JSLHR

Research Article

Word Retrieval Difficulties and Cognitive Control in Specific Language Impairment

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Purpose: The study aims to test whether children with specific language impairment (SLI) show weaknesses in word retrieval and cognitive control and to find out whether impairments in the 2 domains are associated.
Method: Thirty-one children with SLI (age: *M* = 8;11 years; months, *SD* = 1;1) and 31 age- and IQ-matched typically developing children completed 2 word retrieval tasks and 3 cognitive control tasks. Word retrieval was assessed with a fluency task and a rapid automatized naming (RAN) task, whereas cognitive control was measured with a backward digit span, an *n*-back task, and a Stroop task.
Results: We found weaker performance in the SLI group than in the typically developing group in all the fluency conditions and in the size–color–shape RAN as well as on the backward digit span and *n*-back tasks. Performance on the letter fluency task was associated with backward digit span, whereas size–color–shape RAN performance was associated with backward digit span and *n*-back scores. Testing the relative contribution of the 3 cognitive control tasks together with verbal short-term memory span and vocabulary size showed that performance on both word retrieval tasks was best explained by nonword repetition and backward digit span measures.
Conclusions: These results suggest that both word retrieval and cognitive control are impaired in SLI and weaker cognitive control may contribute to word retrieval problems, although weaker short-term memory also has a crucial contribution to word retrieval difficulties during these tasks. If further research confirms this association with cognitive control, training of this ability should be included in the therapy of at least some children with SLI.

Children with specific language impairment (SLI) show various language problems that cannot be accounted for by impairments in other cognitive domains or perceptual deficits, neurological disorders, emotional or social problems, environmental deprivation, or intellectual disability. Usually, morphosyntactic and syntactic problems are emphasized (e.g., Bishop, 1997; Leonard, 1998/2014), but lexical impairments are reported as well. The potential first sign of SLI is if the child starts to produce words later than typically developing (TD) peers (although not all children with a delay in word production will have SLI). The vocabulary size of children with SLI lags behind age-based expectations at older ages too (Bishop, 1997; Trauner, Wulfeck, Tallal, & Hesselink, 1995; Watkins, Kelly, Harbers, & Hollis, 1995). The retrieval of already known words is also often impaired: Children with SLI make more errors in picture naming tasks than TD children (Kail & Leonard, 1986; McGregor & Leonard, 1995), and they have longer naming latencies (Anderson, 1965; Ceci, 1983; Kail & Leonard, 1986; Katz, Curtiss, & Tallal, 1992; Lahey & Edwards, 1996; Leonard, Nippold, Kail, & Hale, 1983; Miller, Kail, Leonard, & Tomblin, 2001; Wiig, Semel, & Nystrom, 1982; Windsor & Hwang, 1999).

In contrast to early studies investigating the source of problems in SLI emphasizing a language-specific impairment, more recent theories assume that various nonlinguistic cognitive functions are also impaired in SLI and language problems can be (partly) accounted for by these nonlinguistic deficits. Some theories proposed a deficit in processing stimuli with certain features, such as rapidly changing auditory stimuli (Tallal, 1976; Tallal & Piercy, 1973; Tallal, Stark, & Mellits, 1985) or less salient morphemes (Leonard, 1989). A general processing capacity limitation (Leonard, 1998/2014) or general slowing of processing (Conti-Ramsden, 2003; Conti-Ramsden & Jones, 1997; Marchman & Bates, 1994; Windfuhr, Faragher, & Conti-Ramsden, 2002) was also assumed, together with the impairment of working memory

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Editor-in-Chief: Sean Redmond
Editor: Geralyn Timler

Received December 4, 2017
Revision received April 16, 2018
Accepted November 4, 2018
https://doi.org/10.1044/2018_JSLHR-L-17-0446

Disclosure: *The authors have declared that no competing interests existed at the time of publication.*

(WM; Gathercole & Baddeley, 1990) or procedural learning (Ullman & Pierpont, 2005).

In the last couple of years, cognitive control/executive functions (EF) also became the focus of research in SLI, with controversial results so far (e.g., Henry, Messer, & Nash, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Lukács, Ladányi, Fazekas, & Kemény, 2016; Marton, Campanelli, Eichorn, Scheuer, & Yoon, 2014; Marton, Kelmenson, & Pinkhasova, 2007; Marton, Schwartz, Farkas, & Katsnelson, 2006). Motivated by these controversial findings, the current study investigates cognitive control in children with SLI further, exploring whether cognitive control impairments contribute to word retrieval problems in children with SLI. In what follows, first, the concept of cognitive control will be introduced. After that, we will describe the role of cognitive control in word retrieval, and studies investigating cognitive control and word retrieval under conflict in children with SLI will be reviewed. At the end of the introduction, the aims of the current study will be presented.

The Concept of Cognitive Control

Cognitive control is responsible for the resolution of conflict or interference between contradicting representations by inhibiting irrelevant and enhancing relevant representations (Miller & Cohen, 2001; Novick, Trueswell, & Thompson-Schill, 2005, 2010). Similar functions have also been referred to as *executive functions*, which are defined as a set of top-down mental processes recruited when we have to concentrate or pay attention and when responding automatically or relying on instinct or intuition would be ill-advised, insufficient, or impossible (Diamond, 2013). The influential EF model of Miyake, Friedman, Emerson, Witzki, and Howerter (2000) assumes that there are three separable components within EF: shifting, updating, and inhibition. Some researchers use these terms (i.e., cognitive control and EF) interchangeably, whereas others differentiate between them. Throughout the article, we follow Novick et al.'s view (e.g., Hussey et al., 2017) in this respect who consider cognitive control as a construct similar to inhibition in Miyake's model defined as a process responsible for the inhibition of dominant, automatic, or prepotent responses when necessary. Hussey et al. (2017) decided against simply using inhibition to refer to this process because, as they argue, they aim to be neutral about whether cognitive control involves inhibition of task-irrelevant representations or promotion of task-relevant ones or a combination of both processes.

Although research on the role of cognitive control in various language processes is continuously growing, it is still not clear which tasks are the most appropriate to measure cognitive control. One of the difficulties is to find a paradigm that investigates cognitive control without the involvement of linguistic skills. Stimuli in most of the cognitive control tasks in the literature—and in our study as well—are letters, numbers, or words, which all require language processing. Even when nonverbal stimuli are used, it is difficult to prevent verbalization. For instance, in the flanker task stimuli are arrows pointing to different directions, and participants are asked to press the arrow on the keyboard based on the direction of the arrow presented on the screen. Although arrows are nonverbal stimuli, directions can be verbalized (i.e., "left," "right"), and that way, the task will involve verbal processes. Using cognitive control tasks with verbal stimuli does not allow firm conclusions about the relationship of cognitive control and language processing in general; it can only inform us about the role of cognitive control resolving conflict between verbal stimuli. However, studying cognitive control in various linguistic contexts also yields essential contributions to the field by offering insight into whether the same cognitive control process is responsible for conflict resolution between letters, numbers, and words. Future research should clarify whether the same process is responsible for conflict resolution between nonverbal stimuli.

Several widely used cognitive control tasks—including some of those used in our study—also face another problem: They involve a WM load, which makes it difficult to tease apart relative contributions of cognitive control and WM and to find out whether impairment in one or another (or both) leads to a weaker performance on the task. At the same time, these associations definitely show the involvement of higher level functions in the given language processes, and future research should disentangle the exact functions playing a role in word retrieval.

The Role of Cognitive Control in Word Retrieval Problems in SLI

Despite the conceptual and methodological controversies in the area, several works suggested that cognitive control is important for word retrieval—among other language processes. In the course of retrieving a word, several semantically or phonologically similar word representations are activated beyond the target word. Conflict appears when the activation of these competing representations is as high or higher than the activation of the target word, and cognitive control is assumed to play a role in the resolution of such conflict (Kan & Thompson-Schill, 2004; Schnur, Schwartz, Brecher, & Hodgson, 2006; Schnur et al., 2009). In our everyday life, conflict during word retrieval can be manifested in the form of word finding difficulties, the tip of the tongue phenomenon, or simply in longer retrieval times (when the target word's activation is similar to those of the competing words) and slips of the tongue (when one of the competing words' activation is higher than that of the target word). Although these word finding difficulties typically appear in sentences, experimental paradigms often investigate the question with word production tasks instead of studying sentence production because it is easier to manipulate the variables and collect RTs (reaction times) with using only words. The most common tasks investigating conflict resolution during word retrieval are picture naming tasks with the manipulation of the level of conflict in the different conditions (see, e.g., Kan & Thompson-Schill, 2004;

Novick, Kan, Trueswell, & Thompson-Schill, 2009; Schnur et al., 2006, 2009).

A growing body of evidence shows that children with SLI have difficulties in tasks that require conflict resolution in both the verbal and nonverbal domains (backward digit span: Lum, Conti-Ramsden, Page, & Ullman, 2012; Vugs, Hendriks, Cuperus, & Verhoeven, 2014; listening span: Archibald & Gathercole, 2006; Ellis Weismer, Evans, & Hesketh, 1999; Mainela-Arnold & Evans, 2005; Marton et al., 2007, 2006; Montgomery & Evans, 2009; Vugs et al., 2014; odd-one-out: Vugs et al., 2014; *n*-back: Evans & Pollak, 2011; Im-Bolter et al., 2006; category judgment under conflict: Marton et al., 2014). As cognitive control plays a role in word retrieval under conflict, word retrieval problems of children with SLI might be partly accounted for by cognitive control impairments. Research targeting this question is, however, very limited.

As far as we know, our previous picture naming study is the only one testing effects of lexical conflict manipulation in children with SLI (Ladányi & Lukács, 2016), which found that they were generally slower in naming pictures but as efficient in resolving conflict during word retrieval as TD children. In the current study, we aimed to investigate word retrieval under conflict further in children with SLI and TD children using a fluency task and a rapid automatized naming (RAN) task. The few results available on research using these tasks in children with SLI are summarized below.

Several studies found an impairment on various fluency measures in children with SLI, and some of them assume that the impairment of cognitive control or EF has a role in these problems. During fluency tasks, participants are asked to produce as many words as they can without any repetitions according to different criteria (e.g., words starting with a certain letter in letter fluency tasks or words belonging to a certain category in category fluency tasks). Fluency tasks are widely used in neuropsychological batteries for assessing verbal functions and EF, although the exact underlying processes required by the task are not clear (Shao, Janse, Visser, & Meyer, 2014). Cognitive control is potentially necessary for the successful execution of the task for overcoming conflict generated by irrelevant words, previously produced words, and to-be-produced words.

Henry et al. (2012) found that 8- to 14-year-old children with SLI produced fewer words in category and letter fluency tasks than their TD peers. In a following study (Henry, Messer, & Nash, 2015), the authors reported a more detailed analysis on the fluency performance of the participants of Henry et al. (2012): Children with SLI produced fewer words, more errors, and fewer switches than TD children in both letter and category fluency. The authors also investigated relationships with EF and found an association between the number of errors in letter fluency and inhibition. Acosta Rodríguez, Ramirez Santana, and Hernández Expósito (2017) also found that 5- to 11-year-old children with SLI produced fewer words in both letter and category fluency tasks than TD children. Similarly, Weckerly, Wulfeck, and Reilly (2001) showed that children with SLI were able to produce fewer words in both category and letter fluency tasks than their TD peers. Both Acosta Rodríguez et al. and Weckerly et al. assumed that lower fluency in the SLI group relative to the TD group is a marker of less efficient EF in children with SLI.

Studies reporting similar performance on fluency tasks in children with SLI and in TD children are also present in the literature. Kail and Leonard (1986) conducted a category fluency task in 6- to 14-year-old children with SLI and did not find a group difference in the number of words retrieved, relative to neither an age- nor a language-matched control group. Weyandt and Willis (1994) made the same observation investigating category fluency in 6- to 12-year-old children. Fluency was also investigated in one of our previous studies (Lukács et al., 2016) in a group of 6- to 9-year-old children with SLI and age- and IQ-matched TD children.[1] We observed significantly weaker scores when we combined category, letter, and action fluency, but further analysis revealed that the group difference can be accounted for by lower short-term memory (STM) in the SLI group.

As suggested above, RAN tasks may also involve cognitive control. During the task, several stimuli are presented on the screen and participants are asked to name them from left to right, row by row, from the first item of the first row. Stimuli are usually letters, digits, objects, or colors. The RAN task is argued to measure different abilities by different studies (e.g., phonological skills, lexical access, naming ability, expressive language, WM, processing speed; Aguilar-Mediavilla, Buil-Legaz, Pérez-Castelló, Rigo-Carratalà, & Adrover-Roig, 2014; Decker, Roberts, & Englund, 2013), and it might require cognitive control as well. As Bexkens, van den Wildenberg, and Tijms (2015) argue, during an RAN task, previously named stimuli compete for selection with the current target stimulus and these competing inappropriate word representations have to be inhibited for the successful naming of the target item. Cognitive control might be required for the resolution of conflict between competing representations and the target word.

The few RAN results from children with SLI come from studies investigating RAN in children with dyslexia, also including children with SLI. In what follows, we only summarize results from these studies for children with SLI but without dyslexia.

De Groot, Van den Bos, Van der Meulen, and Minnaert (2015) found slower naming times in both letters and digits RAN in 8- to 13-year-old children with SLI than in age-matched TD controls, with a bigger effect in the case of the letters RAN. Similarly, in Claessen, Leitão, Kane, and Williams (2013), 6- to 8-year-old children with SLI showed significantly slower naming times than TD children in an objects RAN task. Katz et al. (1992) also found that children with SLI were significantly slower than

[1]Participants in Lukács et al. (2016) partly overlap with participants of the current study (with a higher age range in this study than in the previous one).

age-matched TD children on an objects RAN in a longitudinal study at all of the three data points (4, 6, and 8 years).

In contrast, Bishop, McDonald, Bird, and Hayiou-Thomas (2009) did not find a significant difference between 9- to 10-year-old children with SLI and TD children in the objects and digits RAN. Neither did Vandewalle, Boets, Ghesquière, and Zink (2012) in either of the RAN tasks (letters, colors, digits, objects) in their longitudinal study in which children were assessed in kindergarten, Grade 1, and Grade 3.

Although the letters, digits, objects, and colors RAN are the most commonly used versions of the task, there is also a variant that requires the naming of shapes together with their size and color (e.g., *big yellow square*). We assume that conflict is higher in this task than in the previously mentioned versions because three lexical units have to be retrieved for each item and each of them will have competitors: Colors, sizes, and shapes of previously named elements will compete with the color, size, and shape of the target item. Furthermore, lexical units referring to the size, color, and shape compete with each other too (e.g., if the shape or the color is activated first instead of the size, which is required to be produced first, then these word representations also generate conflict). Beyond cognitive control, this task requires sequential organization as well, which is also vulnerable in SLI (Lukács & Kemény, 2014; Ullman & Pierpont, 2005) making the size–color–shape more difficult for children with SLI RAN than the other versions of the task. We are aware of only one study (Aguilar-Mediavilla et al., 2014) using the size–color–shape RAN paradigm in 6- to 8-year-old bilingual children with SLI, finding significantly lower accuracy scores in the SLI group than in the TD group.

The Current Study

Motivated by the contradictory findings of fluency and RAN performance in SLI, our first aim in this study was to test whether children with SLI show weaker performance on the various conditions of the fluency (letter, category, and action fluency) and RAN (letters, numbers, objects, and size–color–shape RAN) tasks than TD children. Conditions differ in their cognitive control demand in the case of both tasks. As it was discussed above, size–color–shape RAN is assumed to have a higher cognitive control demand than the other conditions of the task. Furthermore, cognitive control is presumably required for the letter fluency task, whereas it has a limited role in the action and category fluency tasks. In the letter fluency task, word representations activated due to semantic similarity are often irrelevant; therefore, they have to be inhibited, whereas they are probably correct answers in the case of the category fluency task. For instance, when a participant produces *strawberry* during a fluency task, *apple, peach, and raspberry* will be also activated; these fruit names are irrelevant if the task is a letter fluency task in which words starting with "s" have to be produced, whereas they are relevant if the task is a category fluency task in which names of fruits have to be produced (see Robinson, Shallice, Bozzali, & Cipolotti, 2012).

Our second aim was to contribute to the research targeting cognitive control in children with SLI. As we mentioned in the section about the concept of cognitive control, there is no single generally accepted measure of cognitive control in the literature. Therefore, we decided to use three relatively different tasks (the Stroop task, the *n*-back task, and the backward digit span task) that require cognitive control to get a more general picture of our participants' cognitive control abilities. Beyond their common cognitive control requirement, these tasks differ in several respects, which might also lead to differences in their sensitivity to cognitive control (Hsu, Jaeggi, & Novick, 2017). During the Stroop task, which is probably the most frequently used cognitive control task, conflict appears between the color activated by the word presented on the screen and the color of the letters and it has to be resolved for the appropriate answer. The *n*-back and backward digit span tasks are often used as WM tasks (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Ellis Weismer et al., 2017), but several studies suggest that performance on these tasks depends on the ability to resolve conflict between competing representations (e.g., Jaeggi, Buschkuehl, Perrig, & Meier, 2010; May, Hasher, & Kane, 1999). Because we wanted to include cognitive control measures that are more complex than the Stroop task and potentially differentiate better between individuals with variable cognitive control abilities, we decided to include these two paradigms as WM loaded cognitive control tasks despite the complexity and controversies about their underlying constructs. Following this view, we aim to interpret our results taking these tasks to yield measures of cognitive control. At the same time, we acknowledge that these tasks can be considered as WM tasks; therefore, we will also discuss shortly the consequences of the WM view in the Discussion.

Based on (a) studies finding weaker performance on fluency and RAN tasks in children with SLI than in TD children, (b) works showing weaker performance on tasks involving cognitive control in children with SLI than in TD children, and (c) studies indicating the involvement of cognitive control in word retrieval, our third aim was to investigate the role of cognitive control in word retrieval in children with SLI and TD children. More specifically, we aimed to find out whether cognitive control and word retrieval are associated in general and whether weaker cognitive control could account (at least partly) for impaired performance on the RAN and fluency tasks in children with SLI.

Both fluency and RAN tasks require several linguistic and nonlinguistic processes beyond cognitive control. STM is necessary for both paradigms and also for the cognitive control tasks; therefore, it is important to rule out the possibility that associations between the language and cognitive control tasks appear only due to their common STM requirement. Therefore, we included nonword repetition scores in the investigation of associations between performances on these tasks. Furthermore, vocabulary size arguably has a role in fluency performance, and it might affect RAN performance as well. To explore the effect of cognitive control separately from vocabulary size and the relative contribution of the different cognitive control measures to performances on the word retrieval tasks, we conducted a linear regression analysis for those word retrieval tasks that showed an association with cognitive control tasks. Beyond the cognitive control and vocabulary scores, age and STM scores were also included in this analysis.

We hypothesized that children with SLI would show weaker performance on the word retrieval tasks, and the difference would be more pronounced in the case of the letter fluency and size–color–shape RAN tasks due to their cognitive control load. Second, we assumed that children with SLI would show a weaker performance on the cognitive control tasks. Our third hypothesis was that performance on the letter fluency and size–color–shape RAN tasks will be associated with performance indices on tasks measuring the efficiency of cognitive control even if we take into account the effect of vocabulary size, STM, and age. During the letter fluency task, cognitive control is assumed to be involved in the resolution of conflict between irrelevant semantically related word representations or already-produced/to-be-produced words and the target word. In the size–color–shape RAN task, conflict between the sizes, colors, and shapes and the target size, color, and shape is hypothesized to be resolved by cognitive control.

Method

Participants

Thirty-one White Caucasian Hungarian children with SLI and 31 age-, gender-, and IQ-matched TD children (eight girls in each group) participated in the study (see age and IQ of the groups in Table 1). Children with SLI were recruited from two different schools; both are special institutions for children with speech problems. One school is in Kőszeg, a small town in Hungary, whereas the other school is in Budapest, the capital of Hungary. All of the children with SLI were receiving speech-language therapy in the school. TD children matched to children with SLI attending the school in the small town were recruited from a school in another small town—Szentes—in Hungary, and TD pairs of children attending the school in Budapest were recruited from five different schools in Budapest.

As a first step of the recruitment process, speech-language therapists selected a larger group of children in both schools who had no history of neurological impairment or psychiatric or social problems and had normal hearing. Nonverbal intelligence (Raven Coloured Progressive Matrices; Raven, Court, & Raven, 1987) and language skills were assessed in these children by the speech-language therapists. Linguistic abilities were assessed with four tests targeting both receptive and expressive skills. The receptive tests were the Hungarian adaptations of the Peabody Picture Vocabulary Test (PPVT; Csányi, 1974; Dunn & Dunn, 1981) and the Test for Reception of Grammar (Bishop, 1983; Lukács, Győri, & Rózsa, 2012). The expressive tests were the Hungarian Sentence Repetition Test (Kas & Lukács, 2011) and the Hungarian version of the nonword repetition test (Racsmány, Lukács, Németh, & Pléh, 2005). In accordance with general practice in SLI research (see, e.g., Leonard 1998/2014, Tager-Flusberg & Cooper, 1999), children who showed normal intelligence (performance scores above 85) and performed at least 1.5 *SD*s below age norms on at least two of the four tests were selected for the SLI group (see the results of screening tests in Table 1).

For the selection of the TD group, nonverbal intelligence was measured in TD children who matched in age (maximum of 3-month difference in date of birth between the TD child and the SLI pair) and gender to the members of the SLI group. Children whose IQ was similar (the difference is not greater than 10 IQ points) to the SLI pair's IQ were selected for the TD group. All children were tested with the informed consent of their parents, in accordance with the principles set out in the Declaration of Helsinki and the stipulations of the local institutional review board.

Design and Procedure

Fluency

In the fluency task, children were asked to produce as many (a) actions or things that people do (action fluency), (b) things they can buy at a supermarket (category fluency), and (c) words starting with "k" (letter fluency) as they can in 1 min for each condition with avoiding repetitions.

Table 1. Demographic data and screening results of the specific language impairment (SLI) and typically developing (TD) groups.

Measure	TD, *M* (*SD*)	TD, range	SLI, *M* (*SD*)	SLI, range	Difference
Age	107 mo (13 mo)	85–136 mo	107 mo (14 mo)	85–135 mo	$F(1, 60) = 0.008$, *ns*
IQ (Raven)	106 (9.86)	85–125	102 (9.98)	85–130	$F(1, 60) = 2.944$, *ns*
PPVT	124 (2.2)	102–146	94 (3.3)	66–132	$F(1, 60) = 42.96, p < .001$
TROG	77 (0.4)	71–80	69 (0.9)	57–78	$F(1, 60) = 65.70, p < .001$
Sentence repetition	37 (0.8)	16–40	21 (1.4)	0–36	$F(1, 60) = 94.78, p < .001$
Nonword repetition	6.4 (0.2)	4–8	3.4 (0.2)	0–5	$F(1, 60) = 120.24, p < .001$

Note. PPVT = Peabody Picture Vocabulary Test; TROG = Test for Reception of Grammar; mo = months.

The task was preceded by a practice session. The answers were recorded by the experimenter on paper.[2] We assessed three measures—the number of correct answers, the number of repetitions, and the number of errors—for all three subtasks, but only the number of correct answers was used in the analysis because most of the children did not produce any repetitions or errors.

RAN

Children were tested with four versions of the RAN task. The design and procedure were the same in all versions; only the stimuli differed. During the task, (a) letters, (b) digits, (c) objects, and (d) shapes in different sizes and colors were presented on the screen. Stimuli were arranged in several rows (three rows in the letters, digits, and objects task and four rows in the shapes task), and in each row, the same five items appeared in different orders. The same set of stimuli was presented three times in a row. The task was to name the items starting with the first one in the first row as fast as possible, and in the case of the shapes, children were asked to produce first the size, then the color, and, finally, the shape of the stimulus (e.g., *big yellow square*). The tasks were preceded by a short practice session. Stimuli were presented, and naming times were recorded with the E-Prime software (Schneider, Eschman, & Zuccolotto, 2012). Response accuracy was coded by the experimenter on paper. In the case of the letters, digits, and objects RAN, children could get 1 point for each correct answer, yielding a maximum score of 45 (15 for each presentation of the slide) for each type of task. In the case of the shapes task, children could get 3 points for each item (1 point for the size, 1 point for the color, and 1 point for the shape of the item); therefore, the maximum score was 180 (60 for each presentation of the slide). Correctness of the sequence of the size, color, and shape was also coded: If a child produced the words in the required order, (s)he gained 1 point; if the order was incorrect, (s)he got 0 point, meaning that the maximum score on the sequence was 60 (20 for each presentation of the slide). The sum of the naming times for the three slides was also measured, and both accuracy scores and naming times were used in the analysis as the measure of the RAN performance. The task took approximately 20 min to administer.

Stroop Task

In the Stroop task, color names (*red*, *blue*, *green*, *yellow*) were presented written in different colors (red, blue, green, yellow), and the task was to press a key (of four different keys, each representing one color) based on the color of the fonts. In the congruent condition, the meaning of the words matched the font color (*blue* written in blue), whereas in the incongruent condition, they did not match (*blue* written in red). In the control condition, a nonlinguistic string was presented in different colors (xxxx in blue). Trials belonging to the incongruent, congruent, and control conditions were presented in a blocked fashion with 60 items in each block, and the order of the blocks was randomized. At the beginning of the task, children completed a short practice session including all types of trials. We used the E-Prime software (Schneider et al., 2012) to present stimuli and to collect data. Both RTs and number of correct answers were collected, and the average RTs and the total number of correct answers were calculated for each block for each child. As a measure of cognitive control, we used the difference between average RTs given for incongruent and control trials. (We did not use accuracy scores during the analysis because children's performance did not differ in the incongruent and control conditions due to the small number of errors.) The Stroop task took approximately 10 min to administer.

***n*-Back Task**

In the *n*-back task, letters were presented on the screen and children were asked to monitor the letters and indicate (by pressing "ENTER") when the same letter appeared two trials earlier. Sixty trials were presented, out of which 10 trials were 2-back trials. Before the test trials, a short practice session was presented. Stimuli were presented, and answers were collected with the E-Prime 2.0 software (Schneider et al., 2012). We calculated the number of hits and the number of false alarms, and we used the difference between hits and false alarms (*n*-back score) in the analyses as a measure of cognitive control. Hits were the responses when the participant correctly pressed "ENTER" on a "2-back trial" (i.e., when the current item was identical to the target item, with a maximum of 10 hits), whereas in the case of false alarms, the participant pressed "ENTER" on a not "2-back trial" (i.e., the actual stimulus was not identical to the one presented two before). The task took about 5 min to administer.

Backward Digit Span

In the backward digit span task, children were presented with a set of numbers and they had to repeat the numbers in a reversed order. At the beginning, two numbers were presented, and the set size was increasing during the task. There were four sets of numbers in each level, and participants could go on to the next level if they could produce the reversed order at least two times out of the four sets. Children completed a few practice trials before the test trials. The measure of the task was the last level that the child successfully completed (span). The task took approximately 5 min to administer. Tasks were presented in a randomized order as part of a larger battery of tasks.

Data Analysis

First, we investigated the patterns of results in the language tasks. In the fluency task, performance on the letter, action, and category fluency tasks was compared

[2]We do not report transcription relaiability indices for either of the tasks requiring spoken responses because the responses were not audio-recorded (see description of the recording of responses in the Method section).

across the two groups. The number of correct answers was analyzed with a 2 × 3 repeated-measures analysis of variance (ANOVA) with group (SLI vs. TD) as a between-subjects factor and fluency type (letter vs. action vs. category) as a within-subject factor. In the four RAN tasks, group differences were investigated with two univariate ANOVAs: one with accuracy and one with naming time as the dependent variable.

Second, performance differences between the SLI and TD groups were investigated in cognitive control tasks—in the backward digit span task, the *n*-back task, and the Stroop task with univariate ANOVAs. If a group difference appeared, we repeated the analysis with including nonword repetition scores as covariates to exclude the possibility that children with SLI performed worse due to their weaker verbal STM.

Associations between the language and cognitive control measures were explored with partial correlations including age as a control variable. Because both the language tasks and the cognitive control tasks require keeping information active in STM, without controlling for differences in STM, correlations might appear due to the common STM component instead of reflecting associations with cognitive control. To avoid this confound, nonword repetition scores (available for all children due to the screening process) were also included as a control variable to control for the effect of STM.

As it was mentioned before, vocabulary size can have an effect on the performances on the word retrieval tasks. For investigating the relative contribution of vocabulary size scores and cognitive control to word retrieval performances, a linear regression analysis was conducted on the whole group for those word retrieval measures that showed a correlation with at least one of the cognitive control measures even after controlling for age and STM. Age and STM were also included as independent variables beyond vocabulary size and the three cognitive control measures. Therefore, five independent variables were included in each of the linear regressions: *n*-back score, backward digit span, Stroop effect, vocabulary score, and age. Correlation and regression analyses were conducted separately in the SLI and TD groups and also on the whole group of children because we assume that cognitive control is involved in word retrieval in general.

Some children did not complete all of the tasks, and scores for the size–color–shape RAN task were not available for each child due to an experimenter error. When data were missing for a child for a specific task, we also excluded the score of his or her match (in age, gender, and IQ) in the other group on the same task. That way, we had the following number of data points per measure: RAN letters RT: 52, RAN letters accuracy: 52, RAN numbers RT: 60, RAN numbers accuracy: 58, RAN pictures RT: 60, RAN pictures accuracy: 58, RAN size–color–shape RT: 56, RAN size–color–shape accuracy: 52, RAN size–color–shape sequence: 52, action/letter/category fluency: 58, backward digit span: 58, *n*-back: 60, and Stroop: 60. Because we excluded both the score of the child with SLI and his or her TD pair if either of them had a missing value for the current task, we do not think that missing data significantly influence the results. We have a relatively high number of data points even in tasks with the highest numbers of missing data (letter and size–color–shape RAN); therefore, it is not likely that missing data would eliminate significant results.

Results

Fluency Tasks

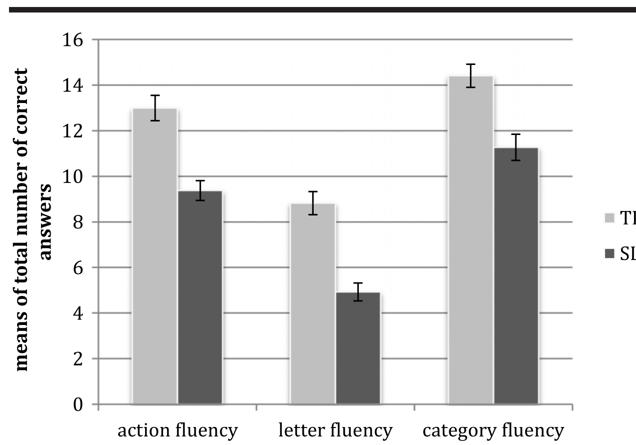
The 2 × 3 ANOVA showed the main effect of fluency type as a within-subject factor, $F(1, 56) = 61.845$, $p < .001$, $\eta_p^2 = .525$, and group as a between-subjects factor, $F(1, 56) = 19.189$, $p < .001$, $\eta_p^2 = .920$, reflecting the significantly better performance in the TD group than in the SLI group. The interaction between fluency type and group was not significant, $F(1, 56) = 0.213$, *ns*, $\eta_p^2 = .004$.

We investigated further the main effect of fluency type with paired-samples *t* tests. Results showed a significantly better performance in category fluency than in letter fluency, $t(57) = 10.438$, $p < .001$, Cohen's $d = 1.39$, and in action fluency, $t(57) = 3.188$, $p = .002$, Cohen's $d = 0.37$. In addition, a significantly better performance appeared in action fluency than in letter fluency, $t(57) = 7.721$, $p < .001$, Cohen's $d = 1.032$ (see Figure 1).

RAN Tasks

Accuracy of the SLI and TD groups did not differ significantly in the RAN task when children had to name letters, digits, or objects (letters: $F(1, 51) = 0.058$, *ns*, $\eta_p^2 = .001$; digits: $F(1, 57) = 1.224$, *ns*, $\eta_p^2 = .21$; objects: $F(1, 57) = 1.545$, *ns*, $\eta_p^2 = .027$). Naming times were also similar in the two groups (letters: $F(1, 51) = 0.357$, *ns*, $\eta_p^2 = .007$; digits: $F(1, 59) = 0.683$, *ns*, $\eta_p^2 = .12$; objects: $F(1, 59) = 1.500$, *ns*, $\eta_p^2 = .025$). Children with SLI were significantly slower in

Figure 1. Means of total number of correct answers in the action, letter, and category fluency tasks in the TD and SLI groups. TD = typically developing; SLI = specific language impairment.



naming shapes together with their size and color, $F(1, 55) = 41.449$, $p < .001$, $\eta_p^2 = .434$. Accuracy on size–color–shape names, $F(1, 51) = 0.268$, *ns*, $\eta_p^2 = .005$, and on their sequence, $F(1, 51) = 2.907$, *ns*, $\eta_p^2 = .055$, did not show a significant group difference, and it was, in fact, close to ceiling in both groups (see Figure 2).

Cognitive Control Tasks

The SLI group had shorter backward digit span than the TD group, $F(1, 57) = 12.323$, $p = .001$, $\eta_p^2 = .180$, and their performance was lower on the *n*-back task as well, $F(1, 59) = 9.804$, $p = .003$, $\eta_p^2 = .145$. These differences were significant even after adding nonword repetition scores as covariates (backward digit span: $F(2, 57) = 7.124$, $p = .002$, $\eta_p^2 = .206$; *n*-back: $F(2, 59) = 7.591$, $p = .001$, $\eta_p^2 = .210$). The size of the Stroop effect did not differ between the two groups, $F(1, 59) = 3.371$, *ns*, $\eta_p^2 = .055$ (see Figure 3).

Associations Between Tasks

Correlations were conducted both in the whole group of children and in the SLI and TD groups separately to test whether the patterns of correlations differ in the two groups. Because almost all of the correlations disappeared when tested in the two groups separately, we only report the results of the analysis performed on the two groups collapsed. We conducted correlation analyses only with the results of those word retrieval tasks (and with those measures) in which children with SLI showed a weaker performance, as our main aim was the investigation of the source of difficulties of children with SLI in word retrieval.

The partial correlation analysis with age as a control variable showed a significant correlation between letter fluency and backward digit span, $r(53) = .464$, $p < .001$, as well as between letter fluency and *n*-back performance, $r(53) = .307$, $p = .023$. A significant correlation appeared between action fluency and backward digit span, $r(53) = .283$, $p = .036$, as well as between action fluency and the Stroop effect, $r(53) = .322$, $p = .017$. Category fluency scores did not correlate with any of the cognitive control measures. After controlling for individual differences in nonword repetition span, the statistically significant correlation between letter fluency and *n*-back disappeared, $r(52) = .108$, *ns*, whereas the correlation between the letter fluency and the backward digit span decreased but remained significant, $r(52) = .316$, $p = .020$. The correlation between action fluency and backward digit span disappeared, $r(52) = .133$, *ns*, but action fluency and the Stroop effect still showed a significant and, in fact, stronger correlation, $r(52) = .503$, $p < .001$.

Total naming times for the size–color–shape RAN task showed a significant correlation with backward digit span, $r(49) = -.571$, $p < .001$, and with *n*-back scores, $r(51) = -.481$, $p < .001$. After including nonword repetition scores as control variables, both correlations were reduced but still significant (backward digit span: $r(48) = -.436$, $p = .002$; *n*-back scores: $r(50) = -.301$, $p = .030$[3]; see the summary of significant correlations in Table 2).

To investigate the contribution of cognitive control to word retrieval and separate it from the effect of age, STM, and vocabulary size, we conducted stepwise multiple linear regressions. Regressions were run only for those measures that showed a significant correlation with at least one cognitive control task even after controlling for age and vocabulary size, namely, the size–color–shape RAN and letter fluency tasks. The dependent variable was the performance on the word retrieval task, whereas the independent variables were the results on cognitive control tasks (Stroop task, backward digit span, *n*-back), on the nonword repetition tasks, and on the PPVT and age.

In the case of the letter fluency task, the regression showed that nonword repetition and backward digit span scores explained 37.5% of the performance and Stroop scores, *n*-back scores, PPVT scores, and age were excluded by the analysis, $R^2 = .366$, $F(1, 51) = 20.405$, $p < .001$, $\beta_{\text{nonword repetition}} = .404$, $\beta_{\text{backward digit span}} = .307$.

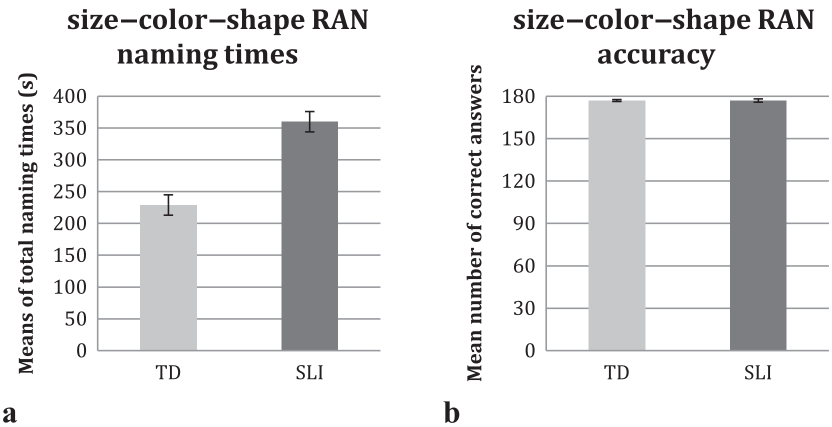
In the case of the size–color–shape RAN task, the regression showed that the best model is the one combining vocabulary, nonword repetition, and backward digit span scores, which explained 60% of the variance, and Stroop scores, *n*-back scores, and age were excluded by the analysis, $R^2 = .601$, $F(3, 47) = 22.126$, $p < .001$, $\beta_{\text{vocabulary}} = .347$, $\beta_{\text{backward digit span}} = .324$, $\beta_{\text{non-word repetition}} = .290$.

Discussion

The main aim of our study was to investigate whether the impairment of cognitive control—the ability responsible for the inhibition of irrelevant and enhancement of relevant representations—contributes to difficulties with word retrieval under conflict in children with SLI. To explore the question, we assessed word retrieval using the fluency task and the RAN task—which both require conflict resolution—together with cognitive control tasks in children with SLI and age- and IQ-matched TD children. We compared performance on the word retrieval and cognitive control tasks in the two groups and investigated associations between these performance measures. We found weaker word retrieval performance in the SLI group than in TD peers on the fluency tasks and on the size–color–shape RAN task and deficits on two cognitive control tasks: the backward digit span task and the *n*-back task. Weaker performance on the letter fluency task was associated with shorter backward digit span, and longer naming times in the size–color–shape RAN task were associated with shorter backward digit span and lower *n*-back scores.

[3]Because 12 correlations were tested in both correlation analyses, the chance of finding false positives is relatively high, motivating corrections for multiple comparisons, which however would increase the chance of finding false negatives. Because there is no general practice in the literature about correction for multiple comparisons in the case of correlations, we decided to report significant values based on both the original and corrected alpha level in Table 2, but results will be discussed only based on the original alpha level.

Figure 2. Means of total naming times (a) and means of correct answers (b) in the size–color–shape RAN task in the TD and SLI groups. RAN = rapid automatized naming; TD = typically developing; SLI = specific language impairment.



Individual performance differences on both word retrieval tasks were best accounted for by a model including nonword repetition and backward digit spans; in the case of the size–color–shape RAN, vocabulary size also had an important effect. Taken together, our results suggest that cognitive control, at least when measured with working-memory loaded tasks, is impaired in children with SLI. This impairment is associated with more word retrieval

Figure 3. Performance on the (a) backward digit span task, (b) *n*-back task, and (c) the Stroop task in TD children and children with SLI. TD = typically developing; SLI = specific language impairment.

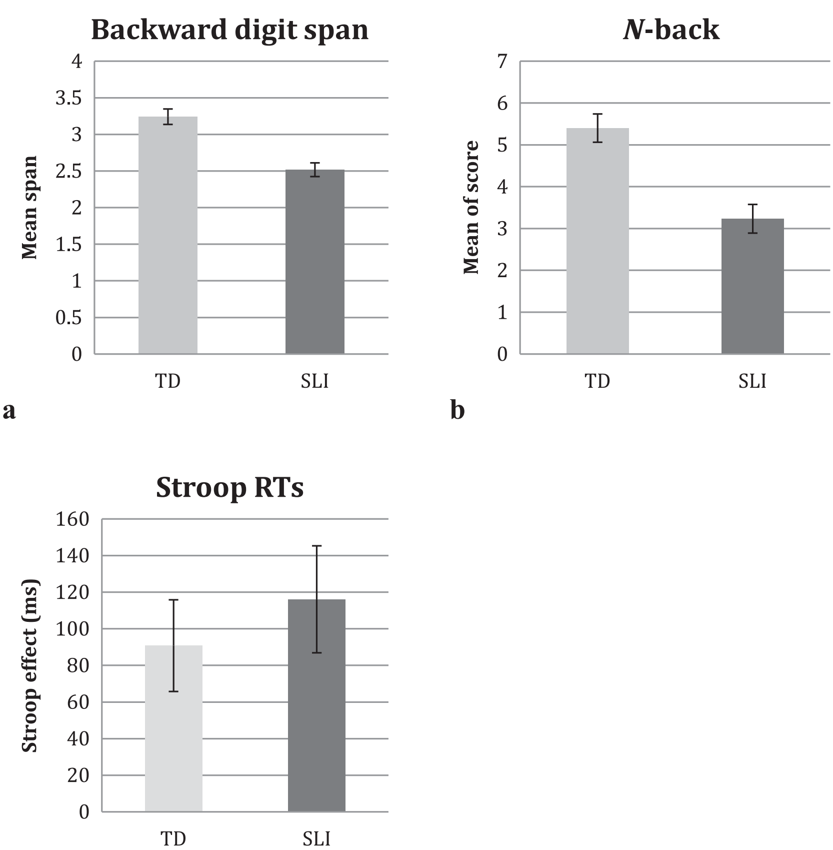


Table 2. Summary of significant correlations between word retrieval tasks and cognitive control tasks.

Correlated measures	Correlations with age as a control variable	Correlations with age and nonword repetition as a control variable
Letter fluency and backward digit span	$r(53) = .464$, $p < .001$*	$r(52) = .316$ $p = .020$
Letter fluency and *n*-back	$r(53) = .307$, $p = .023$	$r(52) = .108$, *ns*
Action fluency and backward digit span	$r(53) = .283$, $p = .036$	$r(52) = .133$, *ns*
Action fluency and Stroop effect	$r(53) = .322$, $p = .017$	$r(52) = .503$ $p < .001$*
Size–color–shape RAN and backward digit span	$r(49) = -.571$, $p < .001$*	$r(48) = -.436$ $p = .002$*
Size–color–shape RAN and *n*-back	$r(51) = -.481$, $p < .001$*	$r(50) = -.301$ $p = .030$

Note. Correlations marked with an asterisk (*) were significant also based on the corrected alpha level ($p = .004$). RAN = rapid automatized naming.

problems in RAN and fluency tasks, although impaired STM and lower vocabulary also have a strong effect.

As predicted by our first hypothesis, children with SLI show weaker performance on the fluency task and on one of the conditions of the RAN task than their TD peers. The SLI group was significantly less fluent on all three conditions of the fluency task and on the size–color–shape version of the RAN task mirrored by longer naming times. On the digits, letters, and objects RAN task, SLI performance was comparable to that of the TD group. This latter result is in accordance with earlier studies finding no group differences between children with SLI and TD children in the case of the digits, letters, and objects RAN task (Bishop et al., 2009; Vandewalle et al., 2012). One explanation for the difficulties of children with SLI with the size–color–shape RAN task is that cognitive control is required for the production of three words for one item but is not when only one word has to be produced in the other versions of the task. Furthermore, the three words have to be produced in a certain order, which requires sequencing skills—and cognitive control is probably necessary for that too (see more details below). To test this hypothesis, associations between the size–color–shape RAN and cognitive control tasks were investigated. Note that factors outside cognitive control (e.g., vocabulary size, syntactic abilities, WM) might also play a role in performance on this RAN version, together with or without cognitive control. From among these potential factors, the effect of vocabulary size was explored together with the effect of cognitive control in the current study, which we discuss below.

According to our second hypothesis, cognitive control is weaker in children with SLI than in TD children. Results partly supported our hypothesis: The SLI group showed a weaker performance on the backward digit span task and on the *n*-back task but not on the Stroop task. A possible explanation for the lack of group difference in the Stroop task is that the SLI group was affected by the conflicting information originating from the meaning of the word to a smaller degree than TD children because of poor reading skills. In other words, even if children with SLI have weaker cognitive control, the Stroop effect would not be increased because their reading is less automatic than their TD peers (although this explanation is contradicted by findings from dyslexia showing bigger Stroop effects associated with poor reading skills; Faccioli, Peru, Rubini, & Tassinari, 2008). Our study did not target reading skills; therefore, the question needs further investigation.

After finding weaker performance both on word retrieval tasks and on cognitive control tasks in children with SLI than in TD children, we explored relationships between these impairments. We hypothesized that weaker performance on word retrieval tasks will be associated with weaker cognitive control measures. First, we will discuss our findings related to the three conditions of fluency task, followed by the discussion of the results connecting to the size–color–shape RAN task—the only RAN task in which children with SLI performed weaker than their TD peers.

In the case of the fluency task, we assumed that cognitive control is involved in letter fluency in the resolution of conflict originating from the activation of irrelevant semantically related words, already-produced words, and to-be-produced words. Results supported our hypothesis, because among the three fluency conditions, only letter fluency was associated with digit span and *n*-back; no other fluency measures showed a relation with any of the cognitive control tasks in a meaningful way. Although letter fluency scores were associated with both backward digit span and *n*-back performance, the latter association disappeared when the potential confound of verbal STM was eliminated by controlling for differences in STM capacity suggesting that the relationship between letter fluency and *n*-back performances appeared only because both tasks require STM. The association between the letter fluency and backward digit span performance was weaker after controlling for differences in STM, but it was still present suggesting the involvement of cognitive control—beyond STM—in the letter fluency task.

In the RAN task, cognitive control may be recruited for the resolution of conflict originating from the activation of already-produced word representations. Conflict was assumed to be higher in the case of the size–color–shape RAN task because shapes are semantically closer to each other than objects, numbers, or letters. Furthermore, the three words that have to be produced for one item can also increase conflict if one of the two others is activated instead of the one that should be produced (e.g., the color is activated first when the size has to be produced). The result that children with SLI did not show weaker performance than their TD peers in the case of the letters, digits, and objects RAN task but a deficit was observed on the size–color–shape task support the hypothesis that cognitive control impairment leads to impaired word retrieval performance under conflict in children with SLI. Associations appearing both with the backward digit span and with the *n*-back performance confirm this assumption. After excluding the effect of STM, the associations were still present, but they were weaker showing that STM is required for the size–color–shape RAN task on the one hand and corroborate the conclusion that cognitive control is involved in word retrieval under conflict on the other hand.

Stroop performance was not strongly associated with any of the word retrieval measures. The lack of associations between the Stroop task and the letter fluency or size–color–shape RAN task is especially surprising because these tasks showed correlations with the other two cognitive control tasks. This result suggests that cognitive control required by the Stroop and word retrieval tasks is different. Another explanation could be that, in the Stroop task, cognitive control is confounded with reading skills. If a child's reading is slower and less automatic, then activation of the meaning of the color word might be weaker, which leads to a smaller level of conflict. That way, the Stroop effect will be small even if the child's cognitive control is weak. The question should be investigated further with using cognitive control tasks that do not require reading.

An association appeared in the unexpected direction between the Stroop task and action fluency scores: Higher action fluency scores were associated with greater Stroop effects. This result suggests that weaker cognitive control led to higher action fluency scores. Although this result is in contrast with our predictions, one could argue that strong cognitive control can have a negative effect on fluency performance when cognitive control requirements of the task are low. If most of the activated word representations are relevant, but they are inhibited because they are not the current target words, then it will take more time to retrieve these word representations when the participant wants to produce them. With weaker cognitive control, inhibition is not that efficient, and it takes less time to retrieve the words later, which leads to better fluency performance. It is not clear, however, if that is the case, why the same positive correlation was not observed between the Stroop effect and category fluency where cognitive control demand is also low according to neuropsychological results and the lack of correlations with the *n*-back and backward digit span tasks in our study. The potential negative consequences of effective cognitive control on fluency performance and on word retrieval in general is another area that would be important to investigate further.

The investigation of relative contribution of cognitive control, STM, vocabulary, and age to word retrieval under conflict showed that the model including the backward digit span and the nonword repetition scores explains the performance on the letter fluency task the best. In the case of the size–color–shape RAN, vocabulary size also had an effect beyond backward digit span and nonword repetition. The importance of STM for these tasks indicated by the presence of nonword repetition in the models is not surprising. Vocabulary scores might appear in the model of the RAN performance because children with higher vocabulary have a more organized lexicon with more efficient retrieval strategies, which might lead to more efficient (faster) retrieval of names during the RAN task. The presence of backward digit span in both the model for fluency and size–color–shape RAN tasks supports our hypothesis that cognitive control contributes to word retrieval under conflict. A significant difference between the backward digit span task and the other two cognitive control tasks is that the backward digit span has a stronger STM demand. Therefore, the result that this measure was included in the model suggests that the ability to apply cognitive control when the STM load is high is especially important for word retrieval under conflict. Furthermore, we can infer from these results that weaknesses in STM, lexical processes, and cognitive control in children with SLI contribute to their problems in word retrieval under conflict.

If further studies support the contribution of cognitive control in language problems of children with SLI, then it would be advisable to include the training of cognitive control in the therapy of these children. For an efficient therapy, it would be important to rely on cognitive control paradigms that are useful in improving everyday language skills (i.e., which have a transfer effect). Currently, research on the topic is very limited (but see, e.g., Hussey et al.'s (2017) training study with adults). There are more studies investigating the effect of WM training on language performance, but most of these studies did not find a transfer effect; even in those studies that did, it lasted only for a short period (see reviews of WM training in Gillam, Holbrook, Mecham, & Weller, 2018, Singer & Bashir, 2018). These first results suggest that extensive research on the topic is necessary to develop an appropriate way of cognitive control training in children with language impairment.

Limitations

As we mentioned in the introduction, several studies (e.g., Alloway et al., 2009; Ellis Weismer et al., 2017) suggest that the *n*-back and backward digit span tasks yield measures of WM without a significant involvement of conflict resolution.

Based on this view, only the Stroop task would be the measure of cognitive control in our study. If we interpret our results within the WM view, we would be led to conclude that WM is impaired in children with SLI but cognitive control is not, as shown by significant group differences in the case of the *n*-back and backward digit span tasks and the lack of group difference in the case of the Stroop task. Furthermore, findings of significant correlations of the word retrieval tasks with the *n*-back and backward digit span tasks and the lack of such correlations with the Stroop task would suggest that WM plays an important role in word retrieval but cognitive control does not.

Although we agree that the *n*-back and backward digit span tasks may not directly target conflict resolution, on our assumption, they do involve conflict resolution (conflicting sequential order in the case of backward digit span and potential distractors in the *n*-back task), and therefore weaker performance on the *n*-back and backward digit span tasks also reflects weaker cognitive control. Following this argumentation, we interpreted our data based on the assumption that these tasks are also cognitive control tasks. The fact that it is not clear whether our cognitive control tasks are sensitive to cognitive control or WM is a limitation, and although it is difficult, further studies should use tasks and conditions that are able to differentiate between these constructs.

Conclusions

In summary, our results are in accordance with the hypothesis that cognitive control is involved in the resolution of conflict between irrelevant word representations and the target word during word retrieval. They also support the view that cognitive control is impaired in children with SLI and this impairment contributes to word retrieval difficulties.

Nonetheless, several questions remained unanswered that need further investigation. First, we did not address the question whether cognitive control involved in word retrieval is a domain-general process or is specific to linguistic stimuli. Future studies should test cognitive control with nonlinguistic stimuli together with language performance to answer this question. The lack of associations between the Stroop task and the word retrieval tasks should be explored with using a modified Stroop task that does not require reading skills. Furthermore, motivated by the positive relationship between the size of the Stroop effect and performance on the action fluency task, the negative role of strong cognitive control on word retrieval has to be investigated directly. Although, overall, our results support the hypothesis that cognitive control is impaired in SLI and word retrieval problems can be partly accounted for by this impairment, some of our results—for example, the lack of group differences in the Stroop task, the lack of associations between word retrieval and the Stroop tasks, and the finding that some associations between word retrieval and cognitive control disappeared after including STM scores in the analysis—argue against it. There is no consensus about the issue in the literature either: Beyond results showing a cognitive control impairment in SLI, there are several studies suggesting that cognitive control is intact in SLI—including two of our previous studies (Ladányi & Lukács, 2016; Lukács et al., 2016). Contradictory results in the current study and in Lukács et al. (2016) are especially surprising because participants in the two studies partly overlapped and some of the tasks were used in both studies; therefore, there was an overlap also between the scores included in the analyses. This pattern of findings suggests that cognitive control might be impaired in some children with SLI, and it might contribute to their language problems, but it does not seem to be a general impairment and a leading cause of SLI. Based on these and earlier findings, we assume that word retrieval difficulties appear due to the co-occurrence of the impairment of several linguistic and nonlinguistic abilities in SLI. STM is one of these factors, and weaker cognitive control might also have a role in word retrieval problems in some children with SLI. Despite these controversies, the results show that cognitive control impairment might contribute to lexical impairments in (at least some) children with SLI, suggesting that training targeting cognitive control might be helpful in improving lexical skills in SLI.

Acknowledgment

This research was supported by Research Grant OTKA K 83619 from the Hungarian National Science Foundation (to Á. L., principal investigator).

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