Journal of Communication Disorders 45 (2012) 46–58

Contents lists available at SciVerse ScienceDirect

Journal of Communication Disorders

Declarative and procedural memory in Danish speaking children with specific language impairment

Jarrad A.G. Lum [a,*], Dorthe Bleses [b]

[a] School of Psychology, Deakin University, Melbourne, Australia
[b] Centre for Child Language, University of Southern Denmark, Odense, Denmark

ARTICLE INFO

Article history:
Received 7 December 2010
Received in revised form 2 September 2011
Accepted 5 September 2011
Available online 10 September 2011

Keywords:
Specific language impairment
Procedural memory
Declarative memory
Past tense
Receptive vocabulary
Danish language

ABSTRACT

It has been proposed that the language problems in specific language impairment (SLI) arise from basal ganglia abnormalities that lead to impairments with procedural and working memory but not declarative memory. In SLI, this profile of memory functioning has been hypothesized to underlie grammatical impairment but leave lexical knowledge relatively unaffected. The current study examined memory and language functioning in 13 Danish-speaking children with SLI and 20 typically developing (TD) children. Participants were administered tasks assessing declarative, procedural and verbal working memory as well as knowledge of past tense and vocabulary. The SLI group performed significantly poorer than the TD group on the measure of verbal working memory. Non-significant differences between groups were observed on the measure of declarative memory, after controlling for verbal working memory. The groups were found to perform at comparable levels on the procedural memory task. On the language measures, the SLI group performed significantly poorer than the TD group on the past tense and vocabulary tasks. However, the magnitude of the difference was larger on the task assessing past tense. These results indicate grammatical knowledge is relatively more affected than lexical knowledge in Danish speaking children with SLI. However, the results were not consistent with the proposal linking impaired grammar to impairments with procedural memory. At the same time, the study does not rule out that other aspects of procedural learning and memory contribute to the language problems in SLI.

Learning outcomes: The reader will be introduced to (1) different memory systems, in particular the declarative, procedural and working memory systems and (2) also research examining the relationship between these different memory systems and language in children with SLI.

1. Introduction

Specific language impairment (SLI) describes a developmental impairment affecting language that is not accounted by intellectual impairments, sensory or medical problems (American Psychiatric Association, 2000; World Health Organization, 2004). Despite the apparent dissociation between language and general development, it has consistently been shown that children with SLI often present with a range of co-occurring cognitive and motor problems (for reviews see Hill, 2001; Leonard, 1998; World Health Organization, 2004). This has led to a number of proposals that one or more of the non-linguistic deficits may underlie the language problems (e.g., Leonard, 1998; Montgomery, Magimairaj, & Finney, 2010; Tallal,

* Corresponding author at: School of Psychology, Deakin University, Geelong, Victoria 3217, Australia. Tel.: +61 3 5227 8474; fax: +61 3 5227 8621.
E-mail address: jarrad.lum@deakin.edu.au (Jarrad A.G. Lum).

0021-9924/$ – see front matter © 2011 Published by Elsevier Inc.
doi:10.1016/j.jcomdis.2011.09.001

2004) although, not all models of the impairment consider a causal relationship between non-linguistic and language faculties (e.g., van Der Lely, 2005). Ullman and Pierpont (2005) proposed that the language problems in SLI can be understood in terms of an impaired procedural memory system whose functions are compensated by an intact declarative memory system. The current study investigated procedural and declarative memory in Danish speaking children with SLI.

1.1. The declarative & procedural model of language

Ullman and colleagues (Ullman, 2001a, 2001b, 2004; Ullman et al., 1997) argued that the declarative and procedural memory systems generally support different components of language. Both declarative and procedural memory systems are capable of storing information from minutes to years, but differ with respect to function and supporting neurological structures (e.g., Squire & Zola, 1996). The declarative memory system is principally involved in learning, storing and retrieving general knowledge about the world as well as personal experiences (Eichenbaum, 2000; Squire, Knowlton, & Musen, 1993). A key process undertaken by this memory system is to bind arbitrarily related information; processes that are primarily supported by the medial temporal lobe, in particular the hippocampus (Eichenbaum, 2004; Mayes, Montaldi, & Migo, 2007). Learning via this memory system can be achieved following a single exposure to the target stimuli. However, with repeated exposures the strength of stored representation increases. Ullman argued that the declarative memory system encodes, stores and retrieves aspects of language that are not rule based (Ullman, 2001a, 2001b, 2004). This includes lexical knowledge as well as irregular nouns and verbs where there is an arbitrary relationship between form and meaning.

The procedural memory system is involved in the acquisition, storage and use of information that is sequentially or probabilistically structured (Knowlton, Mangels, & Squire, 1996; Packard & Knowlton, 2002). Initially, procedural memory was considered to primarily support motor routines and habits, however subsequent research has shown an involvement in higher order operations such as probabilistic classification and sequence learning (Knowlton et al., 1996; Seger, 2006). Unlike the declarative memory system, learning via procedural memory requires repeated exposures. The procedural memory system is principally supported by a network that includes the prefrontal cortex, basal ganglia and cerebellum (Packard & Knowlton, 2002). Ullman (2001a, 2001b, 2004) proposed that this system underlies the acquisition and use of grammar such as the regular past tense and regular noun inflections across different language domains including syntax, morphology and phonology. The role of procedural memory in grammar is argued on the grounds that this memory system is better suited to learning and storing of information that may be either deterministic or probabilistic in structure. That is, even though there are differences between information that is deterministically and probabilistically structured both are supported by the procedural memory system.

1.2. Declarative & procedural memory in SLI

Ullman and Pierpont (2005) hypothesized that children with SLI have some form of dysfunction affecting the basal ganglia leading to an impairment of the procedural memory system. At the same time, the model also holds that the medial temporal lobes are largely unaffected thereby sparing the learning and memory functions of the declarative memory system. It is further hypothesized that in SLI, language learning and processing proceeds via the declarative memory system that compensates for the impaired procedural memory system. As a result, lexical items, irregular nouns and verbs as well as all inflectional morphology must be acquired and processed item-by-item via the declarative memory system. While the declarative memory system may be able to learn and process all aspects of grammar, any language related functions that are supported by the basal ganglia are also hypothesized to be impaired. Ullman and Pierpont suggest that lexical retrieval is supported by the basal ganglia and therefore children with SLI should have difficulties recalling regular and irregular forms such as the past tense. Finally, Ullman and Pierpont also suggest that that those aspects of language, which rely largely on the declarative memory system, should be intact in SLI. Specifically, it is hypothesized that children with SLI should be able to complete lexical recognition tasks, because these processes are minimally supported by the basal ganglia.

The difficulty children with SLI have with grammar has been well established. Considerable evidence has accumulated showing that children with SLI have difficulties with syntax and grammatical morphology in both expressive and receptive domains (for review see Leonard, 1998). Of particular relevance to Ullman and Pierpont's claims are findings relating to past tense. Children with SLI have been shown to perform significantly more poorly than typically developing (TD) children on tasks assessing the production of the regular and irregular past tense forms (Marchman, Wulfeck, & Ellis Weismer, 1999; Rice, Wexler, & Cleave, 1995). Interestingly, longitudinal research has shown that the developmental trajectories of regular and irregular past tense use of children with SLI are comparable to TD children. Thus a key difference between past tense use in SLI and TD groups relate to the onset of mastery (Rice, Wexler, & Hershberger, 1998).

The difficulties children with SLI have with grammar are consistent with Ullman and Pierpont's (2005) hypothesis. However, the status of the procedural and declarative memory systems in SLI remains the subject of ongoing research. First, central to Ullman and Pierpont hypothesis is that children with SLI should perform significantly more poorly than typically developing (TD) children on tests of procedural memory. To date, the results of several studies support this position. Both Tomblin, Mainela-Arnold, and Zhang (2007) and Lum, Gelgec, and Conti-Ramsden (2010) examined procedural memory using Serial Reaction Time (SRT) Tasks (e.g., Nissen & Bullemer, 1987). In these tasks participants are repeatedly shown a visual stimulus that appears in different spatial locations on a computer screen. Participants' task is to press a button on a response panel that corresponds to the stimulus' location. Unknown to the participants is that the visual stimulus follows a sequence. In adult and pediatric non-clinical populations' reaction times (RTs) decrease as participants are presented with trials that contain the repeating sequence. However, an increase in RTs is observed when the visual stimulus appears randomly (e.g., Thomas et al., 2004). This increase in RTs is taken as evidence that knowledge about the sequence has been acquired. This is because if no information had been acquired, RTs would be expected to further decrease or reach asymptote after the stimulus begins to appears randomly. This task has been shown to be particularly sensitive to neurological disorders affecting the basal ganglia (Knopman & Nissen, 1991; Siegert, Taylor, Weatherall, & Abernethy, 2006).

In the study undertaken by Lum et al. (2010), TD children and those with SLI were presented with a 10-item sequence that was continuously repeated in four blocks. In the final block, the visual stimulus appeared randomly. After controlling for motor response times and handedness, the TD group evidenced a significantly larger increase in RTs from the sequenced block to the random block, whereas the difference was not significant for the SLI group. This suggests the children with SLI acquired less information about the repeating sequence than the TD children. Tomblin et al. (2007) examined differences between SLI and TD adolescents with respect to the learning rates on a SRT task. Their analyses examined whether there were differences between the groups with respect to the change in RTs over the blocks containing the repeating sequences. This showed that the TD children were faster to reach asymptote than the adolescents with SLI. The study conducted by Tomblin et al. suggests differences in learning of a visuo-spatial sequence.

Procedural memory in SLI has also been studied using probabilistic classification paradigms such as the Weather Prediction Task (Knowlton, Squire, & Gluck, 1994). In this task participants implicitly learn the association between different combinations of four cards, which represent different cues, with one of two outcomes. The relationship between the different combination of cards and outcomes is probabilistic. Thus a rule generated about the relationship between cue and outcome based on a single trial will not always be correct. Performance on this task has been shown to be impaired in adults with neurodegenerative diseases affecting the basal ganglia (Shohamy, Myers, Onlaor, & Gluck, 2004) and spared in those with temporal lobe amnesia (Knowlton et al., 1996). In the study by Kemény and Lukács (2009), children with SLI as well as groups comprising non-language impaired children and adults were presented with the Weather Prediction Task. As anticipated the non-SLI groups' ability to predict outcomes based on the cues improved over the trials. In contrast, there was no improvement in the ability for the SLI group to predict outcomes. Finally, in the verbal domain Evans, Saffran and Robe-Torres (2009) presented evidence suggesting relatively poorer implicit learning of phonotactics in SLI. Thus collectively, there is evidence from a range of different tasks that indicates procedural memory may be impaired in SLI.

Another tenet of Ullman and Pierpont's (2005) hypothesis is that the declarative memory system is intact in SLI. Available research examining declarative memory functioning in SLI provides mixed support for this proposal. In SLI, a number of studies have examined declarative memory using list learning tasks that have been shown to depend on the integrity of the left medial temporal lobe (Helmstaedter, Wietzke, & Lutz, 2009; Jambaqué, Dellatolas, Dulac, Ponsot, & Signoret, 1993; Jambaqué et al., 2007). The general structure of list learning tasks involves repeatedly presenting a single word list to a participant. Usually, the word list is presented three or four times. After each presentation the participant is asked to recall each word. The number of words successfully recalled is typically taken as a measure of learning. After this part of the task has been completed participant's knowledge of the lists is evaluated in either (or both) immediate or delayed recall (and/or recognition) trials. Performance on recall or recognition provides a measure of memory (Lezak, 2004).

Some research has shown that children with SLI perform poorly on composite measures indexing both the learning and the memory components of list learning tasks compared to typically developing children of comparable age and non-verbal intelligence (Cohen, 1997; Lum et al., 2010). Other research has compared children with and without SLI on separate measures assessing learning and memory functioning. Studies by Nichols et al. (2004), Shear, Tallal, and Delis (1992) and Riccio, Cash and Morris (2007) all reported significant differences between SLI and TD children on the learning component of list learning tasks. In relation to recall of studied material, only Nichols et al. (2004) reported a significant difference between SLI and TD children on the recall component. In contrast, Shear et al. and Riccio et al. reported no significant differences in recall.

Individual and group differences in working memory need to be taken into account when examining declarative memory (Ullman & Pierpont, 2005). Working memory supports the short-term storage and processing/manipulation of information (Baddeley, 2003; Cowan, 2005) and has been shown to be supported by the functions of the prefrontal cortex (Baddeley, 2003). Working memory has also been implicated in the encoding and retrieval activities of the declarative memory system (Foerde, Knowlton, Poldrack, & Smith, 2006). Such interactions are to be expected given the connectivity between the medial temporal lobe and prefrontal cortex (Mabbott, Rovet, Noseworthy, Smith, & Rockel, 2009; Ranganath, Johnson, & D'Esposito, 2003). Indeed, it has been suggested that working memory may act as a gateway for information to be encoded and retrieved from long-term memory (Baddeley, 2000).

Children with SLI have been shown to perform poorly on tests assessing verbal working memory (e.g., Ellis Weismer, Evans, & Hesketh, 1999; Gathercole and Baddeley, 1990). That is, they have difficulties with the short term storage and processing of verbal information. In the first instance, Ullman and Pierpont (2005) note that a deficit in working memory is to be expected in SLI following dysfunction of the basal ganglia given the interconnectivity between this part of the brain and the prefrontal cortex. The presence of verbal working memory impairments in SLI represents a potential confound for investigating declarative memory in this population. This is because it is unclear whether previous differences observed between children with and without SLI on declarative memory tests reflect an impairment with declarative memory or working memory. Thus in order to examine declarative memory functioning in SLI it is necessary to take working memory into account.

Collectively, the literature suggests that children with SLI perform significantly more poorly on tasks assessing procedural memory. Differences between children with and without SLI have also been observed on declarative memory tests, but it is unclear whether these results arise because of impaired working memory. These issues were addressed in the current study by examining working, declarative and procedural memory as well as vocabulary and past tense in Danish speaking children with SLI.

1.3. The Danish past tense system

As with English, Danish past tense morphology makes a distinction between regular and irregular verb types. Furthermore, the formation of irregular verbs occurs via vowel change and without suffixation. Based on Ullman's (2001a, 2001b, 2004) claims it would seem plausible that the Danish irregular past tense forms would be supported by the declarative memory systems given the arbitrary association between form and meaning. The Danish language has two regular past tense classes; a small and large class. The large regular class carries an unstressed disyllabic suffix beginning with a schwa-vowel *(-ede* as in *spillede* 'played') and the past tense of the small regular class is formed by adding the suffix *(-te* as in *kaldte* 'called'). However, in spoken Danish, there exist at least five phonetic forms of the large regular class suffix ([sbelɘ ðɘ, sbelɘ dɘ, sbelɘ ð:, sbelɘ ð, sbelɘ d]), depending on the regional speech variant of the child. This is the result of frequent but non-obligatory schwa reductions in combination with consonant gradation. Consonant gradation (Rischel, 1970) has been described as a process whereby an obstruent is turned into a non-lateral approximant. For the small weak class suffix, two distinct different forms co-occur in spontaneous speech, a distinct two-syllable form (kald*te* [kaldɘ] 'called') and a reduced monosyllabic form (as in [kald] 'called'). The existence of assimilated and reduced stop forms also results in overlapping suffixes of the large weak and the small weak classes. Therefore in acquiring past tense morphology, Danish children are frequently faced with phonetically reduced realizations of the regular suffixes that are weakly signaled in the input.

Arguments can be forwarded whereby the Danish regular past tense forms can be supported by either the declarative or procedural memory systems. Ullman and Pierpont's (2005) claimed that the procedural memory supports grammar across sub-domains of language including phonology. Based on this claim, as long as the inflection exhibits rule-like behavior, it will be supported by the procedural memory system. At the same time, if the inflection is no longer distinguishable from the stem, the past tense form may be stored and processes as a lexical item by the declarative memory system.

Available research indicates that in typical development, the acquisition of the regular small class lags behind the regular large class with both forms not acquired until after 8-years of age (Bleses, 1998). Furthermore, at 8-years of age children still have difficulty with irregular past tense forms. One explanation offered to account for differences between children's use of the regular small and large classes are that the phonetic cues for the small weak suffix in Danish are very weakly signaled (Bleses et al., in press). Specifically, the suffix in spontaneous speech is most frequently reduced to a non-syllabic stop form causing this suffix to be very difficult to segment from the stem and therefore hard to identify and generalise from the input. Indeed, these characteristics of the Danish regular past tense system may lend itself to be learnt and processed by the declarative memory system in TD children and those with SLI given the lack of regularity between form and function.

1.4. Aims & hypotheses

The aim of the current study was to examine declarative and procedural memory in Danish speaking children with SLI. In this study children with SLI and a comparison group of TD children were presented with tasks assessing working, declarative and procedural memory. Children were also presented with two language tasks; past tense elicitation and receptive vocabulary tasks. Based on Ullman and Pierpont's (2005) proposals the following hypotheses were forwarded:

1. On the language measures, groups were expected to differ maximally on the regular and irregular past tense task. Smaller differences between the groups were predicted on the task assessing receptive vocabulary.
2. In relation to the memory tests, differences between the children with and without SLI were expected on the measures of working and procedural memory. However, differences between the SLI and TD groups were not expected on the declarative memory test after controlling for working memory.

2. Methods

2.1. Participants

A total of 13 children with SLI aged between 81 and 116 months and 20 TD children of comparable age participated in the study. All children were recruited from Odense and surrounding areas in Funen which is located in Southern Denmark. All children came from homes where Danish was spoken as the first language. Children in the TD group were matched to those in the SLI group with respect to age and gender. Furthermore, they also came from the same schools as those with SLI. The TD children did not have any language or educational difficulties.

2.2. Identification of children with and without SLI

A significant challenge undertaking research with pediatric language-impaired populations in Denmark is the scarcity of standardized tests to assist with identification. As a consequence, the assessment and diagnosis of language problems by speech pathologists is based primarily on clinical observations with less emphasis on psychometric assessment (Slott, Vach, & Bleses, 2008). In order to identify children with SLI, a combination of referrals from speech pathologists and scores from non-standardized as well as standardized tests was used. In the first instance, we contacted speech pathologists to refer children whom they were currently treating in relation to a language problem but did not have co-occurring articulation, hearing, global intellectual impairments or other medical problems. Furthermore, the children did not come from socially disadvantaged backgrounds or from homes where Danish was spoken by either parent as a second language. Between April and October 2009 a total of 19 children were referred to the study and whose parents also consented to participate in the study that met the criteria.

To confirm the referred children as well as the TD children did not have global intellectual impairments they were administered the Raven's Colored Progressive Matrices (RCPM Raven, 1998). This test provides a measure of fluid intelligence and is standardized to a mean of 100 and standard deviation of 15. All children participating in the study required a score of at least 90. Of the 19 referred children with language impairments one child obtained a score 84 and was subsequently excluded from the study.

An attempt was also made to psychometrically identify children with language impairments using the translated Danish version of the Reynell Language Development Scale (D-RLSD Edwards et al., 1997). This test provides measures of expressive and receptive language. At present, normative data for this instrument has not been collected for Danish children older than 5-years of age. Subsequently, in order make quantitative judgments about the language skills of the SLI group we used the modified t-test developed by Crawford and Howell (Crawford & Garthwaite, 2006; Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006; Crawford & Howell, 1998). This test compares whether an individual's test score is significantly different from the mean score of a control group. The procedure is designed specifically when normative data is only available from a small sample size (i.e., <50). When using an alpha level of .05, this version of the modified t-test has been shown to have a Type I error rate (i.e., incorrectly concluding a case to be from an atypical population) of 5% when the normative sample size is 20 and distribution normal. An increase of up to 8% has been observed in situations when the distribution is both extremely skewed and leptokurtic (Crawford & Garthwaite, 2006).

In order for the referred children to be included in the SLI group they were required to have either an expressive or receptive score from the D-RLSD that was significantly lower than the mean score of TD group. Using this criteria a further five children were excluded from the study. All remaining 13 children obtained an expressive score that was significantly lower than the TD group. Only two of the children obtained a receptive language score that was significantly lower than the TD group. Summary statistics showing participants' age and z-scores from the RLDS-D and RCPM are presented in Table 1. The z-scores are referenced to the mean and standard deviation of the entire sample. As to be expected significant differences were only observed on the expressive, receptive and total scores from the RLDS-D. The effect size, expressed as r^2, shows that the difference is considerably larger for the expressive than receptive subtest. In this context r^2 describes, as a proportion, the amount of variance in the dependent variables that is accounted for by the independent variable (i.e., group membership). The larger effect size for the expressive scores arise because all of the children with SLI in the sample had scores that were significantly lower than the mean of the control group. Using Cohen's (1988) taxonomy[1] large effect sizes were observed on all the language measures. Small effect sizes were found for age and scores from the Raven's Colored Progressive Matrices.

2.3. Materials

Children participating in the study were presented with tasks assessing memory and language. An additional task measuring handedness was also presented. The need to assess children's handedness arises from the apparatus used to examine procedural memory which can only be used with the right thumb.

2.3.1. Verbal working memory

Verbal working memory was assessed using the Digit Span Forwards and Backwards subtests from the Wechsler Intelligence Scale for Children – 4th edition (Wechsler, 2003). Confirmatory factor analysis undertaken with children indicates the Digits Span Forward subtest assesses the short-term storage of verbal information and the Digits Span Backwards subtest assesses the short-term storage and manipulation of verbal information (Alloway, Gathercole, Willis, & Adams, 2004).

In the Digit Span subtests, children are asked to repeat a string of digits that increase in number. The digits used in all trials range from 1 to 9. In the Digits Span Forwards subtest children are asked to repeat the numbers verbatim. In the Digits Span Backwards subtest, children are asked to reverse the order of the digits. In the WISC-IV version of the Digit Span task, there are two trials assessing each string length with a score of 1 awarded for each correctly repeated sequence. There are a total of eight trials on each of the Digit Span Forwards and Backwards subtest. Testing is discontinued if the child scores zero on both

[1] According to Cohen (1988) $r^2/\eta^2 = .134$ is large; $r^2/\eta^2 = .059$ is medium and $r^2/\eta^2 = .010$ is small.

Table 1
Summary statistics for age and scores from language and non-verbal intelligence tests.

Variable	SLI ($n = 13$)			TD ($n = 20$)			Comparison of means	
	M	*SD*	Min.–Max.	*M*	*SD*	Min.–Max.	*t*	r^2
Age (months)	92.5	10.1	81–116	95.0	8.6	79–115	0.75	.017
Expressive Language Score[a]	−1.04	0.86	−2.91–0.21	0.71	0.44	−0.48–1.14	7.63**	.621
Receptive Language Score[a]	−0.87	0.74	−2.00–0.68	0.28	0.90	−2.00–1.68	3.86**	.328
Total Language Score[a,b]	−1.14	0.68	−2.27 to −0.02	0.68	0.52	−0.71–1.45	8.48**	.693
Raven's Colored Progressive Matrices[c]	106.8	11.3	97–125	106.5	8.6	92–128	1.16	<.001

[a] Test scores are *z*-scores referenced to the mean and standard deviation of all children participating in the study.
[b] Computing by summing Expressive and Receptive Language scores.
[c] Test standardized to a mean of 100 and standard deviation of 15.
*$p < .05$.
** $p < .001$.

trials assessing the same span. Raw scores from this test were used in the analyses. The maximum score achievable on either of the Digit Span subtests is 16.

A direct translation of this task was used in the study. This did not appear to alter the properties of the test in a substantial way with respect to the syllabic length of each number. In Danish the numbers between 1 and 9 have one syllable with the exception of 4 and 8 that have two.

2.3.2. Declarative learning & memory

A verbal paired-associates task based on the Word Pairs subtest from the Children's Memory Scale (Cohen, 1997) was used to assess declarative learning and memory for verbal information. In this task children were orally presented with a list comprising 14 semantically unrelated word pairs. This list is presented three times, although the order of word pairs in the list varies in each trial. After each trial, children are presented with the first word in each pair and then asked to recall the second. Children were provided with the correct word pair following an incorrect response. After the third trial children are then asked to recall as many word pairs as they can. A measure of learning is obtained by summing the number of words recalled in each of the three trials. Memory was quantified by examining the total number of word pairs recalled in the recall condition. The highest score achievable on a single learning or memory trial was 14.

2.3.3. Procedural memory

Procedural memory was assessed using a version of Nissen and Bullemer's (1987) Serial Reaction Time (SRT) Task. The SRT Task used in this study was the same task previously used by Lum et al. (2010). In this task children implicitly learn a 10-item visuo-spatial sequence. Specifically, a visual stimulus repeatedly appeared in one of four designated spatial locations on a computer display. For this study the locations were arranged in a diamond and marked with white boarders. The only instructions provided to the child were to press the button on a response panel that corresponded to the location that the visual stimulus appeared. The response panel used in this study was a gamepad found in many commercially available computer game consoles. The response panel was held in both hands and the buttons, which were arranged in a diamond shape, were pressed with the right thumb.

Prior to the test phase a series of 10 practice trials was presented to ensure children understood the task. All children participating in the study achieved 90% accuracy. During the test trials the visual stimulus was repeatedly presented in five blocks. Each block consisted of 60 stimulus presentations. Unknown to the children, on the first four blocks, presentation of the visual stimulus followed a 10-item sequence. In the fifth block the visual stimulus appeared pseudo-randomly. Specifically, in this block the number of times the visual stimulus appeared each of the four spatial locations was the same as for the preceding blocks. Furthermore, the probability of the visual stimulus appearing in one of the spatial location given the preceding location was also the same as for the blocks with the repeating sequence.

Children's accuracy and RTs were recorded from this task. Accuracy was described as the proportion of correct button responses. RTs described the amount of time (in ms) it took for children to press the button following presentation of the visual stimulus. For each child, the average RT for each block was computed using only those data points associated with a correct response. One concern with using unadjusted RTs was that individual or group differences observed on this task may arise from differences in children's visuo-motor speed associated with button presses on the response panel. This issue was addressed by converting each child's reaction time to a *z*-score. This procedure has been previously used by Thomas et al. (2004) in order to compare children and adults who differ in gross motor speed. Using this procedure, for each child we transformed their RTs that were associated with a correct response to a *z*-score that was referenced to the median of all valid data points. The median rather than the mean was used as the measure of central tendency because the distribution of RTs was positively skewed. For each child we then computed an average *z*-score for each block. Transforming the data using this approach ensured children's shortest and longest RTs would have approximately the same value regardless of the amount of time taken to press the button. For example, the longest RTs for two children might be 5000 ms and 1000 ms respectively. However, after *z*-normalizing the data, both children might be 3 (i.e., 3 *SD* above the median of their overall RTs).

2.3.4. Past tense task

All children participating in the study were presented with a past tense elicitation task adapted from Bleses (1998) and Bleses et al. (in press). The overall structure of the test was similar to previous past tense elicitation tasks used by Bybee and Slobin (1982). In this task children were shown a picture of someone performing an action (e.g., a boy running) and then presented with a sentence designed to elicit the past tense form of the verb (e.g., The boy knows how to run. The boy runs. The boy did the same thing yesterday. What did he do then? He______________"). The task used in the current study consisted of 51 verbs: 26 irregular verbs and 25 regular verbs. Twelve of the regular verbs were from the large class (suffixed using –*ede*) and 13 were from the small class (suffixed using –*te*). A list of all individual items is presented in Appendix A.

Frequency of the past tense forms were estimated using KorpusDK (Danske Sprog og Litteraturselskab, 2008) which is a database of 56 million words obtained from Danish media organizations, publishing houses, schools, unions, websites and individuals collected between 1990 and 2000. Investigating the frequency of items is important within the context of examining language processing and declarative memory. This is because more frequent items may have an increased propensity to be stored and processed by the declarative memory system. Thus a potential source of difference between verb classes that may account for group differences is past tense frequency. The average frequency per 56 million words for the irregular items was 3543 (*SD* = 4375; *Range*: 80–15083). The frequency for the regular large class was 1534 (*SD* = 1472; *Range*: 224–5311) and for the small class 1638 (*SD* = 1739; *Range*: 161–5485). A between-subjects ANOVA revealed a non-significant effect of verb type on frequency ($F(2, 51) = 2.173$, $p = .125$, *partial* $\eta^2 = .083$). Individual frequencies for each item are also presented in Appendix A.

2.3.5. Vocabulary

A measure of receptive language was presented to the children. In this study children were presented with a translated version of the British Picture Vocabulary Test (Dunn, Dunn, Whetton, & Pintille, 1997). Thus the test items were presented to children in Danish. In this test children are orally presented with a target word and asked to point to one of four pictures that best matches a target word. A child receives a score of 1 for each correct response and testing is discontinued if the child makes eight or more errors in a set of 12. Raw scores from this test were used in the analyses. The highest score that could be obtained is 168.

2.3.6. Controlling for handedness

A measure of handedness was also included in the battery. This was necessary given that the response panel used in the SRT Task required children to press a button with their right thumb. Hand preference was measured using a version of Bishop's Quantification of Hand Preference Task (Bishop, Ross, Daniels, & Bright, 1996; Hill & Bishop, 1998). In this task children are seated in front of seven sets of three cards placed in 30° increments that form a semi-circle around the child. During testing children pick up the cards in a random order and the hand used is noted. In this study a score of 1 was awarded if the child picked up the card with their right hand and 0 for the left. Each child's performance on the task was described as the proportion of total cards picked up with the right hand.

2.4. Procedure

All children were tested individually at his/her respective school. The tasks were presented to the children over three to four sessions lasting approximately 35 min.

3. Results

3.1. Vocabulary and past tense use in Danish children with SLI

The first set of analyses compared the SLI and TD groups on the vocabulary and past tense tasks. Summary statistics for each of these tasks reported by group are presented in Table 2. This table shows that the SLI group obtained lower scores on both tasks. A medium to large effect size was observed for the receptive vocabulary test and large effect sizes for all components from the past tense task. The difference between the groups on the receptive vocabulary test was not found to be statistically significant ($F(1, 31) = 3.897$, $p = .057$, *partial* $\eta^2 = .093$). However, power analysis revealed only a 48.6% chance of detecting a significant effect for this analysis. Thus, the data concerning receptive vocabulary appear to indicate a difference between the groups, as evidenced by the medium to large effect size. However, the sample size was insufficient to evaluate whether this was statistically significantly.

Data from the past tense task was analyzed with a 2 (Group: SLI, TD) × 3 (Past Tense Type: Irregular, Regular-Small, Regular-Large) mixed design factorial ANOVA. This analysis revealed a significant main effect for Group ($F(1, 31) = 34.477$, $p < .001$, *partial* $\eta^2 = .645$) and Past Tense Type ($F(2, 62) = 22.653$, $p < .001$, *partial* $\eta^2 = .544$). The interaction between Past Tense Type and Group was also statistically significant ($F(2, 62) = 4.058$, $p = .022$, *partial* $\eta^2 = .176$). An analysis of simple main effects revealed that within the TD group, there were significant differences between all components of the past tense task (irregular & small regular class, $p < .001$; irregular & large regular class, $p < .001$; regular small class & regular large class $p = .029$). Within the SLI group, the only significant difference reported was between the regular small and large classes ($p = .041$) and between the regular large class and irregular past tense ($p = .016$).

Table 2
Summary statistics for vocabulary and past tense reported by group.

Variable	SLI			TD			Effect size
	M	*SD*	Range	*M*	*SD*	Range	r^2
Vocabulary[a]	77.9	24.8	30–112	91.4	18.2	60–120	.093
Past tense[b]							
Irregular	0.35	0.24	0.10–0.81	0.52	0.20	0.27–0.88	.149
Regular							
Small	0.38	0.16	0.15–0.54	0.79	0.13	0.54–1.00	.677
Large	0.52	0.16	0.33–0.75	0.89	0.10	0.67–1.00	.685

[a] Maximum score = 138.
[b] Shows proportion correct responses.

An additional analysis was conducted to evaluate whether the magnitude of the difference between the SLI and TD groups observed on the vocabulary test (i.e., *partial* η^2 = .093) was comparable to the magnitude of the difference observed on the past tense task (i.e., *partial* η^2 = .645). Examining whether there was a significant difference in effect size was achieved by converting *partial* η^2 to a correlation (i.e., finding the square root of each effect size) and then using a Fisher *z*-transformation to find probability values. This analysis revealed a significant difference in effect sizes (z = 3.07, p = .001). Thus the magnitude of the difference between the groups was significantly larger for the past tense task compared to the receptive vocabulary test.

3.2. Memory functioning in Danish children with and without SLI

The second set of analyses examined differences between the groups on the memory tasks. Summary statistics for the Forward and Backward Digit Span subtests (which measured working memory) and verbal paired associates task (which measured declarative memory) is presented in Table 3. To examine differences between groups on these tasks separate ANOVA's were used. The first set compared groups on the Forward and Backward Digit Span subtests and the second set compared groups on the verbal paired associates task.

Children's performance on the Digit Span Task subtests was examined using a 2 (Group: SLI, TD) × 2 (Task: Forward Digit Span subtest, Backward Digit Span subtest) Mixed Design Factorial ANOVA. This analysis revealed a significant main effect and large effect size for Group (F(1, 31) = 42.770, $p < .001$, *partial* η^2 = .536) and Task (F(1, 31) = 49.497, $p < .001$, *partial* η^2 = .572). The interaction between these two terms was not found to be significant and a small effect size was observed (F(1, 31) = 0.116, p = .736, *partial* η^2 = .003). This result indicates that the SLI group obtained lower scores on both components of the Digit Span subtests.

As an exploratory analysis, differences between the groups on the Digit Span subtests were re-examined controlling for performance on the verbal paired associates task. This was to control for the possibility that differences between the groups on the Digit Span subtests reflected group differences in declarative memory and not verbal working memory. To examine this possibility a 2 (Group: SLI, TD) × 2 (Task: Forward Digit Span, Backward Digit Span) Mixed Design Factorial ANCOVA was used. The covariate in this analysis was the total score from the verbal paired associates task shown in Table 3. After controlling for declarative memory the main effect for group was still found to be statistically significant (F(1, 30) = 24.950, $p < .001$, *partial* η^2 = .454).

The next set of analyses compared the SLI and TD groups performance on the verbal paired associates task. These data were first submitted to a 2 (Group: SLI, TD) × 4 (Task Type: Trial 1, Trial 2, Trial 3, Recall) Mixed Design Factorial ANOVA. Statistically significant main effects and large effect sizes were observed for Group (F(1, 31) = 13.267, $p < .001$, *partial* η^2 = .287) and Task Type (F(3, 93) = 62.423, $p < .001$, *partial* η^2 = .654). The interaction between Group and Task Type was not statistically significant (F(2, 31) = .547, p = .584, *partial* η^2 = .016). The next analysis examined group differences on the verbal paired associates task while controlling for verbal working memory. This analysis was undertaken using the total score from the Digit Span subtests as a covariate. After controlling for verbal working memory the main effect for Group, a medium effect size was observed but this was no longer found to be statistically significant (F(1, 30) = 2.569, p = .119, *partial* η^2 = .079).

Data from the SRT Task (which measured procedural memory) is now presented. In the first analysis, data from the handedness task revealed that the average proportion of cards picked up with the right hand for the TD group was .72 (*SD* = .34, *Range*: 0, 1) and for the SLI group .67 (*SD* = .35, *Range*: 0, 1). This difference was not found to be significantly different (t (31) = 0.395, p = .670, p = .040, r^2 = .005). Thus the groups were comparable with respect to handedness and therefore data from the handedness task was not used as a covariate.

Accuracy from the SRT Task is now examined to ensure children in both groups were responding with equal levels of proficiency. The mean proportion of correct responses for both groups approached ceiling and was well above chance level. Specifically, SLI group was .88 (*SD* = .081; *Range* = .69, .98) and for the TD group .93 (*SD* = .079; *Range* = .68, 1.00). However, the difference between groups on the task did approach statistical significance (t (31) = 1.832, p = .077, r^2 = .089) and subsequently only those RTs associated with correct responses were used in the analysis.

Fig. 1 shows the mean normalized RTs reported by Block and Group. This figure shows a decrease in RTs for both groups from Block 1 to Block 4. There is also an increase in RTs from Block 4 to Block 5 that is evident for both groups. In the first

Table 3
Summary statistics for the digit span and paired associates tasks reported by group.

Variable	SLI			TD			Effect size
	M	*SD*	Range	*M*	*SD*	Range	r^2
Digit Span[a]							
Forwards	4.9	1.3	3–8	7.0	1.3	4–9	.384
Backwards	3.1	1.4	0–5	5.2	1.0	4–8	.449
Total Score[b]	8.0	2.2	4–12	12.2	1.7	9–16	.536
Verbal Paired Associates[c]							
Trial 1	1.6	1.8	0–5	3.5	1.9	0–7	.232
Trial 2	4.2	2.1	1–7	6.5	1.3	5–9	.300
Trial 3	5.9	2.2	2–10	7.5	2.0	2–10	.120
Recall	3.0	1.6	0–5	4.6	2.1	1–7	.167
Total Score[d]	14.7	6.3	5–25	22.0	5.5	12–32	.287

[a] Max. Possible score on either the Forwards or Backwards components is 16.
[b] Total Score is the sum of the correct responses on the Forwards and Backwards components.
[c] Max. Possible score on each trial is 16.
[d] Total Score is the sum of correct responses across Trials 1, 2 and 3 as well as for Recall.

analyses we examined whether both groups demonstrated a significant increase in RTs from Block 4 to Block 5. Given the small sample size, differences between Blocks 4 and 5 were examined separately in each group rather than using a factorial design. The first analysis revealed that the TD group had significantly slower RTs in Block 5 compared to Block 4 ($F(1, 19) = 42.194$, $p < .001$, *partial* $\eta^2 = .690$). The second analysis indicated that the SLI group also had significantly slower RTs in Block 5 compared to Block 4 ($F(1, 12) = 6.354$, $p = .027$, *partial* $\eta^2 = .389$). While both groups were found to have slower RTs in Block 5, it is interesting to note that the effect size for the TD group is larger in comparison to the SLI group. However, the difference in effect sizes was not found to be statistically significant ($z = 1.15$, $p = .250$).

4. Discussion

This study examined memory and language in Danish speaking children with SLI. The broader goal of this investigation was to examine the role of declarative and procedural memory in relation to some of the language difficulties associated with this population. Overall, the results provided mixed support Ullman and Pierpont's (2005) claims. The results from the language tasks were generally consistent with expectations. In particular, the effect size observed for the analyses comparing the SLI and TD groups on past tense was significantly larger relative to the observed effect size examining receptive vocabulary. In relation to the memory tasks, consistent with predictions, significant differences were found on the measure of verbal working memory. Also, the difference between the SLI and TD groups on the declarative memory task was no longer found to be statistically significant after controlling for verbal working memory. However, against expectations both the SLI and the TD groups demonstrated knowledge of the repeating sequence on the SRT Task. This result was not consistent with the hypothesis of a procedural memory impairment in SLI. Collectively, the results indicate that Danish-speaking children with SLI are especially delayed or impaired with respect to grammatical development, compared to vocabulary, but this language profile does not appear to co-occur with an impaired procedural memory system. An important caveat when interpreting these results concerns the study's small sample size. The main limitation associated with small sample sizes concerns the precision of the means, standard deviations and effect sizes computed. Thus, additional research with this population is required to substantiate the results observed in this study.

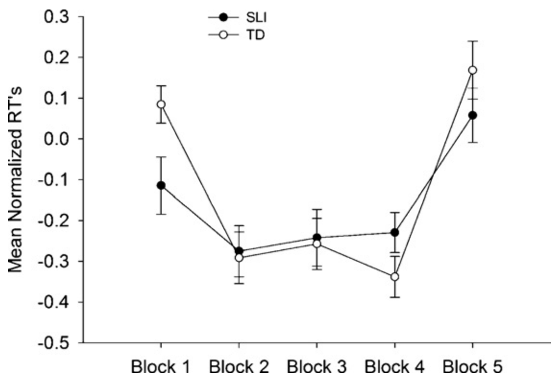

Fig. 1. Normalized mean RT's reported by Group and Block.

To our knowledge no study examining Danish children with SLI has been published in a peer-reviewed journal. Thus comparing the performance of the results of this study to other Danish children with SLI is problematic at this time. However, it is interesting to note that the overall profile of this SLI group mirrors the performance of younger typically developing Danish children, whereby lower levels of accuracy are observed on the regular small class (Bleses, 1998). Thus as noted with English speaking children, the acquisition of past tense in these children may reflect a maturational delay (Rice et al., 1998, 2000). However, in the absence of longitudinal data such proposals are necessarily tentative.

At a broader level, the performance of the SLI group relative to the TD group on the language and memory tasks, parallel results from studies examining SLI in other languages. In the current study, the children with SLI obtained lower scores on the vocabulary and past tense tasks. However, the difference between the groups was larger on the past tense task. This general finding of poor performance on tests assessing grammar relative to vocabulary has been well documented in English speaking children (for a review see Leonard, 1998). Also, the presence of between-subject differences on the past tense task replicates findings reported with other Germanic languages. Specifically, to date this profile has supported in English (Rice et al., 1998), German (Clahsen, Bartke, & Göllner, 1997), Norwegian (Simonsen & Bjerkan, 1998) and Swedish (Håkansson, 2001).

The significant differences observed between the SLI and TD groups on the Digit Span subtests are consistent with a number of studies demonstrating a verbal working memory deficit in this population (Archibald & Gathercole, 2006; Ellis Weismer et al., 1999; Gathercole & Alloway, 2006). On both the Digit Span Forwards and Backwards subtests the children with SLI obtained significantly lower scores than the TD children. Collectively, this indicates a problem with the short-term storage and processing/manipulation of verbal information. Importantly, the differences remained significant after controlling for performance on the verbal paired associates task. Thus difficulties with respect to the short-term storage and manipulation of verbal information is not solely accountable by declarative memory. Overall, along with the past tense results, the current study indicates that previously reported impairments with past tense and working memory also appear to be characteristic of Danish speaking children with SLI.

The current study extends our knowledge concerning declarative memory by showing problems with this memory system may be related to working memory. In the first set of analyses, the SLI group obtained significantly lower scores on both the learning and the recall phases of the verbal paired associates task. This result has been previously reported in several studies undertaken to date (Nichols et al., 2004; Shear et al., 1992). However, the difference between groups was no longer found to be significant after controlling for verbal working memory. Thus as suggested by Ullman and Pierpont (2005), declarative memory problems in SLI may be secondary to verbal working memory problems.

In relation to procedural memory, the non-significant differences reported in this study are inconsistent with a number of recent studies that have examined implicit learning and memory (Kemény & Lukács, 2009; Lum et al., 2010; Tomblin et al., 2007). The difference between the results of this study and that of Tomblin et al. (2007) may reflect methodological differences. The SRT Task used by Tomblin et al. examined implicit learning of a visuo-spatial sequence. In contrast, the SRT Task used in the present study examined children's knowledge of the sequence presented in earlier trials. Thus, even though the results observed in this study indicated that both groups of children demonstrated comparable levels of knowledge on the SRT Task, it cannot be ruled out that the learning rates between the groups were also comparable. Indeed, evidence can be found in this study that suggests there might be differences in the learning rates. Specifically, in the analyses comparing differences in RTs between the sequenced and random block, the effect size was the TD group (*partial* $\eta^2 = .690$) was larger than the SLI group (*partial* $\eta^2 = .389$). This indicates the magnitude of the difference in RTs between the sequenced and random block was larger in the TD group. While the subsequent analysis did not reveal this difference to be statistically significant, caution is required given the small sample size of the study.

In accounting for inconsistent findings of the current study to past research, it is also important to acknowledge differences in the language profile of the participants. In the studies by Tomblin et al. (2007) and Lum et al. (2010), the data reported from the standardized language tests show that the children in their studies had both expressive and receptive language problems.[2] In comparison, nearly all the children with SLI in the current study had language problems confined to the expressive domain. Thus it could be that procedural memory impairments are only present in children with expressive and receptive language problems. An alternative view is that because expressive and receptive language skills are generally correlated (Bishop, 1997), it could be that procedural memory impairments may be related to the severity of the general language problems.

While the results of this study do not necessarily rule out the possibility that language problems in SLI arise from an impaired procedural memory system, it is interesting to note that the data from the past tense task are consistent with phonological processing based accounts of grammatical impairment in SLI. Joanisse and Seidenberg (1998) suggest grammatical deficits including past tense can be understood as a consequence of a phonological processing deficit. This proposal is supported by the claim that the acquisition of past tense forms is dependant upon being able to adequately process and represent the incoming speech so phonotactics can be learnt. As an example Joanisse and Seidenberg point out that the surface form of the English regular past tense inflection is dependent upon whether the final consonant of the verb stem is a vowel or either a voiced or voiceless consonant. The presence of phonological processing deficits in SLI may reduce the ability to accurately represent representations of speech sounds.

The phonotactics of the Danish language may represent a particular challenge for individuals who have difficulties with the veridical representation of speech sounds. As noted earlier, the large regular class in Danish has at least five surface forms

[2] Comparisons with the participants from Kemény and Lukács (2009) study were not possible because data from the language tests was not reported.

and the small class has two. Despite this, children with and without SLI acquire the small regular class at a slower rate. As noted earlier, the phonotactics concerning the use of the small class is not readily accessible in speech which is somewhat consistent with the hypothesis forwarded by Joanisse and Seidenberg (1998). If the problem for these children was limited to induction of a rule or with lexical retrieval we might expect to see children with SLI perform equally poorly on both the small and the large regular class, which was not the case. Thus a phonological processing based account of grammatical impairment in SLI appears consistent with the data concerning verbal working memory and past tense obtained in the current study.

The proposal that children with SLI have difficulty with acquiring phonotactic information might implicate other implicit learning and memory mechanisms (Squire et al., 1993) that are not assessed in SRT paradigms. For instance, a study by Evans et al. (2009) reported that children with SLI evidenced poor learning statistical learning of phonotactic information. The task used in their study examined implicit verbal learning of statistically rather than deterministically structured information. Thus this study does not rule out other implicit memory systems not examined in this study may be related to the language problems in SLI.

5. Conclusion

This study examined memory and language functioning in Danish speaking children with and without SLI. The study reaffirms previous reports of impaired verbal working memory and past tense use in SLI with data from Danish-speaking children, which is a group yet to be studied in detail. The results did not reveal differences between the SLI and TD groups on the measures of declarative and procedural memory. In the first instance this questions whether procedural and declarative memory systems are implicated in the language problems of children with SLI. However the strength of such claims are tempered by the small sample size and differences in the language profile of the children with SLI participating in this study compared to past research. Thus the results of this study may open up the possibility that procedural memory impairments may be related to the severity or type of language problems.

Appendix A. Continuing education

1. Declarative memory primarily supports the:
   a. short-term storage of information.
   b. learning, storing and retrieving of general knowledge and personal experiences.
   c. acquisition of new motor skills.
   d. encoding of visual information only.
2. Working memory primarily supports the:
   a. long-term storage of information.
   b. short-term storage of information.
   c. short-term storage and processing/manipulation of information.
   d. none of the above.
3. Research has repeatedly shown that children with specific language impairment perform most poorly on tasks assessing:
   a. short-term storage and processing/manipulation of visuo-spatial information.
   b. All tasks assessing memory.
   c. short-term storage and processing/manipulation of verbal information.
   d. recall of information in declarative memory tasks.
4. Which memory system is best suited for binding arbitrarily related information?
   a. Working memory.
   b. Declarative memory.
   c. Procedural memory.
   d. All of the above.
5. The structure of the brain named the basal ganglia principally supports:
   a. Declarative memory.
   b. Semantic memory.
   c. Episodic memory.
   d. Procedural memory.

References

Alloway, T. P., Gathercole, S. E., Willis, C. S., & Adams, A. M. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of Experimental Child Psychology, 87*, 85–170.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders: DSM-IV-TR* (4th ed.). Washington, DC: American Psychiatric Association.

Archibald, L. M., & Gathercole, S. E. (2006). Short-term and working memory in specific language impairment. *International Journal of Language & Communication Disorders, 41*, 675–693.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417–423.
Bishop, D. V. M. (1997). *Uncommon understanding: Development and disorders of language comprehension in children*. Hove: Psychology Press.
Bleses, D. (1998). The role of input, productivity and transparency in Danish children's acquisition of past tense morphology. *Odense Working Papers in Language and Communication, 17*, 1–210.
Bleses, D., Basbøll, H., & Vach, W. (in press). Is Danish difficult to acquire? Evidence from Scandinavian past tense studies. Language and Cognitive Processes.
Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience, 4*, 829–839.
Bybee, J. L., & Slobin, D. I. (1982). Rules and schemas in the development and use of the English past tense. *Language,* 265–289.
Bishop, D. V. M., Ross, V. A., Daniels, M. S., & Bright, P. (1996). The measurement of hand preference: A validation study comparing three groups of right handers. *British Journal of Psychology, 87*, 269–285.
Clahsen, H., Bartke, S., & Göllner, S. (1997). Formal features in impaired grammars: A comparison of English and German SLI children. *Journal of Neurolinguistics, 10*, 151–171.
Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.) Hillsdale: Lawrence Erlbaum Associates.
Cohen, J. (1997). *Children's Memory Scales*. London: The Psychological Corporation.
Cowan, N. (2005). *Working memory capacity*. Hove: Psychology Press.
Crawford, J. R., & Garthwaite, P. H. (2006). Methods for testing for a deficit in single-case studies: Evaluation of statistical power by Monte Carlo Simulation. *Cognitive Neuropsychology, 23*, 877–904.
Crawford, J. R., Garthwaite, P. H., Azzalini, A., Howell, D. C., & Laws, K. R. (2006). Testing for a deficit in single-case studies: Effects of departures from normality. *Neuropsychologia, 44*, 666–677.
Crawford, J. R., & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. *The Clinical Neuropsychologist, 12*, 482–486.
Danske Sprog og Litteraturselskab. (2008). *KorpusDK* Retrieved from http://ordnet.dk/korpusdk.
Dunn, L. M., Dunn, L. M., Whetton, C., & Pintille, D. (1997). *British Picture Vocabulary Test* (2nd ed.). Berkshire: NFER-Nelson.
Edwards, S., Fletcher, P., Garman, M., Hughes, A., Letts, C., & Sinka, I. (1997). *Reynell Sprogudviklingsskaler/The Reynell Developmental Language Scales III*. Windsor: NFER-Nelson.
Eichenbaum, H. (2000). A cortical–hippocampal system for declarative memory. *Nature Reviews Neuroscience, 5*, 721–728.
Eichenbaum, H. (2004). Hippocampus: Cognitve processes and neural representations that underlie declarative memory. *Neuron, 44*, 109–120.
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.
Evans, J. L., Saffran, J. R., & Robe-Torres, K. (2009). Statistical learning in children with specific language impairment.. *Journal of Speech Language, and Hearing Research, 52*, 321–335.
Foerde, K., Knowlton, B. J., Poldrack, R. A., & Smith, E. E. (2006). Modulation of competing memory systems by distraction. *Proceedings of the National Academy of Sciences of the United States of America, 103*, 11778–11783.
Gathercole, S. E., & Alloway, T. P. (2006). Practitioner review: Short-term and working memory impairments in neurodevelopmental disorders: Diagnosis and remedial support. *Journal of Child Psychology and Psychiatry, 47*, 4–15.
Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336–360.
Håkansson, G. (2001). Tense morphology and verb-second in Swedish L1 children, L2 children and children with SLI. *Bilingualism: Language and Cognition, 4*, 85–99.
Helmstaedter, C., Wietzke, J., & Lutz, M. T. (2009). Unique and shared validity of the "Wechsler logical memory test", the "California verbal learning test", and the "verbal learning and memory test" in patients with epilepsy. *Epilepsy Research, 87*, 203–212.
Hill, E. L. (2001). Non-specific nature of specific language impairment: A review of the literature with regard to concomitant motor impairments. *International Journal of Language & Communication Disorders, 36*, 149–171.
Hill, E. L., & Bishop, D. V. M. (1998). A reaching test revealed weak hand preference in specific language impairment and developmental co-ordination disorder. *Laterality, 3*, 295–310.
Jambaqué, I., Dellatolas, G., Dulac, O., Ponsot, G., & Signoret, J. L. (1993). Verbal and visual memory impairment in children with epilepsy. *Neuropsychologia, 31*, 1321–1337.
Jambaqué, I., Dellatolas, G., Fohlen, M., Bulteau, C., Watier, L., Dorfmuller, G., et al. (2007). Memory functions following surgery for temporal lobe epilepsy in children. *Neuropsychologia, 12*, 2850–2862.
Joanisse, M. E., & Seidenberg, M. S. (1998). Specific language impairment: A deficit in grammar or processing. *Trends in Cognitive Sciences, 2*, 240–246.
Kemény, F., & Lukács, A. (2009). Impaired procedural learning in language impairment: Results from probabilistic categorization. *Journal of Clinical and Experimental Neuropsychology, 32*, 249–258.
Knopman, D., & Nissen, M. J. (1991). Procedural learning is impaired in Huntington's disease: Evidence from the serial reaction time task. *Neuropsychologia, 29*, 245–254.
Knowlton, B., Squire, L., & Gluck, M. A. (1994). Probabilistic classification learning in amnesia. *Learning and Memory, 1*, 106–120.
Knowlton, B. J., Mangels, J. A., & Squire, L. R. (1996). A neostriatal habit learning system in humans. *Science, 273*, 1399–1402.
Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: The MIT Press.
Lezak, M. D. (2004). *Neuropsychological assessment* (4th ed.). Oxford: Oxford University Press.
Lum, J. A. G., Gelgec, C., & Conti-Ramsden, G. (2010). Procedural and declarative memory in children with and without specific language impairment. *International Journal of Language & Communication Disorders, 45*, 61–71.
Mabbott, D. J., Rovet, J., Noseworthy, M. D., Smith, M. L., & Rockel, C. (2009). The relations between white matter and declarative memory in older children and adolescents. *Brain Research, 1294*, 80–90.
Marchman, V. A., Wulfeck, B., & Ellis Weismer, S. (1999). Morphological productivity in children with normal language and SLI: A study of the English past tense. *Journal of Speech, Language, and Hearing Research, 42*, 206–219.
Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal lobes. *Trends in Cognitive Sciences, 11*, 126–135.
Montgomery, J. W., Magimairaj, B. M., & Finney, M. C. (2010). Working memory and specific language impairment: An update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology, 19*, 78–94.
Nichols, S., Jones, W., Roman, M. J., Wulfeck, B., Delis, D. C., Reilly, J., et al. (2004). Mechanisms of verbal memory impairment in four neurodevelopmental disorders. *Brain and Language, 88*, 180–189.
Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology, 19*, 1–32.
Packard, M. G., & Knowlton, B. J. (2002). Learning and memory functions of the basal ganglia. *Annual Review of Neuroscience, 25*, 563–593.
Ranganath, C., Johnson, M. K., & D'Esposito, M. (2003). Prefrontal activity associated with working memory and episodic long term memory. *Neuropsychologia, 41*, 378–389.
Raven, J. (1998). *Raven's progressive matrices and vocabulary scales*. London: Psychological Corporation.
Riccio, C. A., Cash, D. L., & Cohen, M. J. (2007). Learning and memory performance of children with specific language impairment (SLI). *Applied Neuropsychology, 14*, 255–261.
Rice, M. L., Wexler, K., & Cleave, P. L. (1995). Specific language impairment as a period of extended optional infinitive. *Journal of Speech, Language & Hearing Research, 38*, 850–863.
Rice, M. L., Wexler, K., & Hershberger, S. (1998). Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language & Hearing Research, 41*, 1412–1431.
Rice, M. L., Wexler, R., Marquis, J., & Hershberger, S. (2000). Acquisition of irregular past tense by children with specific language impairment. *Journal of Speech Language, and Hearing Research, 43*, 1126–1145.

Rischel, J. (1970). Acoustic features of syllabicity in Danish. *Proceedings of the 6th International Congress of Phonetic Sciences*, 767–770, Prague: Academia.
Seger, C. A. (2006). The basal ganglia in human learning. *The Neuroscientist, 12*, 285–290.
Shear, P. K., Tallal, P., & Delis, D. C. (1992). Verbal learning and memory in language impaired children. *Neuropsychologia, 30*, 451–458.
Shohamy, D., Myers, C. E., Onlaor, S., & Gluck, M. A. (2004). Role of the basal ganglia in category learning: How do patients with Parkinson's Disease learn? *Behavioral Neuroscience, 118*, 676–686.
Siegert, R. J., Taylor, K. D., Weatherall, M., & Abernethy, D. A. (2006). Is implicit sequence learning impaired in Parkinson's disease? A meta-analysis. *Neuropsychology, 20*, 490–495.
Simonsen, H. G., & Bjerkan, K. M. (1998). Testing past tense inflection in Norwegian: A diagnostic tool for identifying SLI children? *International Journal of Applied Linguistics, 8*, 251–270.
Slott, M., Vach, W., & Bleses, D. (2008). Evaluation of methods used to assess language development of 3–4-year-old Danish children. *Logopedics Phoniatrics Vocology, 33*, 190–207.
Squire, L. R., Knowlton, B., & Musen, G. (1993). The structure and organization of memory. *Annual Review of Psychology, 44*, 453–495.
Squire, L. R., & Zola, S. M. (1996). Structure and function of declarative and nondeclarative memory systems. *Proceedings of the National Academy of Sciences of the United States of America, 93*, 13515–13522.
Tallal, P. (2004). Improving language and literacy is a matter of time. *Nature Reviews Neuroscience, 5*, 721–728.
Thomas, K. M., Hunt, R. H., Vizueta, N., Sommer, T., Durston, S., & Yang, Y. (2004). Evidence of developmental differences in implicit sequence learning: An fMRI study of children and adults. *Journal of Cognitive Neuroscience, 16*, 1339–1351.
Tomblin, J., Mainela-Arnold, E., & Zhang, X. (2007). Procedural learning and adolescents with and without specific language impairment. *Language Learning and Development, 3*, 269–293.
Ullman, M. T. (2001a). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research, 30*, 37–69.
Ullman, M. T. (2001b). A neurocognitive perspective on language: The declarative/procedural model [Review]. *Nature Reviews: Neuroscience, 2*, 717–726.
Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition, 92*, 231–270.
Ullman, M. T., Corkin, S., Coppola, M., Hickok, G., Growdon, J. H., Koroshetz, W. J., et al. (1997). A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience, 9*, 266–276.
Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: The procedural deficit hypothesis. *Cortex, 41*, 399–433.
van Der Lely, H. K. (2005). Domain-specific systems: Insights from grammatical SLI. *Trends in Cognitive Sciences, 9*, 53–59.
Wechsler, D. (2003). *Wechsler Intelligence Scale for Children – fourth edition (WISC-IV)*. San Antonio: The Psychological Corporation.
World Health Organization. (2004). *ICD-10: International statistical classification of diseases and related health problems* (10th revision, 2nd ed.). Geneva: World Health Organization.