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Executive functioning in children with specific language impairment

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Background: A limited range of evidence suggests that children with specific language impairment (SLI) have difficulties with higher order thinking and reasoning skills (executive functioning, EF). This study involved a comprehensive investigation of EF in this population taking into account the contributions of age, nonverbal IQ and verbal ability. **Methods:** Ten separate measures of EF were assessed in 160 children: 41 had SLI; 31 had low language/cognitive functioning but did not fulfil the criteria for SLI (low language functioning or LLF); and 88 were typically developing with no language difficulties. Group differences in performance were assessed after controlling for age, nonverbal IQ and verbal ability in a series of regression analyses. **Results:** Children with SLI and LLF had significantly lower performance than typical children on 6 of the 10 EF tasks once age and nonverbal IQ had been controlled (verbal and nonverbal executive-loaded working memory, verbal and nonverbal fluency, nonverbal inhibition and nonverbal planning). Performance on these EF tasks remained lower for those in the SLI group even when verbal IQ was entered in the regressions. **Conclusions:** Children with language impairments showed marked difficulties on a range of EF tasks. These difficulties were present even when adjustments were made for their verbal abilities. **Keywords:** Specific language impairment, executive functioning, children, verbal IQ, nonverbal IQ.

Introduction

There is increasing evidence that distinct profiles of executive functioning (EF) impairment are characteristic of different developmental disorders (e.g. autism/Attention Deficit Hyperactivity Disorder (ADHD); Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Hill, 2004; Ozonoff & Jensen, 1999). Such research provided the context for the current study of children with specific language impairment (SLI).

EF involves high-level goal-directed behaviour, encompassing strategic planning, flexibility of thought and action (switching), inhibition of inappropriate responses, generation of new responses (fluency) and concurrent remembering and processing (working memory). In other words, *processes that control and regulate thought and action* (Friedman et al., 2006, p. 172). There is good evidence for the 'fractionation' of EF in adults and children, into working memory, switching and inhibition, although some uncertainties remain (Fisk & Sharp, 2004; Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). Executive skills have different developmental trajectories: inhibition matures relatively early (10–12 years); whereas switching and working memory continue to develop into adolescence/adulthood (Huizinga et al., 2006; Levin et al., 1991; Welsh, Pennington, & Groisser, 1991).

SLI is a developmental disorder involving delayed language in the absence of any obvious cause. Individuals with SLI have nonverbal IQs in the average range, but there is increasing evidence that they have difficulties with nonlinguistic tasks including mental rotation, number skills and motor skills (Bishop, 2002; Cowan, Donlon, Newton, & Lloyd, 2005; Johnston & Ellis Weismer, 1983). The fact that SLI may not be entirely limited to language difficulties is reflected in current theorising, with two broad approaches in the literature. One is that there is a delay/deficit specific to the language domain, particularly grammar, in which case EF may be unaffected in SLI or difficulties restricted to EF tasks in the verbal domain (Gopnik & Crago, 1991; van der Lely, 2005; Rice & Wexler, 1996). The other approach is that SLI involves more general processing deficits (in working memory/processing speed, Leonard et al., 2007; or procedural memory, Ullman & Pierpont, 2005), in which case SLI groups might show poor EF on a range of tasks, regardless of domain of processing.

The current study provided a comprehensive evaluation of EF in children with SLI, as evidence on this topic is limited and sometimes contradictory. For example, *inhibition* appears to be impaired (Bishop & Norbury, 2005b; Im-Bolter, Johnson, & Pascual-Leone, 2006; Weyandt & Willis, 1994) and difficulties with *planning* using Tower tasks have been reported (Marton, 2008; Weyandt & Willis, 1994); yet, several studies have found no difficulties with *switching* (Dibbets, Bakker, & Jolles, 2006; Kiernan, Snow, Swisher, & Vance, 1997; Weyandt & Willis, 1994; but, see Marton, 2008) or *fluency* (Bishop & Norbury, 2005a; Weyandt & Willis, 1994). Nevertheless,

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weaknesses in verbal fluency have been reported in children with a related disorder, word finding difficulties (Messer, Dockrell, & Murphy, 2004). Possibly the clearest finding in this area concerns impairments on *verbal* measures of executive-loaded working memory (ELWM) in children with SLI. Sentence and listening span tasks, which draw on concurrent processing and storage skills in the verbal domain, present particular difficulties (Ellis Weismer, Evans, & Hesketh, 1999; Marton & Schwartz, 2003; Montgomery, 2002). Evidence concerning ELWM in the *nonverbal* domain is mixed. Archibald and Gathercole (2006) found no differences between children with SLI and age-matched comparisons, but Marton (2008) and Im-Bolter et al. (2006), using larger samples, reported weaker visuospatial ELWM performance in children with SLI.

The current research assessed EF in five areas using large samples to increase the sensitivity of detecting differences. A broad view of EF was taken by including measures of ELWM, inhibition and switching, key areas identified in previous studies of children/adults (Lehto et al., 2003; Miyake et al., 2000); plus measures of fluency and planning commonly used in the literature on developmental disorders (Pennington & Ozonoff, 1996). To minimise difficulties of interpretation when using complex assessments of EF, which may involve multiple executive processes (Im-Bolter et al., 2006; Miyake et al., 2000), we selected simple tests, used standardised assessments where possible and controlled for component skills if necessary to ensure that each assessment focused on *executive* and not other skills.

Each EF dimension was assessed using a verbal and a related nonverbal task. This allowed investigation of whether difficulties in the SLI group were limited to verbal EF tasks (as might be expected with a language-specific disability, van der Lely, 2005); or extended to the nonverbal domain either because of general cognitive processing problems (Ullman & Pierpont, 2005) or because of verbal mediation. In relation to the latter possibility, Russell, Jarrold, and Hood (1999) have suggested that 'verbal self-reminding', that is, using language for self-regulation, underpins EF performance. Similarly, Marcovitch and Zelazo (2009) have argued that language (labelling salient objects or cues) allows 'reflective consciousness' which assists goal-directed problem-solving.

An SLI and a typical sample were identified on the basis of commonly used criteria (see Methods). The typical group included children with *chronological* and *language* ages of a similar range to those in the SLI sample, in the spirit of a 'developmental trajectories' approach (Thomas et al., 2009) whereby comparison samples reflect the range of abilities of the target sample rather than being individually matched. In the literature, most studies compare groups with and without SLI, matching individual participants for age and nonverbal IQ. Our method increased the power to detect group differences and reduced the likelihood of unrepresentative samples (we included virtually every participant tested). During data collection some participants did not fit criteria for the SLI or typical groups, because they had limited language difficulties and in some cases below average scores on nonverbal reasoning. These participants with 'low language functioning' (LLF) were included as a separate group to maximise the representativeness of our sample. This allowed the investigation of children who did not fit established clinical criteria, but showed nontypical levels of language performance.

To examine group differences in EF, regression analyses were conducted. Age and nonverbal IQ were first controlled, before assessing group differences on each EF measure by the use of dummy variables (SLI, LLF and typical). In a second series of regression analyses, age, nonverbal and verbal IQs were controlled before examining group differences. As selection criteria meant that there were differences in verbal abilities between groups, it might be expected that controlling for verbal IQ would remove group differences in EF performance. However, if group differences remained this would indicate that poor EF performance in, for example, the SLI group, was unlikely to result from weaknesses in verbal ability and could be considered an important feature of their cognitive profile.

To summarise, based on previous research and theory we investigated whether children with SLI had poor EF abilities compared with a typical sample. If these were present, our design allowed us to investigate whether difficulties were confined to language-based EF tasks (Rice & Wexler, 1996) or extended to nonverbal EF tasks (Ullman & Pierpont, 2005). In this way, we hoped to contribute to discussions about difficulties with information processing in children with SLI. We also investigated whether low EF in the SLI group might be independent of their language difficulties by controlling for both nonverbal and verbal IQ. Finally, we assessed whether EF difficulties were present in the LLF group; it might be expected that these individuals would have less severe impairments.

Methods

Participants

A total of 161 participants were recruited from 22 schools and specialist language units/classes within Greater London and, very occasionally, via direct contact with parents/guardians. Every child tested was included in the sample ($n = 160$), except one with intellectual disabilities [British Ability Scales-II (BAS-II) T-scores of 20]. There were three groups: typical, SLI and low language functioning (LLF).

All participants in the SLI ($n = 41$) and typical ($n = 88$) groups had nonverbal abilities in the average range (T-scores of 40 or greater: $M = 50$, $SD = 10$, on BAS-II Matrices; Elliott, Smith, & McCullough, 1996).

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All children with SLI had formal diagnoses from appropriate health professionals according to standard clinical criteria (DSM-IV; American Psychiatric Association, 1994). No participants with SLI had diagnoses of hearing impairments, intellectual disability or other developmental disorders (e.g. ADHD, Autism Spectrum Disorders (ASD). Inclusion in the SLI group was dependent on the participant having at least three of four scaled scores of 7 or below (M = 10; SD = 3) on subscales from the CELF-4-UK (Clinical Evaluation of Language Fundamentals-4-UK, Semel, Wiig, & Secord, 2006) that we administered (Recalling Sentences; Formulated Sentences; Word Classes-Receptive; Word Classes-Expressive). In contrast, all participants in the typical group had scaled scores of 8 or higher on the four CELF-4-UK subscales.

Participants who did not fit criteria for inclusion in either the typical or SLI groups constituted the LLF group (n = 31); they had scaled scores of 7 or below on one or two CELF-4-UK subscales, and 9, additionally, had BAS Matrices T-scores in the atypical range ('borderline': 30–39).

Table 1 gives details of sample characteristics. Scores on each EF measure are also given, although it should be noted that the groups were not matched for age and IQ. Scores on verbal switching were highly variable, so findings related to this assessment should be treated with caution.

This project was granted ethical approval from the Research Ethics Committee, London South Bank University, and was discussed in detail with appropriate school staff before recruitment. Informed consent for participation was obtained in writing (telephone permission occasionally) from parents/guardians; children/students also gave their written consent and were told they could opt out at any time. Testing took place across 3–8 sessions, making up 3½ hr for the complete battery, usually at school but occasionally at the child's home.

EF tests

Executive-loaded working memory. These tasks required concurrent processing and storage. The verbal task was Listening Recall (Working Memory Test Battery for Children, WMTB-C, Pickering & Gathercole, 2001). The experimenter read a series of short sentences and the child judged whether each was

Table 1 Summary of means/*SD*s/ranges for descriptive/executive functioning variables: children with specific language impairment (SLI), low language functioning (LLF) and typical development

Variable/group	SLI (n = 41; 28 boys)	LLF (n = 31; 24 boys)	Typical (n = 88; 59 boys)
Age (months)	138.4 (15.9) (97–169)	126.8 (26.9) (81–165)	118.0 (28.3) (72–176)
BAS-II Matrices T-score[a]	54.6 (6.2) (46–71)	51.1 (10.9) (30–72)	57.4 (6.9) (40–78)
BAS-II verbal IQ[b]	87.8 (13.6) (55–109)	99.5 (12.9) (70–122)	110.9 (10.4) (83–143)
Recalling sentences[c]	5.2 (2.5) (1–10)	6.6 (2.8) (1–11)	10.4 (1.9) (8–15)
Formulated sentences[c]	3.8 (2.5) (1–8)	6.6 (3.0) (1–11)	10.5 (1.9) (8–14)
Word classes receptive[c]	5.2 (1.6) (1–7)	7.7 (3.1) (1–13)	10.2 (2.0) (8–15)
Word classes expressive[c]	5.7 (1.8) (1–9)	7.8 (3.0) (1–13)	10.7 (1.8) (8–15)
Language age (months)	93.3 (12.6) (72–123)	103.2 (24.4) (70–153)	123.1 (32.9) (79–191)
ELWM verbal[d]	12.00 (3.89) (2–21)	10.00 (4.00) (5–23)	14.24 (3.97) (5–27)
ELWM nonverbal[d]	8.49 (3.02) (4–15)	7.8 (3.57) (2–14)	10.30 (2.93) (4–17)
Fluency verbal[e]	10.13 (2.47) (6.4–17.8)	10.54 (3.67) (3.8–16.8)	13.16 (3.28) (6.8–22.8)
Fluency nonverbal[e]	7.50 (3.05) (3–16)	7.05 (2.92) (2.5–14)	7.89 (2.76) (2–14)
Inhibition verbal[f]	8.29 (5.89) (1–29)	6.90 (5.38) (0–22)	6.32 (4.66) (0–20)
Inhibition nonverbal[f]	24.88 (13.71) (5–60)	23.81 (11.74) (3–53)	16.05 (7.31) (5–41)
Planning verbal[g]	2.32 (0.88) (0–4)	2.58 (1.23) (0–5)	2.66 (1.20) (0–5)
Planning nonverbal[g]	4.02 (2.04) (0–8)	4.13 (2.55) (0–9)	5.23 (2.19) (0–9)
Switching verbal[h]	26.51 (32.65) (−60–108)	23.26 (36.13) (−60–112)	29.98 (31.20) (−58–132)
Switching nonverbal[f]	29.76 (12.46) (7–59)	31.26 (13.51) (11–63)	27.15 (11.39) (7–54)

BAS-II, British Ability Scales-II; ELWM, executive-loaded working memory.
[a]Standard score: M = 50, SD = 10; [b]standard score: M = 100, SD = 15; [c]standard score: M = 10, SD = 3; [d]trials correct; [e]items generated per minute; [f]number of errors; [g]correct sorts; [h]switch cost in seconds.

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true/false (processing). The child then recalled the final word from each sentence in correct serial order (storage). Trials commenced with list lengths of one item, and proceeded to longer lists, with six trials per list length, until 4/6 trials were incorrect. Total number of trials correct were scored, as this is more reliable than 'span' (Ferguson, Bowey, & Tilley, 2002). Test–retest reliabilities of .38–.83 are reported for relevant ages (Pickering & Gathercole, 2001).

The nonverbal ELWM task was the odd-one-out test (Henry, 2001). The experimenter displayed three cards depicting simple nonsense diagrams (horizontally orientated on 20 × 4 cm cards). The child pointed to the 'odd-one-out' (processing). The spatial location of each odd-one-out card was then recalled via a set of response sheets (20 × 30 cm) depicting the relevant number of 'empty' cards (storage). Trials commenced with lists of one item, and proceeded to longer lists, with three trials per list length, until 2/3 trials were incorrect. Total number of trials that were correct were scored. The span version of this task has a reliability of .80 (Henry, 2001).

Fluency. Verbal fluency (Delis-Kaplan Executive Functioning System, D-KEFS, Delis, Kaplan, & Kramer, 2001) involved two tasks, in which the child/ was asked to generate as many words as possible in 1 min according to a criterion. 'Letter fluency' used the letters F, A and S; 'category fluency' used the semantic categories of 'animals' and 'boy's names'. Verbal fluency was the average raw score from all five tasks.

Nonverbal fluency (design fluency, D-KEFS) required the use of a response booklet containing patterns of dots in boxes. The child was asked to draw as many different designs as possible in 1 min, each in a different box, by connecting dots using four straight lines (with no line drawn in isolation). Condition 1 contained only filled dots; Condition 2 contained arrays of filled and empty dots and the child connected only empty dots. Design fluency was the average raw score from these two conditions.

Test–retest reliabilities are reported as: letter (.67), category (.70), filled dots (.66) and empty dots (.43; Delis et al., 2001).

Inhibition. A new test was developed, 'Verbal Inhibition, Motor Inhibition' (VIMI) that had two types of response: to copy the experimenter; or to inhibit copying and produce an alternative response. For Part A of the *verbal task*, the experimenter said either 'doll' or 'car' and the participant was asked to copy by repeating the same word (Block 1). Next, in Block 2, the child was expected to inhibit this copying response: 'if I say doll, you say car; and if I say car, you say doll'. This was followed by a second 'copy' block and a second 'inhibit' block. Each of the four blocks consisted of 20 trials. This entire sequence of copy/inhibit blocks was repeated in Part B, with new stimuli ('bus' and 'drum').

The *nonverbal motor task* followed the same format, but words were replaced with hand actions. For Part A, the stimuli were a pointed finger versus a fist; for Part B, the stimuli were a flat horizontal hand versus a flat vertical hand.

The combined number of errors made across Parts A and B on each task was used as the measure of inhibition. Cronbach's alpha, based on total error scores from Parts A and B was .915 for the nonverbal task, and .727 for the verbal task.

Planning. The sorting test (D-KEFS) assessed verbal and nonverbal planning. Participants sorted sets of six cards into two groups of three, in as many ways as they could. There were three possible 'verbal' sorts (e.g. transport/animals; things that fly/things that move along the ground); and five possible 'perceptual' sorts (e.g. small/large; straight/curved edges). Total numbers of correct verbal/perceptual sorts were used as the measures of verbal/nonverbal planning, respectively (test–retest reliability reported as .49; Delis et al., 2001).

Switching. The trail-making test (D-KEFS) was the verbal measure. Children joined small circles containing letters and numbers alternately, in sequence (1-A-2-B-3-C through 16-P), involving cognitive flexibility on a sequencing task based on easily named verbal items. Four control conditions assessed component skills. Most relevant here were: number sequencing (connecting the numbers 1–16); and letter sequencing (connecting the letters A–P). 'Switching cost' was the total time taken for combined letter/number switching, minus the sum of the time taken for the number and letter sequencing component skills. Test–retest reliabilities for measures contributing to 'switching cost' are reported as: number sequencing (.77), letter sequencing (.57) and letter/number switching (.20; Delis et al., 2001). Reliability for switching measures can be low, given they are difference scores; consequently, somewhat lower reliabilities may be inevitable in this area (Miyake et al., 2000).

The nonverbal switching test was intra-/extradimensional shift (Cambridge Neuropsychological Test Automated Battery, Cambridge Cognition, 2006). This test of rule acquisition and reversal involves *simple* stimuli made of coloured shapes and/or white lines: *complex* stimuli involve both features. Initially, two coloured stimuli were presented on a computer screen, and by touching one, the child learned from feedback which was 'correct', and followed a rule. Later, the second dimension, an irrelevant white line (initially adjacent to the coloured shape, but then overlaying it) was introduced. The 'intradimensional shift' introduced new shape and line stimuli, yet the child still responded to the shape stimuli. The complex stimuli were later changed and the child had to switch attention to the previously irrelevant dimension to obtain 'correct' responses ('extradimensional' shift). Total error scores were used (test–retest reliability reported as .40; Cambridge Cognition, 2006).

Results

Hierarchical multiple regression analyses were carried out with each of the 10 EF measures as dependent variables (see Appendix S1 for full correlation matrix of EF measures) to assess group differences in performance. Age and nonverbal IQ (BAS-II Matrices T-score) were entered at Step 1 to control

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Table 2 Summary details of regressions predicting performance on each executive functioning (EF) measure. For each regression, two predictor variables were entered in a block at Step 1 (age, nonverbal IQ; note Step 1 of each model is not shown). Two further dummy-coded group variables were entered in a block at Step 2 (SLI-vs.-LLF group, SLI-vs.-typical group). The information provided about Step 2 of each model involves total variance accounted for (total R^2), standardised beta values for each predictor variable and change in R^2. Significant values are indicated where relevant

EF measure	Total R^2 accounted for by the model	Details of Step 2 for each regression				
		Age	β NVIQ	β SLI-vs.-LLF	β SLI-vs.-typical	ΔR^2; Step 2
ELWM verbal	.48	.54***	.31***	.05	.42***	.13***
ELWM nonverbal	.40	.44***	.32***	.05	.39***	.11***
Fluency verbal	.56	.54***	.33***	.20**	.58***	.22***
Fluency nonverbal	.41	.59***	.26***	.08	.25**	.04**
Inhibition verbal	.07	−.18*	−.12	−.16	−.24*	.04¶
Inhibition nonverbal	.20	−.13	−.19*	−.09	−.42***	.12***
Planning verbal	.12	.24**	.23**	.17	.20*	.03
Planning nonverbal	.29	.46***	.18*	.13	.41***	.11***
Switching verbal	.10	−.29***	−.10*	−.11	−.04	.01
Switching nonverbal	.15	−.32***	−.16*	−.03	−.20*	.03

SLI, specific language impairment; LLF, low language functioning; ELWM, executive-loaded working memory; NVIQ, nonverbal intelligence.
*p < .05; **p < .01; ***p < .001; ¶p = .05.

for differences in EF performance associated with age and nonverbal intellectual ability. The dummy-coded group variables (LLF, typical) were entered at Step 2 (children with SLI were the reference group) to assess whether, after controlling for age and nonverbal IQ, group differences in performance remained. Table 2 summarises information for Step 2 of each regression. Significant group differences (indicated by a significant change in R^2 at Step 2) were found for 6 of the 10 EF measures: verbal and nonverbal ELWM, verbal and nonverbal fluency, nonverbal inhibition and nonverbal planning.

The SLI group obtained significantly *poorer* scores on these six measures than typical children, even when the effects of age and nonverbal IQ had been taken into account. For three further EF variables (verbal inhibition, verbal planning and nonverbal switching), the beta values at Step 2 showed that when all predictor variables were adjusted in relation to one another, group was significant. Nevertheless, these three effects must be regarded as less robust than the others, because the overall significance of the change in variance (R^2) accounted for by group at Step 2 of the model was not significant.

Most analyses failed to identify significant differences between the LLF and SLI groups, indicating that some degree of language/cognitive difficulty was enough to depress EF. The exception was verbal fluency; here, children with LLF obtained significantly higher scores than children with SLI.

Further regression analyses were carried out in which *verbal IQ* was entered at Step 2 in addition to nonverbal IQ and age. This stringent control assessed whether EF difficulties were independent of both nonverbal and verbal abilities. Table 3 summarises these regressions, including information relating to Step 2 in each case.

Table 3 Summary details of regressions predicting performance on each executive functioning (EF) measure. For each regression, three predictor variables were entered in a block at Step 1 (age, nonverbal IQ, verbal IQ; note Step 1 of each model is not shown). Two further dummy-coded group variables were entered in a block at Step 2 (SLI-vs.-LLF group, SLI-vs.-typical group). The information provided about Step 2 of each model involves total variance accounted for (total R^2), standardised beta values for each predictor variable and change in R^2. Significant values are indicated where relevant

EF measure	Total R^2 accounted for by the model	Details of Step 2 for each regression					
		β age	β NVIQ	β VIQ	β SLI-vs.-LLF	β SLI-vs.-typical	ΔR^2; Step 2
ELWM verbal	.53	.58***	.21**	.33***	−.06	.21*	.04**
ELWM nonverbal	.40	.45***	.31***	.02	.05	.38***	.08***
Fluency verbal	.60	.57***	.24***	.30***	.10	.39***	.07***
Fluency nonverbal	.41	.60***	.24**	.07	.06	.20*	.02
Inhibition verbal	.07	−.18*	−.11	−.02	−.15	−.22	.02
Inhibition nonverbal	.20	−.13	−.19*	.00	−.09	−.42***	.08**
Planning verbal	.14	.27**	.16	.20	.11	.07	.01
Planning nonverbal	.31	.48***	.12	.19¶	.07	.28***	.04*
Switching verbal	.10	−.30***	−.08	−.09	−.08	.02	.01
Switching nonverbal	.16	−.34***	−.11	−.17	.02	−.09	.01

SLI, specific language impairment; LLF, low language functioning; ELWM, executive-loaded working memory, NVIQ, nonverbal intelligence; VIQ, verbal intelligence.
*p < .05; **p < .01; ***p < .001; ¶p = .05.

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Significant group differences (indicated by a significant change in R^2 at Step 2) were found for 5 of the 10 EF measures: ELWM (verbal and nonverbal), verbal fluency, nonverbal inhibition and nonverbal planning. The SLI group obtained significantly *poorer* scores than typical children on these measures even when the effects of age, nonverbal *and verbal* IQ had been taken into account. For nonverbal fluency, the beta values at Step 2 indicated that when all predictor variables were adjusted in relation to one another, group was significant. Again, this finding should be regarded as less robust than the others, because the significance of the change in variance accounted for at Step 2 of the model by group (R^2) was not significant. Children with LLF never differed significantly from children with SLI, suggesting their difficulties with EF were as great as those who had more severe levels of language impairment.

In all the regression analyses, key statistical checks (e.g. Durbin–Watson, tolerance/variance inflation factor (VIF) statistics, Cook's/Mahalanobis distances, standardised DF betas, plots of standardised residuals/predicted standardised values, standardised residuals and partial plots) suggested the absence of both multicollinearity and cases with undue influence, and revealed no evidence for outliers (Field, 2005).

Table 4 shows, for each EF measure, the percentage of children with SLI who had scores that were 1 or 2 *SD*s below the means for typical children of the same chronological age range (n = 63, 8–14 years). Between 15% and 76% of the EF scores for children with SLI were 1 *SD* below the mean of the typical children; and up to a quarter were below 2 *SD* of the mean. The numbers of children with SLI who had impaired performance on EF tasks, using the 1 *SD* cut-off, were as follows: 12 children had impairments on 1/2 tasks (29%); 12 children on 3/4 tasks (29%); 10 children on 5/6 tasks (24%), and 5 children on 7/8 tasks (12%). Only two children with SLI (5%) obtained typical scores on all EF tasks and none showed deficits on 9/10 tasks.

Table 4 Percentage of children with specific language impairment showing impairments on each executive functioning (EF) measure (performance at or below 1/2 *SD* of the mean for typical children of the same age range)

EF task	<1 *SD*	<2 *SD*
ELWM verbal	37	24
ELWM nonverbal	49	17
Fluency verbal	76	22
Fluency nonverbal	39	5
Inhibition verbal	20	12
Inhibition nonverbal	56	22
Planning verbal	15	2
Planning nonverbal	39	24
Switching verbal	20	7
Switching nonverbal	15	7

ELWM, executive-loaded working memory.

Discussion

Children with SLI showed significant difficulties with EF skills compared with typical children. Initial regression analyses of group differences in performance, when controlling for age and nonverbal IQ, revealed that individuals with SLI obtained lower scores than typical children on 6 of the 10 executive tasks, including: verbal and nonverbal ELWM, verbal and nonverbal fluency, nonverbal inhibition and nonverbal planning.

In a second set of regression analyses, a more stringent approach was adopted by controlling for verbal IQ in addition to age and nonverbal IQ, before examining group differences in EF. Controlling for verbal IQ is likely to reduce the chance of finding group differences between individuals with and without SLI, as verbal IQ should play an influential role in group membership. Group differences *remained* on five of the EF measures, which constituted persuasive evidence that executive skills were weak in individuals with SLI, over and above both their nonverbal *and* verbal intellectual abilities. The EF difficulties related to ELWM (verbal/nonverbal measures), verbal fluency, nonverbal inhibition and nonverbal planning. Group differences for nonverbal fluency were less marked, but in other respects the results of the two sets of regressions were compatible.

An important feature of the findings was that executive difficulties in children with SLI were not confined to verbal EF tasks but extended to nonverbal measures. This could reflect a general cognitive difficulty as suggested by Ullman and Pierpont (2005). Alternatively, verbal mediation may be involved in EF through the use of verbal self-reminding (Russell et al., 1999) or reflective consciousness (Marcovitch & Zelazo, 2009). If verbal mediation occurred on most EF tasks, one might expect verbal IQ to be significantly related to EF (as indicated by the beta values). This occurred in only two instances (verbal ELWM and verbal fluency; see Table 3); and for both these tasks performance may have been aided by better vocabulary abilities, not necessarily by verbal mediation. Therefore, in general, the findings were consistent with EF performance not being the result of verbal mediation, but involving a domain general impairment in SLI (Ullman & Pierpont, 2005). However, further research is required before firm conclusions can be drawn, with an interesting possibility being the use of articulatory suppression to investigate whether eliminating verbal mediation affects performance (Wallace, Silvers, Martin, & Kenworthy, 2009).

The EF difficulties were clinically meaningful, as two thirds of the children with SLI showed at least three EF impairments; and, in each of the six areas of EF that were significant in the regressions, between 37% and 76% demonstrated weaknesses. Similar data about children with ADHD indicate that

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between 35% and 50% show EF impairments (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2004). Given these findings, a limitation of the current study should be noted: although no children with SLI had diagnoses of ADHD, we did not assess subclinical levels of attention deficit, which could have depressed EF performance. In addition, many regression models were not a good fit to the data with the percentage of total variance accounted for ranging from 7% to 60% (highest for ELWM and fluency), so other factors are clearly important for EF.

The findings also suggested that children with less severe language difficulties (LLF) had significant problems with EF. For virtually every executive measure, the regression analyses did not distinguish between individuals with SLI and LLF. This implied that even a moderate degree of language impairment was associated with weak EF.

The finding of low EF in the SLI group in both verbal and nonverbal domains, and even after verbal ability had been controlled, raises important questions about the cognitive abilities of the SLI group. Previous investigations have pointed to these young people having difficulties with some nonverbal tasks (Bishop, 2002; Cowan et al., 2005; Johnston & Ellis Weismer, 1983). Our findings extend this line of research and indicate a general difficulty with more complex forms of cognition that involve EF, regardless of modality. Such findings call into question the 'specific' nature of SLI as a disorder and are consistent with multiple deficit models (e.g. Bishop, 2006) where impairments with different aetiologies, such as phonological short-term memory and syntax, can have additive effects that contribute to the likelihood of clinically significant language difficulties. In this way, EF may contribute to the *profile* of causal risk and protective factors in SLI. Future research is needed to assess whether comorbidity of SLI with other developmental disorders might also vary with level of EF impairment.

Another important issue concerns whether children with SLI can be helped by interventions/strategies that target EF abilities. Dealing with novelty is the hallmark of executive skill and nonoptimal executive abilities may jeopardise educational performance (St Clair-Thompson & Gathercole, 2006). With broad and varied executive difficulties, remediation strategies beyond those confined to language and verbal short-term memory may be helpful (e.g. reducing task-related ELWM loads, 'hints' for generating/planning solutions to problems, reminders to inhibit prepotent, but unhelpful/immature responses/strategies).

Conclusion

Children with SLI showed difficulties on a range of verbal and nonverbal EF tasks after age, nonverbal and verbal IQs had been taken into account. Specific areas of EF difficulty were: verbal/nonverbal ELWM, verbal fluency, nonverbal inhibition and nonverbal planning. Children with milder forms of language impairment showed the same EF impairments as those with SLI, indicating that individuals with SLI and LLF have a broader set of cognitive difficulties than that has been commonly assumed.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Correlations between EF variables

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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Key points

- Children with SLI have difficulties with language, but it is unclear whether they have additional broader cognitive problems.
- This research assessed higher level of thinking and reasoning skills, EF, in children with SLI.
- Marked difficulties on a range of EF skills were found, and these were present even after stringent controls for age, verbal IQ and nonverbal IQ.
- EF difficulties were also found for children with 'LLF', who did not meet the criteria for SLI.
- Interventions for those with SLI should, therefore, tackle broader cognitive difficulties with EF skills.

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References

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th edn). Washington, DC: Author.

Archibald, L.M.D., & Gathercole, S.E. (2006). Visuospatial immediate memory in specific language impairment. *Journal of Speech, Language and Hearing Research*, *49*, 265–277.

Bishop, D.V.M. (2002). Motor immaturity and specific speech and language impairment: Evidence for a common genetic basis. *American Journal of Medical Genetics*, *114*, 56–63.

Bishop, D.V.M. (2006). Developmental cognitive genetics: How psychology can inform genetics and vice versa. *Quarterly Journal of Experimental Psychology*, *59*, 1153–1168.

Bishop, D.V.M., & Norbury, C.F. (2005a). Executive functions in children with communication impairments, in relation to autistic symptomatology: I: Generativity. *Autism*, *9*, 7–27.

Bishop, D.V.M., & Norbury, C.F. (2005b). Executive functions in children with communication impairments, in relation to autistic symptomatology: 2: Response inhibition. *Autism*, *9*, 29–43.

Cambridge Cognition (2006). *The Cambridge Neuropsychological Test Automated Battery (CANTAB®)*: Test–retest reliability characteristics. Cambridge: Author.

Cowan, R., Donlon, C., Newton, E.J., & Lloyd, D. (2005). Number skills and knowledge in children with specific language impairment. *Journal of Educational Psychology*, *97*, 732–744.

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). *Delis–Kaplan Executive Function System (D-KEFS)*. London: Psychological Corporation.

Dibbets, P., Bakker, K., & Jolles, J. (2006). Functional MRI of task switching in children with specific language impairment (SLI). *Neurocase*, *12*, 71–79.

Elliot, C.D., Smith, P., & McCullough, K. (1996). *British Ability Scales* (2nd edn). Texas: Psychological Corporation.

Ellis Weismer, S., Evans, J., & Hesketh, L.J. (1999). An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *42*, 1249–1260.

Ferguson, A.N., Bowey, J.A., & Tilley, A. (2002). The association between auditory memory span and speech rate in children from kindergarten to sixth grade. *Journal of Experimental Child Psychology*, *81*, 141–156.

Field, A. (2005). *Discovering statistics using SPSS* (2nd edn). London: Sage.

Fisk, J.E., & Sharp, C.A. (2004). Age -related impairment in executive functioning: Updating, Inhibition, Shifting, and Access. *Journal of Clinical and Experimental Neuropsychology*, *26*, 874–890.

Friedman, N.P., Miyake, A., Corley, R.P., Young, S.E., DeFries, J.C., & Hewitt, J.K. (2006). Not all executive functions are related to intelligence. *Psychological Science*, *17*, 172–179.

Geurts, H.M., Verte, S., Oosterlaan, J., Roeyers, H., & Sergeant, J.A. (2004). How specific are executive functioning deficits in attention deficit hyperactivity disorder and autism? *Journal of Child Psychology and Psychiatry*, *45*, 836–854.

Gopnik, M., & Crago, M.B. (1991). Familial aggregation of a developmental language disorder. *Cognition*, *39*, 1–50.

Henry, L.A. (2001). How does the severity of a learning disability affect working memory performance? *Memory*, *9*, 233–247.

Hill, E.L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review*, *24*, 189–233.

Huizinga, M., Dolan, C., & van der Molen, M. (2006). Age related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*, 2017–2036.

Im-Bolter, N., Johnson, J., & Pascual-Leone, J. (2006). Processing limitations in children with specific language impairment: The role of executive function. *Child Development*, *77*, 1822–1841.

Johnston, J., & Ellis Weismer, S. (1983). Mental rotation abilities in language disordered children. *Journal of Speech and Hearing Research*, *26*, 397–403.

Kiernan, B., Snow, D., Swisher, L., & Vance, R. (1997). Another look at nonverbal rule induction in children with SLI: Testing a flexible reconceptualization hypothesis. *Journal of Speech, Language and Hearing Research*, *40*, 75–82.

Lehto, J.E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*, 59–80.

van der Lely, H.K.J. (2005). Domain-specific cognitive systems: Insight from grammatical-SLI. *Trends in Cognitive Sciences*, *9*, 53–59.

Leonard, L.B., Ellis Weismer, S., Miller, C.A., Francis, D.J., Tomblin, J.B., & Kail, R.V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research*, *50*, 408–428.

Levin, H.S., Culhane, K.A., Hartmann, J., Evankovich, K., Mattson, A.J., Harward, H., …, Fletcher, J.M. (1991). Developmental changes in performance on tests of purported frontal lobe functioning. *Developmental Neuropsychology*, *7*, 377–395.

Marcovitch, S., & Zelazo, P.D. (2009). A hierarchical competing systems model of the emergence and early development of executive function. *Developmental Science*, *12*, 1–25.

Marton, K. (2008). Visuo-spatial processing and executive functions in children with specific language impairment. *International Journal of Language and Communication Disorders*, *43*, 181–200.

Marton, K., & Schwartz, R.G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *46*, 1138–1153.

Messer, D., Dockrell, J., & Murphy, N. (2004). The relation between naming and literacy in children with word finding difficulties. *Journal of Educational Psychology*, *96*, 462–470.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.

Montgomery, J.W. (2002). Understanding the language difficulties of children with specific language impairments: Does verbal working memory matter? *American Journal of Speech-Language Pathology*, *11*, 77–91.

Nigg, J.T., Willcutt, E.G., Doyle, A.E., & Sonuga-Barke, E.J.S. (2004). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry*, *57*, 1224–1230.

Ozonoff, S., & Jensen, J. (1999). Specific executive function profiles in three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders*, *29*, 171–177.

Pennington, B.F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *37*, 51–87.

Pickering, S., & Gathercole, S.E. (2001). *Working Memory Test Battery for Children (WMTB-C)*. London: Psychological Corporation.

Rice, M.L., & Wexler, K. (1996). A phenotype of specific language impairment: Extended optional infinitives. In M.L. Rice (Ed.), *Toward a genetics of language* (pp. 215–237). Mahwah, NJ: Lawrence Erlbaum.

Russell, J., Jarrold, C., & Hood, B. (1999). Two intact executive capacities in children with autism: Implications for the core executive dysfunctions in the disorder. *Journal of Autism and Developmental Disorders*, *29*, 103–112.

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Semel, E., Wiig, E.H., & Secord, W.A. (2006). *Clinical Evaluation of Language Fundamentals CELF-4 UK* (4th edn). London: Psychological Corporation.

St Clair-Thompson, H.L., & Gathercole, S.E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*, 745–759.

Thomas, M.S.C., Annaz, D., Ansari, D., Scerif, G., Jarrold, C., & Karmiloff-Smith, A. (2009). Using developmental trajectories to understand developmental disorders. *Journal of Speech, Language, and Hearing Research*, *52*, 336–358.

Ullman, M.T., & Pierpont, E.I. (2005). Specific language impairment is not specific to language: The procedural deficit hypothesis. *Cortex*, *41*, 399–433.

Wallace, G.L., Silvers, J.A., Martin, A., & Kenworthy, L.E. (2009). Further evidence for inner speech deficits in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*, 1735–1739.

Welsh, M.C., Pennington, B.F., & Groisser, D.B. (1991). A normative-developmental study of executive function: A window of prefrontal function in children. *Developmental Neuropsychology*, *7*, 131–149.

Weyandt, L.L., & Willis, W.G. (1994). Executive functions in school-aged children: Potential efficacy of tasks in discriminating clinical groups. *Developmental Neuropsychology*, *10*, 27–38.

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