false alarm measures did not differ across groups. The results of the task suggest that the children with SLI were attending to the stimuli but had difficulty deciding whether the stimulus was relevant or not. The use of different measures in studies of visual sustained attention in preschool children has similarly revealed different results. Finneran and colleagues (2009) reported problems in visual sustained attention in children with SLI, particularly over time, whereas Spaulding and her colleagues (2008) found between-group differences in auditory sustained attention but no group differences in sustained attention in the visual modality. Results from a meta-analysis study (Ebert & Kohnert 2011) indicate that children with SLI show a weakness in sustained attention across modalities (auditory, visual) and domains (verbal, non-verbal). This study reported many limitations, however. The authors showed that the tasks varied in both their demands and outcome measures and participants' selection criteria were not consistent across the different research projects. These findings indicate the need for more systematic research in the area of sustained attention in children with SLI, particularly because sustained attention plays an important role in language processing (Cowan *et al.* 2005).

The overall latency results of the children with SLI across tasks do not support the general slowness hypothesis (Miller *et al.* 2001). Most latency measures showed no difference between the children with SLI and their age-matched peers. The children with SLI did not show slower responses in the Spatial Span task, Stop Signal task, delayed condition in the Delayed Matching to Sample task and in the baseline vigilance task. The latency differences in these tasks indicated an age effect, with the younger, language-matched participants often performing more slowly than the older children. This is an expected outcome. It was only in the interference condition of the Delayed Matching to Sample task that children with SLI showed more difficulties than both control groups, and this was reflected in their slower speed of processing. Based on this finding, interference control seems to be a vulnerable area for children with SLI and this result is consistent with previous data (e.g., Spaulding 2010).

Overall, when we examine performance across EF tasks in children with SLI, we may conclude that they show a profile that is distinct from that of typically developing children. On certain executive function tasks, school-age children with SLI perform similarly to their age-matched peers (e.g., response inhibition, visual vigilance). In other executive functions, they show a delay and perform similarly to younger typically developing participants (e.g., spatial span length, correct rejection in visual sustained attention). In resistance to interference, the results showed differences between the children with SLI and both control groups. Thus, the children with SLI showed a distinct performance pattern from the typically developing children regardless of their age. The differences in executive function profiles were further supported by the results of the regression analyses: children with SLI showed a

delay in spatial span, an age appropriate performance in response inhibition, and there was an interaction between age and language status in interference control and in visual sustained attention. As mentioned earlier, this interaction shows that the difference in performance between the SLI and the control groups is larger in younger children than in older ones (see Figure 1).

A limitation of the study is that the children with SLI did not form a homogeneous group with regards to their language performance. Although all children in the SLI group met the inclusion criteria, some children showed better performance on certain language tasks than others. This is a recurring problem in the SLI literature, especially in studies with older children.

Our findings fill a gap in the literature regarding specific executive functions in school-age children with SLI. The findings suggest that children with SLI show some strengths and weaknesses in executive functions and that their performance profiles differ from that of the typically developing controls.

To describe these performance profiles more specifically, we need to perform studies that include experimental manipulations of task demands and contexts. The mixed data on the visual sustained attention task also suggest that it is important to examine performance using a variety of outcome measures. We propose that future studies move beyond accuracy and RT data and include other measures in their analyses, such as performance monitoring, strategy use, and error adjustments. More specific data on the association between executive functions and language processing will have significant clinical and educational implications. If we better understand the contexts and conditions under which children with SLI show the most difficulty, we can develop more efficient assessment and intervention tools. More precise data from a clinical population, such as children with SLI, may also help to develop better models of executive functions, particularly with regard to the role that executive functions play in language processing.

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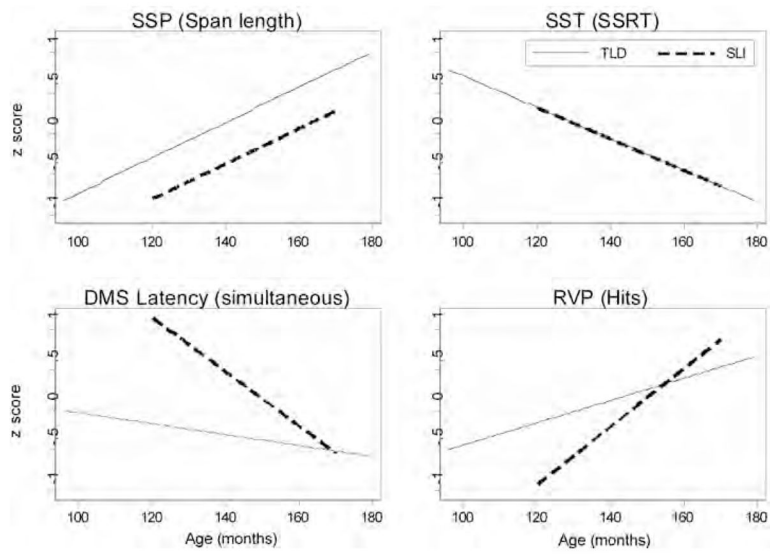
## References

- Anderson MC. Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language*. 2003; 49(4):415–445.
- Barkley RA. Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*. 1997; 121(1):65–94. [PubMed: 9000892]
- Barrouillet P, Bernardin S, Camos V. Time constraints and resource sharing executive function profiles in children *71 in adults’ working memory spans*. *Journal of Experimental Psychology: General*. 2004; 133(1):83–100. [PubMed: 14979753]
- Bavin EL, Wilson PH, Maruff P, Sleeman F. Spatio-visual memory of children with specific language impairment: Evidence for generalized processing problems. *International Journal of Language & Communication Disorders*. 2005; 40(3):319–332. [PubMed: 16195191]

- Bishop, DVM. Test for Reception of Grammar - Version 2 (TROG-2). San Antonio, TX: The Psychological Corporation; 2003.
- Bjorklund DF, Harnishfeger KK. The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review*. 1990; 10(1):48–71.
- Brown, L.; Sherbenon, R.; Johnsen, SK. Test of nonverbal intelligence. Third edition (TONI-3). Austin, TX: ProEd; 1997.
- Brownell, R. Expressive One-Word Picture Vocabulary Test (eopvt). Novato, CA: Academic Therapy Publications; 2000.
- Cambridge Cognition LTD. Cambridge Neuropsychological Test Automated Battery (CANTAB). Cambridge: Cambridge Cognition Ltd; 2006.
- Caplan D, Waters GS. Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*. 1999; 22(1):77–94. [PubMed: 11301522]
- Cowan N, Elliott EM, Scott Saults J, Morey CC, Mattox S, Hismjatullina A, Conway ARA. On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*. 2005; 51(1):42–100. [PubMed: 16039935]
- De Luca CR, Wood SJ, Anderson V, Buchanan JA, Proffitt TM, Mahony K, Pantelis C. Normative data from the cantab. I: Development of executive function over the lifespan. *Journal of Clinical and Experimental Neuropsychology*. 2003; 25(2):242–254. [PubMed: 12754681]
- Dempster FN, Corkill AJ. Interference and inhibition in cognition and behavior: Unifying themes for educational psychology. *Educational Psychology Review*. 1999; 11(1):1–88.
- Ebert KD, Kohnert K. Sustained attention in children with primary language impairment: A meta-analysis. *Journal of Speech, Language, and Hearing Research*. 2011; 54(5):1372–1384.
- Ellis Weismer S, Evans J, Hesketh LJ. An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech Language and Hearing Research*. 1999; 42(5):1249–1260.
- Engle RW. Working memory capacity as executive attention. *Current Directions in Psychological Science*. 2002; 11(1):19–23.
- Engle, RW.; Kane, MJ.; Tuholski, SW. Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex. In: Miyake, A.; Shaw, P., editors. *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*. London: Cambridge University Press; 1999. p. 102-134.
- Engle RW, Tuholski SW, Laughlin JE, Conway ARA. Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*. 1999; 128(3):309–331. [PubMed: 10513398]
- Finneran DA, Francis AL, Leonard LB. Sustained attention in children with specific language impairment (SLI). *Journal of Speech, Language, and Hearing Research*. 2009; 52(4):915–929.
- Friedman NP, Miyake A. The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General*. 2004; 133(1):101. [PubMed: 14979754]
- Gathercole SE. Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics*. 2006; 27(04):513–543.
- Hale S, Bronik MD, Fry AF. Verbal and spatial working memory in school-age children: Developmental differences in susceptibility to interference. *Developmental Psychology*. 1997; 33(2):364–371. [PubMed: 9147843]
- Hasher, L.; Zacks, RT. Working memory, comprehension, and aging: A review and a new view. In: Bower, GH., editor. *The Psychology of Learning and Motivation*. Vol. 22. New York: Academic Press; 1988. p. 193-225.
- Im-Bolter N, Johnson J, Pascual-Leone J. Processing limitations in children with specific language impairment: The role of executive function. *Child Development*. 2006; 77(6):1822–1841. [PubMed: 17107463]
- Luciana M. Practitioner review: Computerized assessment of neuropsychological function in children: Clinical and research applications of the Cambridge neuropsychological testing automated battery (CANTAB). *Journal of Child Psychology and Psychiatry*. 2003; 44(5):649–663. [PubMed: 12831110]

- Luciana M, Nelson CA. The functional emergence of prefrontally-guided working memory systems in four-to eight-year-old children. *Neuropsychologia*. 1998; 36(3):273–293. [PubMed: 9622192]
- Marton K. Visuo-spatial processing and executive functions in children with specific language impairment. *International Journal of Language & Communication Disorders*. 2008; 43(2):181–200. [PubMed: 17852522]
- Marton K. Imitation of body postures and hand movements in children with specific language impairment. *Journal of Experimental Child Psychology*. 2009; 102(1):1–13. [PubMed: 18823904]
- Marton K, Kelmenson L, Pinkhasova M. Inhibition control and working memory capacity in children with SLI. *Psychologia*. 2007; 50(2):110–121. [PubMed: 18545677]
- Marton K, Schwartz RG. Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*. 2003; 46(5):1138–1153.
- Marton K, Schwartz RG, Farkas L, Katsnelson V. Effect of sentence length and complexity on working memory performance in Hungarian children with specific language impairment (SLI): A cross-linguistic comparison. *International Journal of Language & Communication Disorders*. 2006; 41(6):653–673. [PubMed: 17079221]
- Mazuka R, Jincho N, Oishi H. Development of executive control and language processing. *Language and Linguistics Compass*. 2009; 3(1):59–89.
- Miller CA, Kail R, Leonard LB, Tomblin JB. Speed of processing in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*. 2001; 44(2):416–433.
- Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The Unity and Diversity of Executive Functions and Their Contributions to Complex, “Frontal Lobe” Tasks: a Latent Variable Analysis. *Cognitive Psychology*. 2000; 41(1):49–100. [PubMed: 10945922]
- Montgomery JW. Verbal working memory and sentence comprehension in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*. 2000; 43(2):293–308.
- Montgomery JW, Leonard LB. Real-time inflectional processing by children with specific language impairment: Effects of phonetic substance. *Journal of Speech, Language, and Hearing Research*. 1998; 41(6):1432–1443.
- Myerson J, Emery L, White DA, Hale S. Effects of age, domain, and processing demands on memory span: Evidence for differential decline. *Aging, Neuropsychology, and Cognition*. 2003; 10(1):20–27.
- Noterdaeme M, Amorosa H, Mildenerger K, Sitter S, Minow F. Evaluation of attention problems in children with autism and children with a specific language disorder. *European Child & Adolescent Psychiatry*. 2001; 10(1):58–66. [PubMed: 11315537]
- Poole BJ, Kane MJ. Working-memory capacity predicts the executive control of visual search among distractors: The influences of sustained and selective attention. *The Quarterly Journal of Experimental Psychology*. 2009; 62(7):1430–1454. [PubMed: 19123118]
- Ridderinkhof KR, Band GPH, Logan GD. A study of adaptive behavior: effects of age and irrelevant information on the ability to inhibit one’s actions. *Acta Psychologica*. 1999; 101(2–3):315–337.
- Robbins TW, James M, Owen A, Sahakian B, McInnes L, Rabbitt P. Cambridge neuropsychological test automated battery (CANTAB): A factor analytic study of a large sample of normal elderly volunteers. *Dementia and Geriatric Cognitive Disorders*. 1994; 5(5):266–281.
- Semel, E.; Wiig, EH.; Secord, WA. *Clinical Evaluation of Language Fundamentals*. 4. San Antonio, TX: The Psychological Corporation; 2003. (CELF-4)
- Senn TE, Espy KA, Kaufmann PM. Using path analysis to understand executive function organization in preschool children. *Developmental Neuropsychology*. 2004; 26(1):445–464. [PubMed: 15276904]
- Spaulding TJ. Investigating mechanisms of suppression in preschool children with specific language impairment. *Journal of Speech, Language, and Hearing Research*. 2010; 53(3):725–738.
- Spaulding TJ, Plante E, Vance R. Sustained selective attention skills of preschool children with specific language impairment: Evidence for separate attentional capacities. *Journal of Speech, Language, and Hearing Research*. 2008; 51(1):16–34.
- Stuss DT. Biological and psychological development of executive functions. *Brain and Cognition*. 1992; 20(1):8–23. [PubMed: 1389124]

- Tomblin JB, Records NL, Buckwalter P, Zhang X, Smith E, O'Brien M. Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research*. 1997; 40(6):1245–1260.
- Towse JN, Hitch GJ, Hutton U. A reevaluation of working memory capacity in children. *Journal of Memory and Language*. 1998; 39(2):195–217.
- Wilson SP, Kipp K. The development of efficient inhibition: Evidence from directedforgetting tasks. *Developmental Review*. 1998; 18(1):86–123.



**Fig. 1.** Effect of age and language status on participants' performance.



**Tab. 1**

## Participants Profile.

	<b>SLI (n=22)</b>	<b>TLD-L (n=22)</b>	<b>TLD-A (n=22)</b>
	<b>Mean (SD)</b>	<b>Mean (SD)</b>	<b>Mean (SD)</b>
Male/Female	13/9	11/11	7/15
Age in months	147 (15.6)	150 (22.9)	117 (18.7)
TONI-3 Nonverbal IQ	101.3 (14.8)	111 (17.2)	103.7 (9.9)
CELF-4 Core Language Standard Score	81.6 (13.8)	119.4 (9.5)	99.4 (11.2)
CELF-4 Recalling Sentences Raw Score	57.1 (13.2)	83.2 (4.6)	60.4 (8.9)
EOWPVT Standard Score	88.3 (13.7)	107.5 (14.8)	102.8 (9.8)
TROG Standard Score	88.3 (12.1)	106.2 (7.2)	96.5 (10.7)

Note. TONI: Test of Nonverbal Intelligence, Third Edition (Brown, Sherbenon, & Johnsen 1997). CELF: Clinical Evaluation of Language Fundamentals, Fourth Edition (Semel, Wiig, & Secord 2003).

EOWPVT: Expressive One-Word Picture Vocabulary Test (EOWPVT; Brownell 2000).

TROG: Test for Reception of Grammar, Second Edition (TROG-2; Bishop 2003).

**Tab. 2**

Analysis of Variance results and effect sizes by group (main effects). See text for post-hoc analyses.

Dependent variable	<i>F</i>	DF(group, error)	<i>p</i>	$\omega^2$
Baseline speed				
Reaction Time	6.57	2, 63	.003**	.144
Stop Signal Task (SST)				
Accuracy	.469	2, 63	.628	.015
Reaction Time	2.42	2, 63	.098	.071
SSRT <sup>a</sup>	5.07	2, 63	.009**	.109
Rapid Visual Information Processing (RVP)				
Accuracy (hits)	2.98	2, 63	.058	.057
Accuracy (correct rejections)	7.78	2, 63	.001**	.170
False alarms	1.74	2, 63	.184	.022
Spatial Span task (SSP)				
Span length	7.28	2, 63	.001**	.16
Latency	.62	2, 63	.541	-.012
Delayed Matching to Sample (DMS)				
Simultaneous condition				
Accuracy <sup>b</sup>	-	-, -	-	-
Latency	5.60	2, 63	.006**	.122
Delayed condition				
Accuracy	5.36	2, 63	.007**	.117
Latency	1.28	2, 63	.285	.008

Note. *N* = 66. SSRT = Stop Signal Reaction Time (see text for a description).

\*  
*p* < .05,

\*\*  
*p* < .01,

\*\*\*  
*p* < .001.

<sup>a</sup>See text for description.

<sup>b</sup>Results not reported because of ceiling effect; all participants in the SLI and TLD-A groups scored 100% correct.

**Tab. 3**

Summary of multiple regression analyses for variables predicting performance on CANTAB tasks.

Variables	SSP (Span length)			SST (SSRT)			DMS (Latency on simultaneous condition)			RVP (Hits)		
	B	SEB	$\beta$	B	SEB	$\beta$	B	SEB	$\beta$	B	SEB	$\beta$
(Intercept)	0.096	0.12	.	-0.028	0.11	.	-0.29	0.09	.	0.093	0.13	.
TONI-3	-0.006	0.02	-0.05	0.008	0.02	0.06	0.008	0.02	0.07	0.008	0.02	0.06
Age	0.022**	0.01	0.57	-0.019**	0.01	-0.47	-0.007	0.01	-0.18	0.014*	0.01	0.34
SLI	-0.504*	0.22	-0.26				0.83**	0.29	0.44	-0.355	0.23	-0.17
Age $\times$ SLI							-0.027*	0.01	-0.27	0.022*	0.01	0.21
$R^2$	0.29			0.20			0.20			0.21		
F	8.32**			7.65**			3.40*			6.37**		

Note.

N = 66.

\*  $p < .05$ ,

\*\*  $p < .01$ .