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Research Report

Verbal strategies and nonverbal cues in school-age children with and without specific language impairment (SLI)

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Abstract

Background: Considerable evidence suggests that performance across a variety of cognitive tasks is effectively supported by the use of verbal and nonverbal strategies. Studies exploring the usefulness of such strategies in children with specific language impairment (SLI) are scarce and report inconsistent findings.
Aims: To examine the effects of induced labelling and auditory cues on the performance of children with and without SLI during a categorization task.
Methods & Procedures: Sixty-six school-age children (22 with SLI, 22 age-matched controls, 22 language-matched controls) completed three versions of a computer-based categorization task: one baseline, one requiring overt labelling and one with auditory cues (tones) on randomized trial blocks.
Outcomes & Results: Labelling had no effect on performance for typically developing children but resulted in lower accuracy and longer reaction time in children with SLI. The presence of tones had no effect on accuracy but resulted in faster reaction time and post-error slowing across groups.
Conclusions & Implications: Verbal strategy use was ineffective for typically developing children and negatively affected children with SLI. All children showed faster performance and increased performance monitoring as a result of tones. Overall, effects of strategy use in children appear to vary based on task demands, strategy domain, age and language ability. Results suggest that children with SLI may benefit from auditory cues in their clinical intervention but that further research is needed to determine when and how verbal strategies might similarly support performance in this population.

Keywords: SLI, strategies, labelling, performance monitoring, post-error slowing.

What this paper adds?
Verbal strategies and nonverbal cues have been shown to support and enhance performance on memory and executive function tasks across many age groups. Little is known about the effects of such strategies in children with SLI. In the present study, children with SLI benefited from auditory cues (tones) but were negatively affected by induced labelling during a categorization task. Typically developing children showed a similar benefit from tones but were unaffected by labelling. Results suggest that clinical intervention for children with SLI may be enhanced by auditory cues but that further research is needed to clarify when verbal strategies may be helpful and when they are counterproductive.

Introduction

Language and cognitive deficits in children with specific language impairment (SLI) are well documented; however, relatively little is known about the effectiveness of spontaneous and trained strategy use in this population. The present study examines the effects of strategies on school-age children's performance during a categorization task. The aim is to determine whether induced verbal strategies and auditory cues benefit this age group and whether children with SLI benefit to a different degree than their typically developing peers.

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Verbal strategy use

Many theoretical models of working memory highlight the role of verbalization in supporting memory representations. In Baddeley's model (Baddeley 2000), verbal rehearsal refreshes traces within the phonological loop to prevent spontaneous fading. In more unitary models (e.g. Cowan 1996), rehearsal helps maintain activated long-term memory traces within the focus of attention. Contemporary theories of cognitive development also recognize the relationship between language and children's emerging working memory, executive functions, problem-solving and self-regulation abilities. According to Cognitive Complexity and Control theory (Zelazo and Frye 1998), successful performance on a card-sorting task with changing rules depends specifically upon children's ability to represent complex rules linguistically.

The importance of language for sustaining memory and supporting task performance is demonstrated by many studies. Several of these examined effects of articulatory suppression (AS) on task switching, based on the premise that irrelevant verbalization during task performance disrupts inner speech and indirectly reflects the support normally derived from this covert form of verbalization. Negative effects of AS have been observed in young adults (Miyake *et al.* 2004, Kirkham *et al.* 2012) as well as children (Fatzer and Roebers 2012), and across tasks with varying working memory demands.

A larger set of studies focused more directly on verbal strategy effects. Facilitative effects of induced labelling have been reported for 4- and 6-year-old children on tasks measuring working memory span and cognitive flexibility (Fatzer and Roebers 2013); for school-age children and older adults on tasks involving switching and selective inhibitory control (Kray *et al.* 2008); and for young adults performing complex span (Turley-Ames 2003) and switching (Kirkham *et al.* 2012) tasks. Based on these studies, labelling appears to support performance by strengthening representations of relevant task rules or stimuli, although some suggest that verbal strategies help sustain general focus and concentration (Kirkham *et al.* 2012).

What determines the extent of benefit derived from verbal strategies?

Regardless of how verbalization facilitates performance, the extent of benefit derived from verbal strategies varies considerably from study to study. One relatively consistent pattern involves age-related differences in beneficial and detrimental effects of strategies and AS, respectively. These differences are thought to reflect developmental changes in the degree to which spontaneous verbalization is utilized and internalized. Consistent with this explanation, college students recalled fewer early items on a serial recall task during conditions interfering with rehearsal (Hagen *et al.* 1970), whereas no detrimental effect was observed for 4th, 6th and 8th graders. Fatzer and Roebers (2012) likewise found larger performance decrement in 9- compared with 6-year-old children performing complex span and flanker tasks with AS. Although these studies all demonstrate an interaction between age and AS effects, the point at which children effectively use verbal strategies remains unclear, with some evidence indicating limited internalization of inner speech until at least age 14 (Hagen *et al.* 1970) but others suggesting earlier strategy use (Fatzer and Roebers 2012).

When participants are instructed to use verbal strategies, performance patterns based on age resemble those observed under AS conditions but in reverse, with younger children showing more change than older children or adults, and with changes reflecting improvement rather than performance decrement (Fatzer and Roebers 2013, Kray *et al.* 2008). These findings suggest that once inner speech is used spontaneously, inducing explicit labelling or rehearsal no longer results in measurable performance benefit. Effects of induced verbalization are also strongest when implemented by participants known to be weak in the ability being measured, as demonstrated by Kray *et al.* (2008), who found that labelling improved switching performance specifically in age groups with poorer general switching ability, namely, younger children and older adults (age 65–75). Turley-Ames (2003) similarly found that effects of verbal rehearsal varied based on working memory ability, with low span participants benefiting more than high span participants. Based on these findings, the degree of change in performance as a result of verbalization depends on individual skill level.

Finally, effects of AS or induced verbalization vary based on task characteristics. As reasoned by Fatzer and Roebers (2012), the role of language in sustaining memory should become more critical as memory demands increase. Although the authors' first study involving AS did not consistently support this prediction, their subsequent study of induced verbal strategy use (Fatzer and Roebers 2013) found an interaction between task type and benefit. When labelling task-relevant rules or response-related words, children's performance improved on span and cognitive flexibility tasks, but not on a flanker task that placed minimal demands on working memory. Kray *et al.* (2008) further demonstrated that AS costs and labelling benefits decreased from the first to the third practice session, indicating that strategies are important for new task sets being implemented but not for well-practiced tasks. Interestingly, although overall effects of verbalization were reduced on the third practice session, costs and benefits associated with verbalization remained larger for mixed blocks (involving task switching) compared with single blocks (without switching). This finding suggests that labelling effects are apparent at more complex levels of a task even after the task set is well established. A final factor influencing verbalization effects is cue type. In a task switching study with young adults (Miyake *et al.* 2004), AS resulted in greater switch cost when cues were not transparent (rules were represented by a single letter rather than complete word). AS effects were absent in the transparent cue condition, suggesting that inner speech was not necessary to support task switching when explicit cues were present.

Verbal strategy use in children with SLI

Children with SLI have known weaknesses in working memory, as well as more generalized deficits across executive functions (e.g., see Montgomery *et al.* 2010, for review). These children stand to gain most from strategies that can support performance on such tasks, particularly since low skill level is associated with greater benefit (Kray *et al.* 2008). Current literature, however, provides limited support for this prediction. In one study comparing two forms of language intervention, children with SLI who were trained to rehearse showed significant improvement in their ability to follow directions (Gill *et al.* 2003). This benefit exceeded that derived from traditional language therapy. The lack of a control group with typical language development (TLD) in this study, however, makes it impossible to determine: (1) whether children with SLI followed directions as well as TLD peers when using verbal strategies, and (2) whether children with SLI derived the same extent of benefit as controls. More recently, Alt and Spaulding (2011) found that children with SLI and TLD controls spontaneously rehearsed with comparable frequency during a recall task but that only TLD children benefited. Based on their findings, these authors suggest that rehearsal may be counterproductive for children with SLI; however, the study only considered spontaneous rehearsal, which occurred on fewer than 50% of trials.

Given the role of language in supporting working memory and executive functions, unclear effects of age in this relationship, and limited data for children with SLI, the first goal of the present study was to examine effects of induced labelling in children with and without language impairment on a categorization task with limited working memory and attention switching demands. Another aim was to test whether auditory cues facilitate attention orienting in the same tasks.

Auditory cues

Although verbal strategies have received much attention in the literature, less is known about nonverbal cue effects. According to Alexander and Judy (1988), effective strategy use depends upon a strong foundation of domain-specific knowledge. Based on this reasoning, children with SLI may show limited or no benefit from language-based strategies but considerable benefit from nonverbal cues, which draw upon unimpaired core abilities. This possibility is also raised by Alt and Spaulding (2011).

Additional evidence suggests that verbal and nonverbal strategies ultimately achieve the same goal. Preschoolers performing a conflict task improved to a similar extent when labelling and when pointing to the relevant (but less salient) aspect of target stimuli (Muller *et al.* 2004). Other studies have examined effects of content-free auditory cues (tones) presented intermittently to healthy and brain-injured adults during a sustained attention task and found immediate performance benefits reflecting increased supervisory control in both participant groups (e.g. Manly *et al.* 2004). Although the precise underlying mechanism is not well understood, intermittent tones are believed to serve as 'markers' that represent higher-level goals and facilitate performance by interrupting automatic response modes and encouraging top-down attentional control.

In sum, most studies indicate that verbal strategies facilitate memory and task-switching performance, although effects vary across tasks, ages, and ability levels. The usefulness of such strategies for children with SLI is considered by few studies and is not well understood. Auditory cues may provide similar benefits, but have not been examined in children with SLI. The present study tested effects of verbal strategies (induced labelling) and auditory cues (tones of varying durations) on the performance of children with and without SLI.

We formulated a series of hypotheses. For the labelling manipulation, we predicted that: (1) baseline (no labelling) accuracy would not differ between groups, given the simple nature of the task and stimuli; (2) baseline reaction time (RT) would show age and language effects, with slower performance in younger language-matched children (TLD-L) and children with SLI compared with age-matched (TLD-A) peers; (3) induced labelling would result in increased accuracy and faster RT for children with SLI and TLD-L due to presumed lack of spontaneous labelling in these groups; and (4) no performance change would be observed in TLD-A who likely use such strategies spontaneously.

For the tone manipulation, we predicted that (5) all groups would benefit from auditory cues, with corresponding increases in accuracy and decreases in RT; and (6) auditory cues would facilitate performance monitoring, as reflected by post-error slowing. Post-error slowing refers to the well-documented tendency to slow down after committing an error and reflects the increased caution and adjusted response threshold adopted by the participant to maintain optimal performance (Dutilh *et al.* 2012). This effect was expected to be similar across groups, based on developmental data for error monitoring in school-age children (e.g. Wiersema *et al.* 2007).

Methods

Participants

Participants included three groups of 22 children each: (1) children with SLI, (2) TLD-A (±3 months based on group means), and (3) TLD-L. Mean age (year;months) for the SLI, TLD-A, and TLD-L groups was 12;3, 12;6 and 9;9, respectively. Although gender distribution varied across groups, there was no effect of gender on any of the dependent measures; therefore this factor is not discussed further in results below. All participants spoke English as their primary language, passed a hearing screening performed at 20 dB between 250 and 8000 Hz, had no other developmental disorders, and achieved average standard scores (> 85) on the Test of Nonverbal Intelligence, Third Edition (TONI-3) (Brown *et al.* 1997). Use of nonverbal intelligence in the diagnosis of SLI is debated (Plante 1998) but remains a commonly used diagnostic criterion for SLI and was used in the present study to enable cross-study comparisons. Although average nonverbal intelligence was part of our selection criteria in theory, no potential participants with SLI were excluded other than a single child with clear attention difficulties. Parental permission and verbal assent were obtained from all children. This project was part of a larger study on inhibitory control (Marton *et al.* 2014).

Language abilities were assessed for all participants via core language subtests on the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4) (Semel *et al.* 2003); Expressive One-Word Picture Vocabulary Test (EOWPVT) (Brownell 2000); and Test for Reception of Grammar, Second Edition (TROG-2) (Bishop 2003). All children with SLI had a previous diagnosis of language impairment as determined by a certified speech–language pathologist, received speech–language therapy in the past and at the time of the study, and achieved standard scores at least 1.25 SD (standard deviations) below the mean of age-matched children's language scores on at least two of the three language measures administered. Children in the TLD-A and TLD-L groups scored within the average range (standard score > 85) across language measures. The TLD-L group was matched to the SLI group based on their performance on the CELF-4 *Recalling Sentences* subtest (±3 raw score units). Preliminary data collected during early phases of this study demonstrated that this subtest was most sensitive in identifying children with SLI and differentiating groups. See table 1 for a full summary of participant characteristics.

Procedures and stimuli

The experimental task consisted of an information processing battery (Marton *et al.* 2014) administered via a tablet computer with coloured, round 2.5-inch response buttons (two black and one red). Buttons were positioned 2–3 inches from the table edge in front of each participant, with the red button in between the black ones. All children were tested in the laboratory or in quiet rooms at participating private practices or schools.

The three subtests included in the present study consisted of a categorization task in which participants determined whether a given word belonged to a specific category. Two subtests focused on strategy use, as described below. Task order was randomized to control for practice, fatigue, or other task order effects. All stimuli consisted of familiar, high-frequency words typically acquired during the preschool years, based on published frequency ratings (Hall *et al.* 1984). Linguistic demands were intentionally kept low as the focus of the study was on strategy use, rather than categorization ability.

On each trial, a category name (e.g. 'Family') appeared at the top centre of the screen, followed by a randomly varying interval (1–2 s) and either a target word that belonged to the category (e.g. 'Mother') or distractor item that did not (e.g. 'Ball). All words were presented visually and read silently by participants. Accuracy and reaction time (RT) were automatically recorded for all button-press responses. Participants were instructed to press and hold the red response button until the category name appeared, then release it as quickly as possible (recorded as RT1). For target words, participants pressed the black button corresponding to the side on which the target word appeared (recorded as RT2). For distractor words, participants pressed the red button in the centre. Pressing the red button for non-target responses was necessary in order to differentiate withheld responses from failure to respond (in which no buttons were pressed). Participants were instructed to respond as quickly and as accurately as possible. The baseline condition consisted of six individual blocks of 14 trials each (total categorization trials = 84, with 60 targets and 24 distractors). This condition did not involve any further manipulations and served as a baseline measure of reading and categorization performance. See table 2 for correlations between baseline accuracy and RT, participant age, and standardized measures (CELF-4, TONI-3).

Table 1. Participant characteristics: mean(SD)

	SLI ($n = 22$)	TLD-A ($n = 22$)	TLD-L ($n = 22$)
Gender (male/female)	13/9	11/11	7/15
Age (years;months, SD in months)	12;3 (15.6)	12;6 (22.9)	9;9 (18.7)
TONI-3 standard score	101.3 (14.8)	111 (17.2)	103.7 (9.9)
CELF-4 Core Language standard score	81.6 (13.8)	119.4 (9.5)	99.4 (11.2)
CELF-4 Recalling Sentences raw score	57.1 (13.2)	83.2 (4.6)	60.4 (8.9)
EOWPVT standard score	88.3 (13.7)	107.5 (14.8)	102.8 (9.8)
TROG-2 standard score	88.3 (12.1)	106.2 (7.2)	96.5 (10.7)

Note: SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children; TONI-3 = Test of Nonverbal Intelligence—3rd Edition; CELF-4 = Clinical Evaluation of Language Fundamentals, 4th Edition; EOWPVT = Expressive One-Word Picture Vocabulary Test; TROG-2 = Test for Reception of Grammar—Version 2.
Source: Adapted from Marton *et al.* (2014).

Table 2. Pearson product-moment correlation of age, standardized scores and baseline measures for the study sample ($N = 66$)

		1	2	3	4	5
1	Age (months)	–				
2	TONI-3 standard score	0.127	–			
3	CELF-4 Core Language standard score	0.103	0.332*	–		
4	Baseline Accuracy	0.489*	0.203	0.229	–	
5	Baseline Reaction Time	–0.581*	–0.097	–0.373*	–0.489*	–

Note: *$p < 0.05$ (two-tailed). TONI-3 = Test of Nonverbal Intelligence—3rd Edition; CELF-4 = Clinical Evaluation of Language Fundamentals, 4th Edition; Baseline Accuracy and Reaction Time = performance on the baseline condition of the information processing battery (see text for description).

In the verbal strategy condition, participants were instructed to label category names aloud each time they appeared. As in the baseline task, participants completed six blocks of trials (84 total; 60 target, 24 distractors).

The effect of auditory cueing was examined by providing auditory cues on randomized trial blocks to help children focus their attention on task goals. Auditory cues consisted of pure tones presented binaurally via headphones at a comfortable listening level. Tones were presented prior to the appearance of category names and alerted children to upcoming stimuli. Participants completed 140 trials without tones and 154 trials with tones. Tone trials consisted of six blocks, each with unique tone durations, ranging from 1000 to 3500 ms. Four of the six blocks (1000, 1500, 2000 and 2500 ms) consisted of 28 trials each; the remaining two blocks (3000 and 3500 ms) consisted of 14 trials each. Although there were more blocks in the tone condition compared with the baseline or labelling conditions, there were fewer blocks for each unique tone duration. This aspect of the experimental design was based primarily on practical considerations (six blocks of trials for each tone duration would not have been feasible). Individual sets of 14 trials (drawn from the six blocks described above) were presented in randomized order. Trials without tones served as the baseline measure for this task. See figure 1 for a representation of trials in the baseline, verbal strategy, and auditory cue conditions.

Statistical analyses

Data were analysed using analysis of covariance (ANCOVA) followed, when appropriate, by Tukey post-hoc tests. Effects are reported as significant for $p < 0.05$. TONI-3 standard scores were used as a covariate in all analyses based on three considerations: (1) TONI scores did not differ significantly between groups and showed a small effect size, $F(2, 63) = 2.74$, $p = 0.072$, $\omega^2 = 0.05$; (2) TONI scores were related to dependent variables, with Pearson correlation coefficients ranging from 0.1 to 0.3 across groups; and (3) identical statistical analyses without TONI scores as covariate produced the same pattern of results but with greater residual variance and smaller F-values in certain cases.

Results of evaluation of the assumptions of linearity, normality, homogeneity of variance, and sphericity were satisfactory. Despite slightly skewed distributions, accuracy and RT data were kept in their original scales and no transformation were made. This decision was made to facilitate interpretation of the estimates and, more importantly, because analyses performed on transformed data produced the same pattern of results.

Univariate outliers (within and between subject) were defined as scores more than 3 SD below or above the mean. Less than 3% of the data met this criterion and were replaced with values corresponding to ± 3 SD.

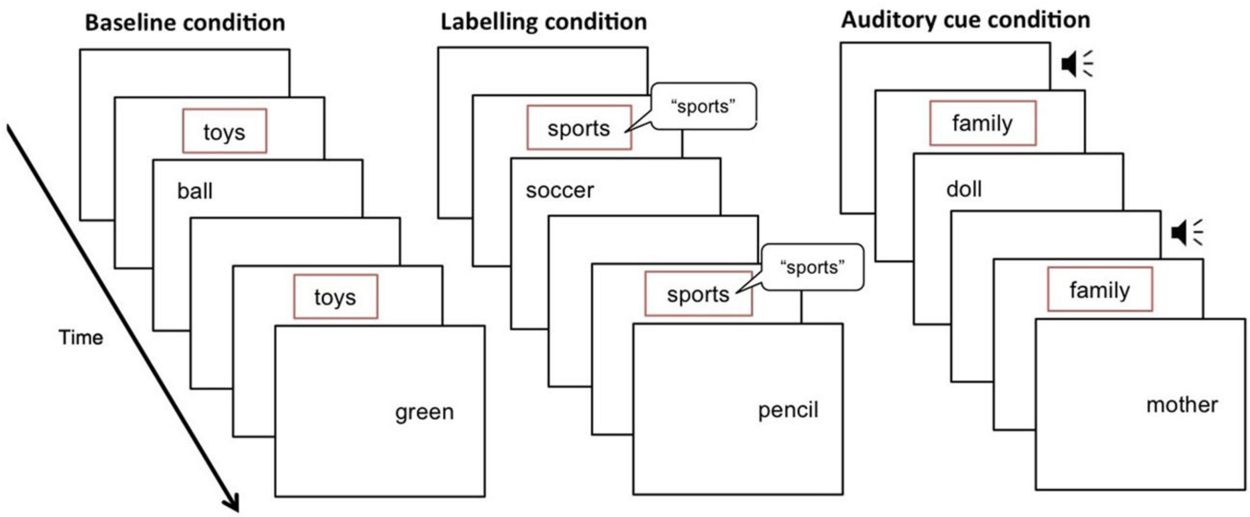

Figure 1. Task paradigm: representation of trials in each condition.

Table 3. Verbal strategy: descriptive statistics for accuracy and reaction time by group and condition: mean(SD)

	Accuracy	RT
SLI (n = 22)		
Baseline	0.85(0.08)	1374(220)
Labelling condition	0.78(0.13)	1542(324)
TLD-A (n = 22)		
Baseline	0.89(0.06)	1131(272)
Labelling condition	0.9(0.07)	1204(281)
TLD-L (n = 22)		
Baseline	0.81(0.9)	1534(229)
Labelling condition	0.82(0.1)	1514(267)

Note: RT = reaction time 1 (ms) (see the text for a description); SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

Results

Verbal strategy effects

A 3 × 2 mixed-design analysis of covariance was performed on accuracy and RT (RT2) data. Independent variables consisted of Group (SLI, TLD-A, and TLD-L) and Condition (baseline and labelling). Nonverbal IQ (TONI-3 standard score) was used as a covariate. Descriptive statistics are reported in table 3.

Accuracy

For accuracy data, analysis revealed a statistically significant main effect of Group, $F(2,62) = 4.05$, $p = 0.022$, $\omega^2 = 0.066$ and significant Group × Condition interaction, $F(2,62) = 7.18$, $p = 0.002$, $\omega^2 = 0.038$. The main effect of Condition did not reach statistical significance, $F(1,62) = 2.49$, $p = 0.119$, $\omega^2 = 0.005$ (figure 2).

Post-hoc Tukey comparisons for Group showed both age and language status effects, with TLD-A performing more accurately than children with SLI and TLD-L, $t(42) = 6.1$, $p < 0.001$, $d = 1.18$ and $t(42) = 6.23$, $p < 0.001$, $d = 1.2$, respectively. The difference between TLD-L and children with SLI was not significant, $t(42) = 0.13$, $p = 0.991$, $d = 0.034$.

Tukey comparisons for the Group × Condition interaction revealed a partial age effect in the baseline condition, with TLD-L performing more poorly than TLD-A, $t(42) = 4.39$, $p = 0.001$, $d = 1.046$, but no significant difference between TLD-L and SLI, $t(42) = 2.44$, $p = 0.158$, $d = 0.496$, and between TLD-A and SLI, $t(42) = 1.95$, $p = 0.385$, $d = 0.614$. These results do not support our first hypothesis, which predicted similar baseline performance across groups.

Different patterns of performance emerged in the labelling condition, where effects of both age and language status were significant (TLD-A—TLD-L, $t(42) = 4.42$, $p = 0.001$, $d = 0.927$; TLD-A—SLI, $t(42) = 6.68$, $p < 0.001$, $d = 1.222$). Accuracy of children with SLI and TLD-L was comparable, $t(42) = 2.26$, $p = 0.224$, $d = 0.362$.

Within groups, Tukey tests and Cohen's d effect size showed that the effect of labelling on accuracy was negligible in typically developing children but large, and negative, in children with SLI (TLD-A, $t(21) = 0.67$, $p = 0.984$, $d = 0.177$; TLD-L, $t(21) = 0.64$, $p = 0.987$, $d = 0.107$, and SLI $t(21) = 4.06$, $p = 0.002$, $d = 0.689$), resulting in an 8% drop in accuracy for this group. These results support hypothesis 4, which predicted no labelling effect in TLD-A, but not hypothesis 3, which predicted increased accuracy in TLD-L children and children with SLI as a result of verbal strategy use.

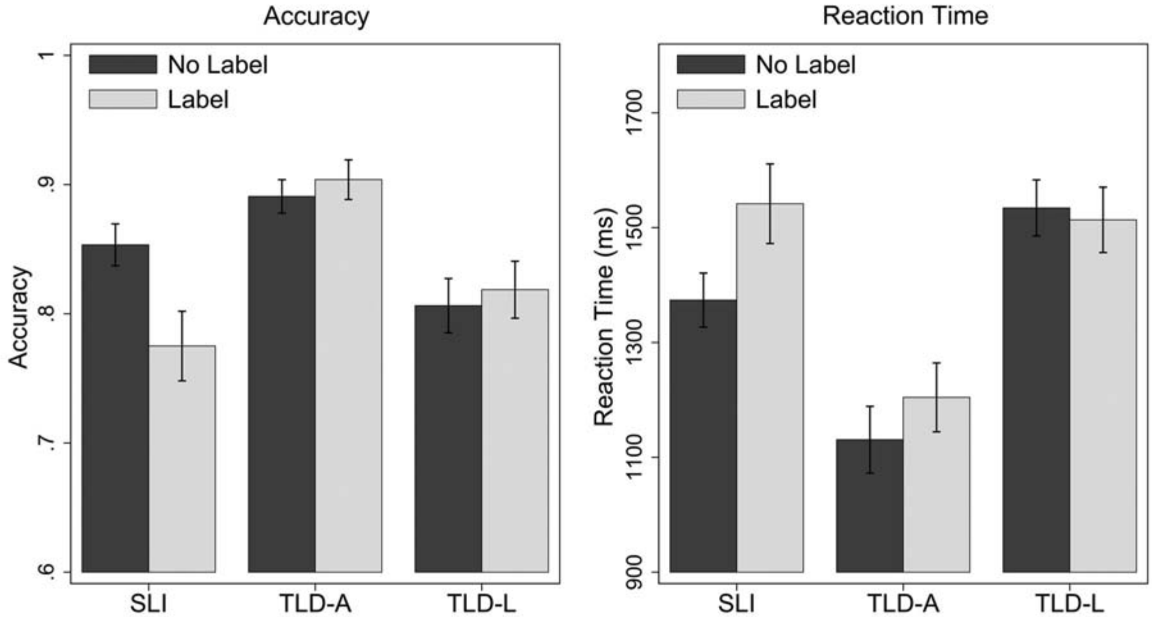

Figure 2. Verbal strategy: effects of group and labelling on accuracy (proportion correct) and reaction time. Error bars: ± SE, SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

Reaction time

RT results showed a statistically significant main effect of Group, $F(2,62) = 8.76$, $p < 0.001$, $\omega^2 = 0.154$, main effect of Condition, $F(1,62) = 6.33$, $p = 0.014$, $\omega^2 = 0.012$, and Group × Condition interaction, $F(2,62) = 3.86$, $p = 0.026$, $\omega^2 = 0.013$ (figure 2).

Like accuracy results, post-hoc Tukey tests for the Group effect revealed that TLD-A performed better (faster) than TLD-L, $t(42) = 9.95$, $p < 0.001$, $d = 1.44$, and children with SLI, $t(42) = 8.1$, $p < 0.001$, $d = 1.172$. No difference emerged between children with SLI and TLD-L, $t(42) = 1.85$, $p = 0.162$, $d = 0.294$.

Tukey comparisons for the Group × Condition interaction allowed us to test hypotheses 2, 3, and 4. Results revealed that in the baseline condition, the three groups all differed significantly from each other: TLD-A−SLI, $t(42) = 4.8$, $p < 0.001$, $d = 0.982$; TLD-L−SLI, $t(42) = 3.17$, $p = 0.027$, $d = 0.713$; TLD-A−TLD-L, $t(42) = 7.97$, $p < 0.001$, $d = 1.6$. RT of the age-matched group was faster than that of children with SLI, which in turn was faster than that of language-matched children. These results partially support hypothesis 2, which predicted age and language status effects in the baseline condition.

For the labelling condition, age and language status effects remained statistically significant, with faster RT for TLD-A as compared with the other two groups, but no significant difference between children with SLI and language-matched peers (TLD-A−SLI, $t(42) = 6.66$, $p < 0.001$, $d = 1.115$; TLD-L−TLD-A, $t(42) = 6.1$, $p < 0.001$, $d = 1.131$; TLD-L−SLI, $t(42) = 0.55$, $p = 0.994$, $d = 0.094$).

Of interest for hypotheses 3 and 4 was the effect of labelling within the three groups. We found no Condition effect, that is, no statistically significant difference between baseline and labelling conditions, in the two typically developing groups, TLD-A, $t(21) = 1.45$, $p = 0.694$, $d = 0.27$ and TLD-L, $t(21) = 0.41$, $p = 0.998$, $d = 0.094$. However, a medium to large negative effect of labelling emerged for the children with SLI, $t(21) = 3.31$, $p = 0.018$, $d = 0.519$, resulting in a 12% (168 ms) increase in RT. Hypothesis 4, which predicted no labelling effect in TLD-A, is therefore supported, but not hypothesis 3, which predicted faster RT in the labelling condition for TLD-L and children with SLI.

Tone effects

A 3 × 7 mixed-design analysis of covariance was performed on accuracy and RT (RT1) data. Independent variables consisted of Group (SLI, TLD-A, and TLD-L) and Condition (no tone, 1000 ms, 1500 ms, 2000 ms, 2500 ms, 3000 ms, and 3500 ms tone). Nonverbal IQ (TONI-3, standard score) was used as a covariate. Descriptive statistics are reported in table 4.

Accuracy

Results revealed a significant main effect of Group, $F(2,62) = 4.55$, $p = 0.014$, $\omega^2 = 0.074$, with

Table 4. Auditory cue: descriptive statistics for accuracy and reaction time by group and condition: mean (SD)

	SLI ($n = 22$)		TLD-A ($n = 22$)		TLD-L ($n = 22$)	
	Accuracy	RT	Accuracy	RT	Accuracy	RT
No tone	0.87(0.09)	822(221)	0.96(0.03)	745(198)	0.86(0.1)	851(186)
Tone 1000 ms	0.85(0.12)	677(204)	0.93(0.05)	609(119)	0.82(0.15)	716(222)
Tone 1500 ms	0.82(0.15)	761(305)	0.92(0.06)	632(163)	0.84(0.14)	708(154)
Tone 2000 ms	0.86(0.11)	727(236)	0.93(0.06)	641(148)	0.83(0.14)	786(232)
Tone 2500 ms	0.86(0.1)	731(264)	0.89(0.07)	605(138)	0.83(0.13)	694(196)
Tone 3000 ms	0.85(0.15)	731(247)	0.93(0.07)	650(148)	0.84(0.17)	737(226)
Tone 3500 ms	0.88(0.13)	749(263)	0.94(0.07)	620(174)	0.86(0.14)	732(243)

Note: RT = reaction time (ms); SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

age-matched children performing more accurately than SLI and TLD-L, and no statistically significant difference between the two latter groups (TLD-A−SLI, $t(42) = 4.7$, $p < 0.001$, $d = 1.01$; TLD-A−TLD-L, $t(42) = 5.7$, $p < 0.001$, $d = 1.087$, and SLI−TLD-L, $t(42) = 0.92$, $p = 0.631$, $d = 0.199$). The main effect of Condition approached but did not reach statistical significance, possibly due to insufficient power, and showed negligible effect size, $F(6,372) = 2.08$, $p = 0.054$, $\omega^2 = 0.006$. The Group × Condition interaction was not significant, $F(12,372) = 0.44$, $p = 0.948$, $\omega^2 = 0.006$. Hypothesis 5, which predicted that all groups would benefit from auditory cues, is therefore not supported by accuracy results.

Reaction time

In contrast to accuracy results, RT data did not reveal a significant main effect of Group, $F(2,62) = 1.65$, $p = 0.2$, $\omega^2 = 0.033$; however, the Condition effect was statistically significant with small to medium effect size, $F(6,372) = 8.68$, $p < 0.001$, $\omega^2 = 0.031$ (figure 3). There was no significant interaction effect between Group and Condition, $F(12,372) = 0.74$, $p = 0.709$, $\omega^2 = 0.002$.

Tukey post-hoc comparisons for Condition are reported in table 5. RT was significantly faster in the tone compared with no tone condition, with no statistically significant difference among different tone durations. RT data therefore support hypothesis 5, which predicted performance benefit across groups as a result of auditory cues.

Post-error slowing

A 3 × 2 × 2 mixed-design analysis of covariance was performed on RT (RT1) data. Independent variables included Group (SLI, TLD-A, and TLD-L), Position (pre- and post-error), and Condition (no tone and tone). Nonverbal IQ (TONI-3, standard score) was used as a covariate. Descriptive statistics are reported in table 6.

For this analysis, tone durations were aggregated, yielding a factor with two levels (no tone and tone). This decision was based on the fact that the difference among tone duration was negligible. Reducing the number of levels from seven to two simplified the complexity of the data and permitted a more parsimonious explanation of the results. Post-error slowing was quantified using pre- and post-error trials. The analysis was done on an average of 9.9 pre-error values and 9.9 post-error data points per participant. This method has been shown to be more valid and reliable than other methods, such as the widely adopted method of comparing post-correct trials to post-error trials (Dutilh *et al.* 2012).

Reaction time

Results of the mixed-design analysis of covariance are summarized in table 7. There was no effect of Group, but effects of Position and Condition were each significant, with slower RT on post-error compared with pre-error trials, and faster RT in the tone compared with no tone condition.

There was also a significant interaction between Position and Condition (figure 4), indicating that the Position effect (pre- versus post-error) differed between tone and no tone conditions. More specifically, Tukey post-hoc tests revealed that there was a large and statistically significant post-error slowing effect in the tone condition, $t(65) = 6.44$, $p < 0.001$, $d = 0.78$, but not in the no tone condition, $t(65) = 0.8$, $p = 0.853$, $d = 0.096$. These results support hypothesis 6, which predicted that auditory cues would facilitate performance monitoring, as reflected by post-error slowing.

Discussion

The goal of this study was to examine how efficiently children with SLI and their age- and language-matched peers use induced labelling and auditory cues to support their performance on a simple categorization task.

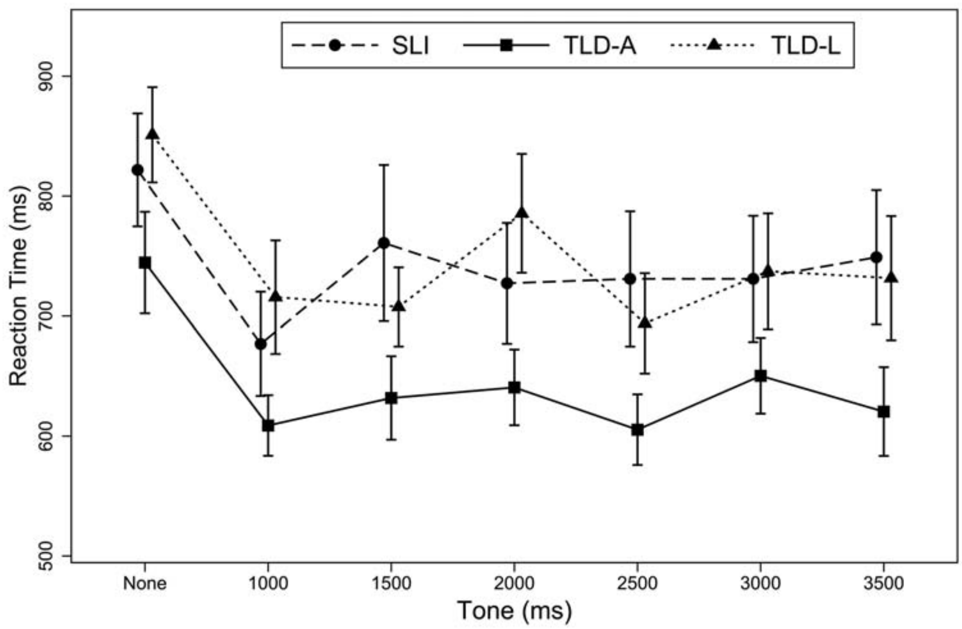

Figure 3. Auditory cue: effects of group and auditory tone on reaction time. Error bars: ± SE, SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

We expected that labelling would provide a scaffold, or form of verbal mediation, to help children inhibit irrelevant categories and redirect the focus of their attention to new categories. We also anticipated that labelling would minimize memory demands by strengthening active representations of relevant categories.

The hypothesis was that accuracy would not differ between groups in the baseline condition, but that labelling would result in increased accuracy in children with SLI and TLD-L due to their lack of spontaneous verbal strategy use. We anticipated no performance change in the TLD-A children who were expected to use verbal strategies spontaneously. The results showed a different pattern. There was a significant main effect of Group, such that overall performance of children with SLI was poorer than that of the TLD-A group but comparable to the performance of TLD-L participants. This finding is somewhat difficult to interpret, given the significantly lower mean standardized CELF-4 score for the TLD-L compared with TLD-A group in our sample. To clarify which factor was more strongly related to baseline performance, we computed partial correlations for the TLD children which showed that baseline accuracy and RT were significantly correlated with age when controlling for CELF-4 scores, $r(41) = 0.477$, $p = 0.001$ and $r(41) = -0.651$, $p < 0.001$, but were not correlated with CELF-4 scores when controlling for age, $r(41) = 0.075$, $p = 0.63$ and $r(41) = -0.113$, $p = 0.469$, suggesting that group differences at baseline were more likely driven by age.

There was a Group × Condition (label versus no label) interaction, with labelling showing no effect on accuracy for both control groups (TLD-A; TLD-L), but negatively affecting children with SLI, as evidenced by a decrease in accuracy. Although this finding was surprising, there are several explanations for it. First, effects of labelling are strongly related to the nature of the task. The simple categorization task involved minimal obvious conflict and included transparent cues. Consistent presence of the category name may have automatically activated the task goal; therefore children did not necessarily need to apply endogenous control. Previous studies have shown that labelling is beneficial when task cues are not transparent (e.g. Miyake *et al.* 2004) and that labelling relevant rules helps participants perform better in cognitive conflict tasks that involve bivalent stimuli and alternate between two rules (Kirkham *et al.* 2012, Kray *et al.* 2008).

A further influential factor is participants' age. Whereas induced verbalization benefited 4–6-year-old children, this strategy did not have a positive effect on 9-year-old children's performance (Fatzer and Roebers 2012). The youngest participant in our study was eight years old; thus, many of the children may have been too old to benefit appreciably from the labelling condition.

An interesting outcome of the current study is that children with SLI did not benefit from labelling. This result is similar to the findings of Alt and Spaulding (2011) who also reported no benefit for children with SLI when using spontaneous rehearsal. The authors

Table 5. Auditory cue: Tukey post-hoc comparisons of tone duration on reaction time

Comparison	t	d.f.	p-value	d^a
Tone 1000 ms–No tone	–6.34	65	< 0.001	0.789
Tone 1500 ms–No tone	–4.76	65	< 0.001	0.556
Tone 2000 ms–No tone	–3.91	65	0.002	0.47
Tone 2500 ms–No tone	–5.88	65	< 0.001	0.698
Tone 3000 ms–No tone	–4.47	65	< 0.001	0.539
Tone 3500 ms–No tone	–5.09	65	< 0.001	0.538
Tone 1500 ms–Tone 1000 ms	1.59	65	0.692	0.178
Tone 2000 ms–Tone 1000 ms	2.44	65	0.185	0.281
Tone 2500 ms–Tone 1000 ms	0.46	65	0.999	0.056
Tone 3000 ms–Tone 1000 ms	1.88	65	0.496	0.217
Tone 3500 ms–Tone 1000 ms	1.23	65	0.883	0.171
Tone 2000 ms–Tone 1500 ms	0.85	65	0.979	0.092
Tone 2500 ms–Tone 1500 ms	–1.12	65	0.921	0.119
Tone 3000 ms–Tone 1500 ms	0.29	65	1	0.031
Tone 3500 ms–Tone 1500 ms	–0.35	65	1	0.005
Tone 2500 ms–Tone 2000 ms	–1.98	65	0.43	0.217
Tone 3000 ms–Tone 2000 ms	–0.56	65	0.998	0.063
Tone 3500 ms–Tone 2000 ms	–1.2	65	0.893	0.089
Tone 3000 ms–Tone 2500 ms	1.42	65	0.792	0.154
Tone 3500 ms–Tone 2500 ms	0.77	65	0.988	0.116
Tone 3500 ms–Tone 3000 ms	–0.64	65	0.995	0.03

Note: [a]Cohen's *d* effect size.

Table 6. Post-error slowing: descriptive statistics for reaction time (ms) (RT1; see the text for a description) by group and condition: mean (SD)

	SLI ($n = 22$)	TLD-A ($n = 22$)	TLD-L ($n = 22$)
Tone, pre-error	745(345)	624(130)	775(279)
Tone, post-error	950(279)	870(251)	933(220)
No tone, pre-error	891(323)	810(213)	872(222)
No tone, post-error	932(277)	797(266)	920(248)

Note: SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

Table 7. Post-error slowing: summary of mixed-design analysis of covariance

Effect	F(d.f.)	p-value	ω^2
Group	1.56 (2,62)	0.218	0.025
Position	26.24 (1,62)	< 0.001	0.043
Position × Group	0.08 (2,62)	0.926	0.003
Condition	6.05 (1,62)	0.017	0.008
Condition × Group	0.12 (2,62)	0.891	0.003
Position × Condition	15.87 (1,62)	< 0.001	0.025
Position × Condition × Group	0.94 (2,62)	0.397	0.001

Note: Group = factor variable with three levels (TLD-A, SLI, TLD-L); Position = factor variable with two levels (pre-error, post-error); Condition = factor variable with two levels (no tone, tone).

interpreted this result as utilization deficiency in children with SLI, meaning that these children use the appropriate strategy but in an inefficient way. This deficiency has been observed in typically developing children, particularly younger children starting to use a novel strategy (Bjorklund *et al.* 1997). This can be an acceptable interpretation for our findings as well.

Another possible reason for the negative results in children with SLI is related to their weakness in working memory and attention control. These children may not have benefited from labelling because it distracted their attention rather than focusing it on the new input. Although labelling minimizes working memory demands in typically developing children, results suggest that it may have interfered with performance in children with SLI. If children do not efficiently remove previous items from working memory, their working memory becomes cluttered, causing interference with current items (Bjorklund and Harnishfeger 1990). This interpretation of our present findings is supported by data from a previous study involving the same sample of children (Marton *et al.* 2012). Results of this study indicated that children with SLI attended to stimuli as well as TLD controls but differed from age-matched children specifically on tasks measuring nonverbal working memory (see spatial span results) and ability to determine relevance of stimuli in a sustained attention task (see rapid visual information processing results). Combined findings of both studies suggest that children with SLI may have difficulty distinguishing between relevant and irrelevant information and allocating resources to process the most relevant items for a given task.

With regard to reaction time, we hypothesized age and language effects in the baseline condition, with slower performance in younger children (TLD-L) and children with SLI compared with the TLD-A group. We also expected that induced labelling would result in faster RT for children with SLI and TLD-L but not in the TLD-A group. Overall, results confirmed our hypotheses. There was, however, a Condition × Group interaction, in addition to a Condition effect, with longer RT in the labelling compared with baseline condition in children with SLI. Labelling had no effect on TLD-L and TLD-A children. RT data were consistent with accuracy results; labelling had a negative effect on both accuracy and speed of processing in children with SLI. Although there are different models of reading aloud suggesting that it is an automatic process, recent data suggest that this process requires a form of attention (O'Malley *et al.* 2008). Thus, reading category names aloud may have placed extra demands on attentional control that did not affect typically developing children but negatively affected children with SLI, who show limitations in this area compared with controls.

The second manipulation involved presentation of pure tones prior to the appearance of category names. This condition was designed to facilitate attention orienting in children. When a cue is presented prior to the stimulus, participants receive advanced preparatory time for activation. Response selection cannot take place

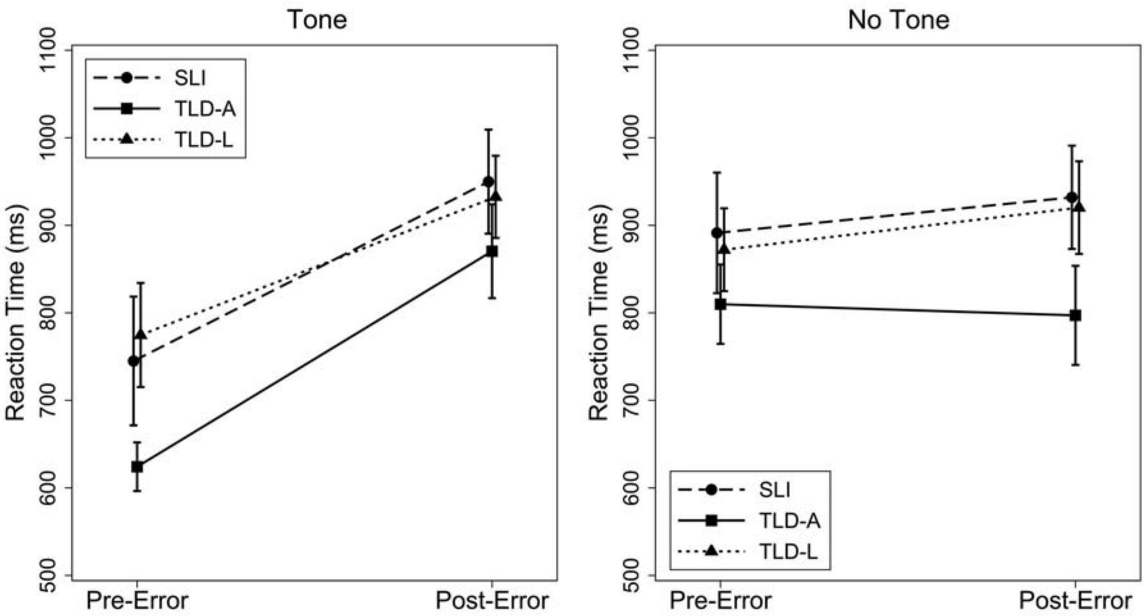

Figure 4. Post-error slowing: effects of group, tone, and position on reaction time. Error bars: ± SE, SLI = children with specific language impairment; TLD-A = age-matched typically developing children; TLD-L = language-matched typically developing children.

during this period because the stimulus has not yet been presented but the cue helps children orient their attention to the upcoming stimulus (Schuch and Koch 2003). We expected presentation of the cue to decrease movement execution time because children are prepared to release the start button. Similarly, we anticipated fewer vigilance errors because the cue helps focus children's attention on the upcoming target.

The data showed no effect of tone on performance accuracy, although results almost reached the level of significance. Overall, TLD-A children were more accurate than TLD-L participants and children with SLI. RT data showed the expected pattern, with all children responding faster in the tone compared with no tone condition, regardless of tone length, indicating that tones helped everyone orient attention to the stimulus. This finding is consistent with the notion that cuing an upcoming item reduces the time needed for stimulus detection, leaving more time to prepare for a task change (Cepeda *et al.* 2001).

The final hypothesis for the tone condition was that the presence of auditory cues would facilitate performance monitoring, as reflected by post-error slowing (longer RT after an error). Based on previous behavioural data on error monitoring in school-age children (Wiersema *et al.* 2007), we expected no group difference in post-error slowing. The data confirmed this hypothesis. Children showed more post-error slowing in the tone compared with no tone condition and groups did not differ in this respect. This finding suggests that children with SLI show performance monitoring patterns that resemble that of their peers. Post-error slowing is often attributed to adaptive cognitive control mechanisms (e.g. Dutilh *et al.* 2012). The orienting account provides an alternative explanation, suggesting that post-error slowing is related to the relative frequency of errors, with infrequent events capturing attention more efficiently than frequent ones (Notebaert *et al.* 2009). This may be the case particularly when attention is already oriented by an external cue. The observed post-error slowing in the tone but not in the no tone condition suggests that children with SLI, like their peers, are able to generate internal feedback when their attention is focused. Thus, they are more cautious after errors and self-regulate their responses by applying more efficient attention control. The results suggest that children with SLI are able to compensate for weakness in attention control if an external cue is presented.

The findings on verbal strategy and auditory cue effects in children with SLI have several clinical implications. The data further support the conclusion of Alt and Spaulding (2011), who recommend that clinicians use caution when training children with SLI to use verbal strategies to support their memory system. Although such strategies may become more automatic with practice, the current research findings suggest limited usefulness of these strategies in school-age children. In contrast, simple auditory cues may more effectively enhance specific aspects of performance in this age group. Although tones in the present study were not contingent upon any aspect of performance, other studies have shown improved performance as a result of tones presented specifically when attention is waning (indexed by RT speeding) and when the link between decreasing attention and tones is made explicit to participants (e.g. Experiment 1; Manly *et al.* 2004). Using tones in this way may be a simple, but effective, way of helping children refocus their attention during speech–language therapy, particularly during tasks that are repetitive. Another important theoretical question is whether post-error behavioural adjustments are achieved by inhibiting inappropriate responses (i.e. selectively suppressing influences of irrelevant material) or facilitating goal-directed ones (by redirecting attention to relevant input) (King *et al.* 2010). This question is particularly relevant for children with SLI who may have difficulty suppressing irrelevant information (Marton *et al.* 2014).

In conclusion, children with SLI are able to use external cues to facilitate performance and behaviour monitoring. The extent of benefit derived from these cues depends on various factors, such as age, cue type, and task complexity. Further research is needed to understand the types of cues that best support children's performance and their ability to monitor and adjust behaviour while completing cognitive tasks.

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