Article

Children With Specific Language Impairment and Resolved Late Talkers: Working Memory Profiles at 5 Years

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Purpose: The evidence of a deficit in working memory in specific language impairment (SLI) is of sufficient magnitude to suggest a primary role in developmental language disorder. However, little research has investigated memory in late talkers who recover from their early delay. Drawing on a longitudinal, community sample, this study compared the memory profiles of 3 groups of 5-year-olds: children with SLI who had been identified as late talkers, resolved late talkers (RLTs), and children with typical language development (TLD).
Method: Participants were 25 children with SLI, 45 RLTs, and 32 children with TLD. Subtests from the Working Memory Test Battery for Children and the Children's Memory Scale plus recalling sentences and nonword repetition tasks were administered to test the components of Baddeley's working memory model.
Results: The SLI group showed significantly poorer performance than the RLT and TLD groups on measures of the phonological loop and episodic buffer. The RLT and TLD groups scored similarly on all memory measures.
Conclusions: The results support previous findings that sentence recall and nonword repetition are markers of SLI. Although residual effects of late-talking status may emerge over time, RLTs do not necessarily show memory deficits at 5 years of age despite delayed early vocabulary development.

Key Words: SLI, memory, late talkers

The developmental trajectory of late-talking children is of clinical significance to practitioners providing early identification and intervention services (Roos & Ellis Weismer, 2008). Children are typically identified as late talkers at age 2 years based on a delay in language production in the context of otherwise typical development (Ellis Weismer, 2007). Approximately 50% to 70% of late talkers have been reported to catch up, that is, "recover" from the late start and go on to demonstrate language abilities within the normal range during preschool or early school years (Dale, Price, Bishop, & Plomin, 2003; Paul, Hernandez, Taylor, & Johnson, 1996). Although resolved late talkers (RLTs), by definition, perform within normal limits on standardized language assessments (D'Odorico, Assanelli, Franco, & Jacob, 2007), research has shown that their language often lags behind that of non-late-talkers through childhood and early adolescence (Bishop & Edmundson, 1987; Ellis Weismer, 2007; Girolametto, Wiigs, Smyth, Weitzman, & Pearce, 2001; Paul et al., 1996; Rescorla, 2002, 2005; Roos & Ellis Weismer, 2008), and this can significantly impact upon educational and academic achievement (Reilly et al., 2010; Rescorla, 2005, 2009). Thus, it is important to monitor the development of language-delayed children.

Although some late talkers do catch up in the preschool years, for those children who do not demonstrate other developmental problems, late talking status can be an early indication of specific language impairment (SLI). This is identified when a child has language skills below chronological age expectations that cannot be explained by below normal nonverbal intelligence, sensory impairments, or a social-pragmatic profile associated with autism spectrum disorders (Archibald & Gathercole, 2007a). SLI can be reliably identified using standardized measures by age 4 years. Once children with SLI approach school age, they are likely to continue to have poor language abilities throughout childhood and early adulthood (Bishop & Edmundson, 1987; Brizzolara et al., 2011).

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A significant body of research has focused on the cognitive processes that underlie the language impairments of children with SLI, with many of the studies implicating deficits in working memory as playing a primary role in the developmental language disorder (Archibald & Gathercole, 2006b; Gathercole & Baddeley, 1990; Montgomery, 2000). There is now substantial evidence for memory deficits in children with SLI (Archibald & Joanisse, 2009; Dodwell & Bavin, 2008; Ellis Weismer, Evans, & Hesketh, 1999; Lum, Conti-Ramsden, Page, & Ullman, 2011). What is not known is whether the memory of children who start off as late talkers, but "catch up" is similar to that of late talkers who go on to be identified with SLI. Such research is an important step in understanding why late talkers who appear to catch up might be at risk for poor outcomes in the later school years.

Before discussing research that has investigated working memory of children with SLI and the limited amount of research that has looked at memory in RLTs, a brief description of Baddeley's model of working memory (Baddeley, 2000; Baddeley & Hitch, 1974) will be provided; this is the model that has generally been adopted in previous research. According to Baddeley (2000), *working memory* refers to a limited capacity system responsible for the temporary storage of information while engaging in processing activities. A key component of Baddeley's model is the *central executive,* which is responsible for attentional control, higher order processing activities, and for the coordination of activities within working memory (Baddeley, 1986). The central executive is supplemented by domain-specific slave systems: the *phonological loop,* which is responsible for the temporary storage and manipulation of verbal information; and the *visuospatial sketchpad,* which is responsible for the temporary storage and manipulation of visual and spatial material (Baddeley, 1992). The fourth component, the *episodic buffer,* is a storage system that links information from the components of working memory and long-term memory to form integrated units of visual, spatial, and verbal information in time sequence (Baddeley, 2000).

Phonological Memory

A verbal storage deficit in SLI is often demonstrated with nonword repetition tasks (Coady & Evans, 2008; Lum et al., 2011). Children with SLI aged 4 to 9 years consistently have lower scores than age-matched children with typical language development, particularly when repeating longer nonwords (Bishop, North, & Donlan, 1996; Briscoe & Rankin, 2009; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Laws & Bishop, 2003; Montgomery & Evans, 2009; Nickisch & von Kries, 2009). They seem to have difficulty maintaining the phonological sequence of novel words long enough to establish the links between meaning representations, acoustic input, and articulatory patterns (Evans, Alibali, & McNeil, 2001). Deficits in phonological memory in children with SLI have also been found with regard to digit span recall (Briscoe & Rankin, 2009; Hick, Botting, & Conti-Ramsden, 2005; Hoffman & Gillam, 2004; Nickisch & von Kries, 2009) and word recall (Briscoe & Rankin, 2009; Lum et al., 2011).

Consistent with patterns of performance in children with SLI, deficits in nonword repetition have also been reported for children who have had language problems that have resolved. Studies with 4- to 11-year-old late talkers or children with a history of SLI but who were no longer classified as language impaired have reported significantly lower scores on nonword repetition tasks (Conti-Ramsden, Botting, & Faragher, 2001; Ellis Weismer et al., 2000; Thal, Miller, Carlson, & Vega, 2005). Based on results of a study with 7- to 9-year-old children, Bishop et al. (1996) proposed that although an underlying deficit in phonological memory remains in RLTs, children learn to compensate.

Episodic Buffer

Repeating sentences is regarded as a measure of the episodic buffer, a component of Baddeley's (2000) model of working memory, and is appropriate for children as young as 4 years (Alloway, Gathercole, Willis, & Adams, 2004). The episodic buffer integrates representations from working memory, long-term memory, and language processing systems; thus, repeating sentences requires the integration of phonological information with semantic and syntactic information. Children with SLI and RLTs have been found to have poor accuracy on sentence repetition tasks (Bishop & Adams, 1990; Rescorla, 2002). For example, a group of 53 children identified as late talkers at 2 years, based on the MacArthur Communicative Development Inventory (CDI), scored at age 5 ½ years within the normal range on the Test of Language Development (TOLD–P:3; Newcomer & Hammill, 1997); however, their scores were significantly lower than those of children with typical language development (TLD) on a sentence repetition task (Ellis Weismer, 2007).

Visuospatial Memory

An important question in understanding SLI is whether the memory deficits in SLI are limited to the auditory-verbal memory domain or are characterized by more general memory impairments (Nickisch & von Kries, 2009). Some studies have found no differences in performance on visuospatial memory tasks between children with SLI and children with TLD of comparable age, at ages 7 to 12 years (Archibald & Gathercole, 2006a, 2007a) and 10 years (Lum et al., 2011). However, other studies have reported differences (e.g., Hick et al., 2005; Hoffman & Gillam, 2004; Marton, 2008; Nickisch & von Kries, 2009); the children in these studies were ages 3 to 10 years. Bavin, Wilson, Maruff, and Sleeman (2005) found significant group differences between children with SLI aged 4 to 5 years and age-matched typically developing children on a series of visuospatial memory tasks from the Cambridge Neuropsychological Test Automated Battery (CANTAB; CeNeS_Ltd., 1999). The children with SLI had shorter spatial spans and were significantly less able to learn to associate a particular pattern with a particular location. There were also significant group differences for the first of two blocks of 10 trials testing spatial recognition; the locations of blocks that had appeared on a screen had to be recalled. Different findings across studies may be due to the age of children or differences in the tasks used; for example, the involvement of the central executive may explain the differences, at least in part. Central executive tasks, as discussed in the next section, often require processing with the retention of information for subsequent recall (Archibald & Gathercole, 2007a).

Central Executive

Studies have shown poor performance by children with SLI on central executive tasks (e.g., Archibald & Gathercole, 2006b; Ellis Weismer et al., 1999; Hoffman & Gillam, 2004; Lum et al., 2011). Archibald and Gathercole (2007a) investigated processing and storage abilities of both verbal and visuospatial material by 14 children with SLI aged 7 to 12 years and two groups of typically developing children, matched on age or language abilities. Children with SLI, recruited from language units and special schools in the United Kingdom, had difficulty temporarily storing phonological representations of material while engaging in any type of concurrent information processing. The authors suggested that the combination of both a domain-general slowing in processing with a verbal storage deficit underlie the poor performance of the children. This is consistent with impairments in both central executive and phonological loop functioning in SLI. Whether this applies to RLTs is yet to be investigated.

Justification for the Current Research

Research investigating working memory of children who were late talkers but recovered is limited, and research comparing the memory profile of RLTs with children with SLI and also typically developing children is lacking. Although similarities between RLT and SLI groups have been reported on nonword repetition and sentence repetition tasks, we are not aware of any research testing visuospatial memory or the central executive with RLTs. Furthermore, research investigating all four components of working memory as defined by Baddeley (2000) with children with SLI is limited (but see Hutchinson, Bavin, Efron, & Sciberras, 2012). In addition, studies on the memory of children with SLI typically recruit across a large age range and/or use clinical samples rather than samples that are more representative of the general population.

In the current study, three groups—children with SLI, RLTs, and children with TLD—were tested on a battery of tests focusing on the four components of Baddeley's model of working memory. Participants were drawn from a large community sample. Based on previous research, five hypotheses were made. Hypotheses concerning the RLTs were based on the premise that there may be residual effects of late talking status in terms of memory development because research with older children has reported academic difficulties for some of these children. It was predicted that the children with SLI would have significantly lower scores than the TLD group, and that the RLTs would perform significantly better than the children with SLI but not as well as the TLD group on the following:

1. Measures of phonological memory (digit and word-list recall)
2. A nonword repetition task
3. A measure of the episodic buffer (recalling sentences)
4. Visuospatial memory tasks (block recall and picture location)
5. A central executive task (backwards digit recall)

Method

Participants

Participants were recruited from the Early Language in Victoria Study (ELVS), a prospective, cohort study of language development, in which 1,910 children are being studied from infancy (8 months of age) to school age (7 years of age) in order to document the pathways of language and early literacy development. ELVS children were recruited through Maternal and Child Health Centres in six of the 31 metropolitan Melbourne local government areas (LGAs) in the state of Victoria, Australia. The centres provide regular checkups for children from birth to 6 years. Two LGAs from each of the three tiers of socioeconomic areas, as determined by the Australian census-based Socio-Economic Indexes for Areas (SEIFA) Index for Relative Socioeconomic Disadvantage, were selected to ensure sampling across the spectrum of disadvantage-to-advantage and geographic spread (for further details, see Bavin et al., 2008; Reilly et al., 2006; Reilly et al., 2008; Reilly et al., 2007; Reilly et al., 2010).

To measure vocabulary at the age of 2 years, the MacArthur Communicative Development Inventories (CDI) Words and Sentences (Fenson et al., 1993) was completed by parents. With permission from the authors and publishers, modifications were made to accommodate differences between American and Australian English usage; 24 vocabulary items were substituted (e.g., *couch* for *sofa, pavement* for *sidewalk*). Children were identified as late talkers if the number of words produced was at or below the 10th percentile. The CDI was selected to be used in ELVS because it is commonly used to identify late talkers or children at the low end of the expressive vocabulary distribution (e.g., D'Odorico et al., 2007; Stokes & Klee, 2009). Although studies have typically used standardized parent report measures of language to identify late talkers, some have identified children who had received regular speech-language therapy as late talkers (e.g., Bishop et al., 1996). At age 4 years, the children in ELVS were assessed with the Clinical Evaluation of Language Fundamentals—Preschool, Second Edition (CELF–P2; Wiig, Secord, & Semel, 2006) to identify SLI status.[1] The children with SLI were identified at age 4 years as a subset of the late talkers identified at age 2. Based on the work of Tomblin, Records, and Zhang (1996), the cutoff score for inclusion in the SLI group was at least 1.25 standard deviations below the mean (standard score of 81) on the Expressive and/or Receptive Language scales, and scores in the normal range (standard score of 85 or greater) on the Matrices task of the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 2004), a measure of nonverbal cognitive ability.

One hundred and two 5-year-old children aged 60 to 68 months (M_{age} = 63.03, SD = 1.76) were recruited for the current study. As part of the ELVS project, children were also assessed at age 5 years. At that session, parent information statements about the current study and informed consent forms were given to parents of all children identified with SLI at age 4 years who were late talkers at age 2, children identified as an RLT at age 4, and a stratified sample (across socioeconomic status [SES] areas) of typically developing children identified by the manager of the ELVS project. Late talkers from non-English-speaking and bilingual backgrounds were excluded in the recruitment, because having a second language in the first 2 years is a possible confound in determining vocabulary level using the CDI (Fenson et al., 1993). Children who participated in other substudies of ELVS were excluded so as not to overtax the families. At the time of recruitment, no child was identified as having a hearing, neurological, or social impairment, or a known developmental delay (other than language). Figure 1 is a flowchart showing the number of children, by language group and gender, participating in the current study: those who met criteria for inclusion in the SLI, RLT, and TLD groups at age 4 years and who were invited because they were not included in other substudies.

Using the recruited sample, a one-way analysis of variance (ANOVA) revealed a main effect of group when comparing the K-BIT Matrices standard scores across the three groups, $F(2, 97) = 5.97$, $p = .004$, $\eta^2 = .11$. The RLT group had significantly higher K-BIT standard scores than both the SLI and TLD groups. To control for the influence of nonverbal cognitive ability on any group differences on the memory measures, the children in the RLT group with the two highest standard scores (127 and 124) were excluded from analyses (n = 5). Although the resulting RLT group had a higher mean score on the Matrices subtest than the other two groups (see Table 1), no significant group differences on the standard scores were found at the .05 alpha level. Post hoc comparisons using Tukey's honestly significant difference (HSD) test indicated that for nonverbal cognitive abilities there were no significant differences between the RLT and SLI groups (p = .16), or the RLT and TLD groups (p = .07).[2]

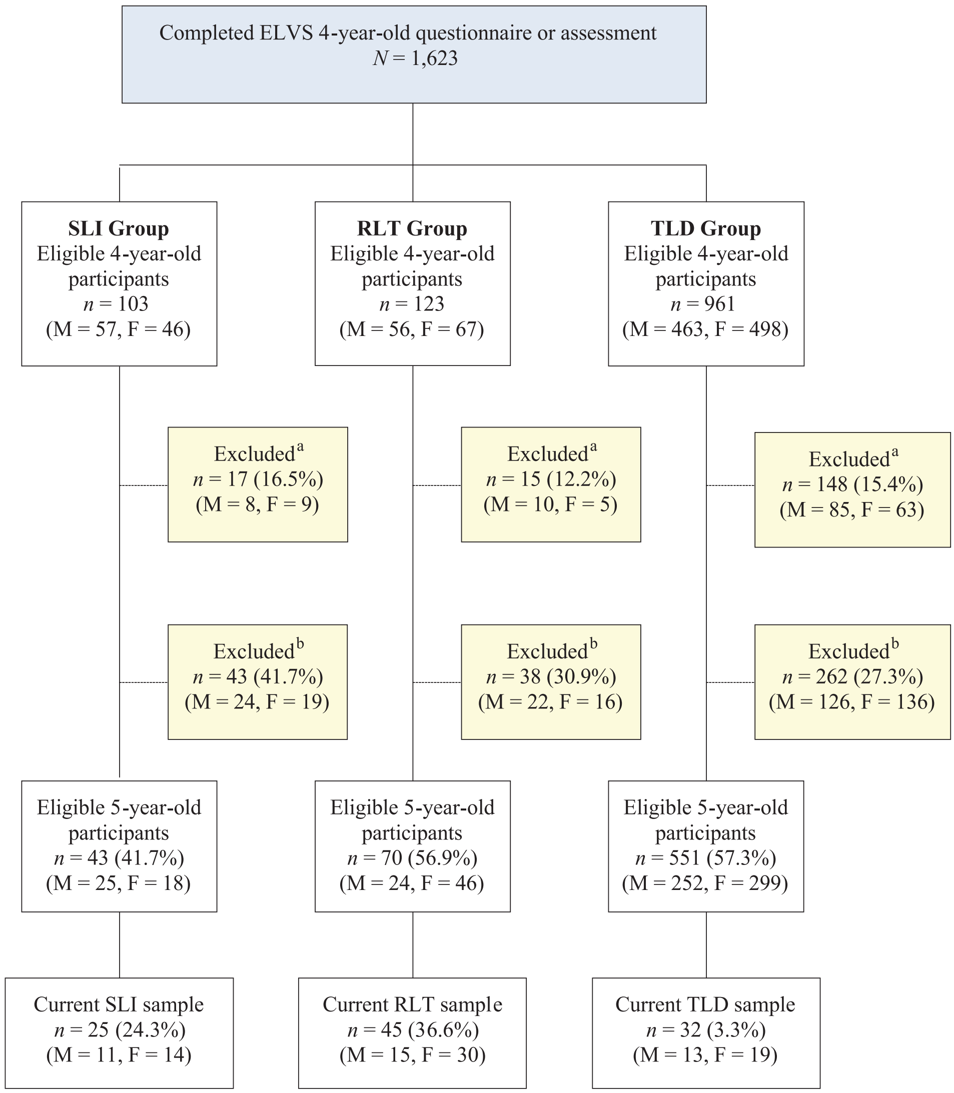
Data are reported for the final sample of 95 children. There were three groups: 24 children with SLI (M_{age} = 63.29 months, SD = 1.99; male = 10, female = 14), 39 RLTs (M_{age} = 62.87, SD = 1.64; male = 13, female = 26), and 32 children with TLD (M_{age} = 63.19, SD = 1.75; male = 13, female = 19). A summary of the characteristics of each group is presented in Table 2. A one-way ANOVA confirmed that there was no significant group difference in age, $F(2, 92) = 0.50$, $p = .61$, $\eta^2 = .01$. The uneven distribution of boys and girls in the groups, particularly in the RLT group, reflects the disproportionate number of girls whose parents consented to their participation in the study.

Based on the composite scores from the Expressive and Receptive subtests of the CELF–P2, nine children from the SLI group met the criteria for Expressive SLI—that is, a standard score of 81 or below on the Expressive scale and a standard score above 81 on the Receptive scale. Seven children met the criteria for Receptive SLI (standard score of 81 or below on the Receptive scale, with

[1]A language assessment, Clinical Evaluation of Language Fundamentals—Fourth Edition (CELF–4; Semel, Wiig, & Secord, 2003), was conducted when the children turned 5 years of age. However, scores were not available at the time of recruitment for the current study, and thus the data collected from the children at 4 years old were used to identify the language status of the participants for this research.

[2]Two additional children were assessed but were subsequently excluded from analyses: One child in the SLI group was later diagnosed with an autism spectrum disorder, and a developmental delay was confirmed for one child in the RLT group.

Figure 1. Flowchart of the number of ELVS children (broken down by language group and gender) from the ELVS 4-year-old assessment who participated in the current study. M = male; F = female. [a]Cases excluded due to child taking part in another substudy of ELVS. [b]Cases excluded due to no 5-year-old assessment data.



standard score above 81 on the Expressive scale), and the remaining eight children were classified as mixed Expressive-Receptive SLI (standard scores at or below 81 on both the Expressive and Receptive scales). The Expressive composite scores for children in the Receptive SLI group were 87 or greater. The children in the TLD group were not late talkers at age 2 years and not identified with SLI at age 4 years. Standard scores for the screening measures at age 2 and 4 years for each group appear in Table 1.

Working Memory Measures

Phonological memory. Three tasks were included to measure the phonological loop: Digit Recall and Word List Recall from the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001) and the Children's Test of Nonword Repetition (CNRep; Gathercole & Baddeley, 1996). The CNRep was included in addition to the two phonological loop tasks because it has been well used in SLI research and it is argued to tap cognitive processes, including speech perception, phonological representations, lexical knowledge, and speech motor output processes (e.g., Archibald & Gathercole, 2006c; Bishop et al., 1996). Alloway and colleagues (2004) found that children's performance on digit recall, word list recall, and nonword repetition tasks were moderately to highly correlated, indicating that these measures tap the same underlying memory component.

Table 1. Comparison of groups (SLI, RLT, and TLD) on screening measures: Vocabulary production, nonverbal IQ, and CELF Expressive and Receptive Language scores.

	SLI			RLT			TLD		
Measure	*M*	*(SD)*	[Min.–Max.]	*M*	*(SD)*	[Min.–Max.]	*M*	*(SD)*	[Min.–Max.]
CDI: Vocabulary	55.96[a]	(37.51)	[1–116]	57.87[a]	(38.49)	[0–187[c]]	321.16[b]	(120.72)	[139–503]
K-BIT	102.29	(10.45)	[85–118]	106.85	(9.90)	[86–121]	101.75	(7.96)	[90–118]
CELF–P2: Expressive composite	80.36[a]	(7.31)	[70–100]	100.00[b]	(9.89)	[85–124]	105.19[b]	(10.52)	[91–126]
CELF–P2: Receptive composite	79.04[a]	(7.20)	[64–92]	100.36[b]	(9.26)	[86–115]	103.37[b]	(8.50)	[88–118]

Note. CDI = MacArthur Communicative Development Inventories; K-BIT = Kaufman Brief Intelligence Test; CELF = Clinical Evaluation of Language Fundamentals—Preschool, Second Edition. The CDI was used to assess children at 2 years old; the K-BIT and CELF–P2 were used to assess children at 4 years old.
[a, b]Group means for the same variable with different superscripts differ significantly at $p < .01$ in the Tukey's HSD comparison. [c]One child in the RLT group was aged 29.5 months at testing; she received a raw score of 187, but this was at the 4th percentile for her age. Next highest score in the RLT group was 126.

Episodic buffer. The Recalling Sentences task from the Clinical Evaluation of Language Fundamentals—Fourth Edition (CELF–4; Semel et al., 2003) was included.

Visuospatial memory. Two tasks were included to measure the visuospatial sketchpad: the Block Recall task from the WMTB-C and the Picture Locations task from the Children's Memory Scale (CMS; Cohen, 1997).

Central executive. The Backwards Digit Recall test of the WMTB-C (Pickering & Gathercole, 2001) was used as a measure of the central executive.

Procedure

Ethics approval to undertake the study was obtained from the La Trobe University Human Ethics Committee and the Royal Children's Hospital Human Research Ethics Committee. Following the 5-year-old ELVS assessment, parents who indicated that they agreed to have their child participate on the returned informed consent form were contacted, and an appointment was made. The first author tested all children individually in one session, which lasted approximately 50 min. All testing was conducted in a quiet area of the child's home or the Language Research Unit at La Trobe University, depending on parents' preference. The examiner was blind to the language status of the children at the time of the assessment and scoring.

Table 2. Characteristics of the three groups of children: children with specific language impairment (SLI), resolved late talkers (RLT), and children with typical language development (TLD).

	Group		
	SLI	RLT	TLD
Characteristic	(*n* = 24)	(*n* = 39)	(*n* = 32)
Chronological age (months)			
M	63.29	62.87	63.19
SD	1.99	1.64	1.75
Gender			
Male	10	13	13
Female	14	26	19
LGA (SES)			
Low	8	11	10
Medium	3	11	7
High	13	17	15

Note. LGA = local government areas; SES = socioeconomic status.

Results

The frequency distribution of each variable was assessed for violations of the assumption of normality using standardized indices (z) of skewness and kurtosis with a conservative criterion of $\alpha = .001$ (see Tabachnick & Fidell, 2007). No variable was found to violate the assumption of normality. Outliers were identified in the following variables: Digit Recall, CNRep, Recalling Sentences, Picture Locations, and Backwards Digit Recall (see Table 3 for the number of lower and upper bound outliers in each group). Prior to statistical analyses, the outlying scores were moved to the next highest (or lowest) possible score plus (or minus) 1, depending on whether it was an upper or lower bound outlier (Tabachnick & Fidell, 2007, p. 77).

A combination of ANOVA and multivariate analysis of variance (MANOVA) was used to test group differences on the memory measures. When the null hypothesis was rejected, pairwise comparisons using post hoc Tukey's HSD tests were performed. Mixed-model repeated-measures ANOVAs were also used to investigate group differences on the CNRep task and, when significant effects were found, univariate ANOVAs were evaluated using a Bonferroni adjusted error rate. Descriptive statistics for the working memory measures for each group are provided in Table 4.

Table 3. Number of lower and upper bound outliers in each group on the measures of working memory.

Variable	Lower Bound Outliers Group SLI	RLT	TLD	Upper Bound Outliers Group SLI	RLT	TLD
Digit Recall	1	0	0	1	0	0
CNRep	0	0	0	2	0	0
Picture Locations	0	1	0	0	0	0
Backwards Digit Recall	0	0	1	0	1	2
Recalling Sentences	0	0	1	0	0	0

Note. CNRep = Children's Test of Nonword Repetition.

Phonological Memory

To examine Hypothesis 1, a Phonological Measure (Digit Recall and Word List Recall) × Group (SLI, RLT, TLD) MANOVA was performed. The CNRep was analyzed separately from the other two measures of phonological memory, because it did not come from the same test battery and because it did not correlate significantly with word list recall for any group, nor with digit recall for the SLI group.

A main effect for group was found, $F(4, 182) = 6.03$, $p < .001$, $\eta_p^2 = .12$, with a medium effect size. When the results for the dependent variables were considered separately, the only significant group difference was on digit recall, $F(2, 91) = 13.03$, $p < .001$, $\eta_p^2 = .22$; word list recall, $F(2, 91) = 2.26$, $p = .11$, $\eta_p^2 = .05$. Post hoc Tukey's HSD tests indicated that children with SLI scored significantly lower than both the RLT group ($p = .002$) and the TLD group ($p < .001$), whereas the RLT and TLD groups did not differ significantly ($p = .13$).

On the digit recall task, 6.3% of children with TLD and 12.8% of the RLTs scored 1 standard deviation (i.e., < 86) below the mean, as compared to 29.2% of children with SLI. On the word list recall task, 16.1% of children with TLD and 17.9% of RLTs scored 1 standard deviation below the mean, as compared to 29.2% of children with SLI. Separate chi-square tests of independence indicated that relative to children with TLD, a greater number of children with SLI scored 1 standard deviation below the mean on the digit recall task ($p = .03$, one-sided Fisher's exact test), but not on word list recall, $\chi^2(1, n = 55) = 1.35$, $p = .25$. A similar number of RLTs and children with SLI scored more than 1 standard deviation below the mean on digit recall ($p = .18$, two-sided Fisher's exact test) and word list recall, $\chi^2(1, n = 63) = 1.08$, $p = .30$.

A univariate ANOVA was used to assess group differences on the CNRep. The results indicated a significant group difference: $F(2, 86) = 5.46$, $p = .006$, $\eta_p^2 = .11$. Tukey's HSD post hoc comparisons indicated that children with SLI accurately repeated significantly

Table 4. Mean standard scores, standard deviations, and range of scores for each of the working memory measures.

Measure	SLI *M*	*(SD)*	[Min–Max]	RLT *M*	*(SD)*	[Min–Max]	TLD *M*	*(SD)*	[Min–Max]
Phonological Loop									
Digit Recall	86.87[a]	(7.18)	[75–101]	96.56[b]	(12.94)	[69–125]	101.50[b]	(9.71)	[83–122]
Word List Recall	90.46	(11.11)	[70–113]	97.28	(18.09)	[59–129]	99.39	(16.22)	[65–124]
CNRep	89.05[a]	(15.90)	[68–115]	97.78	(14.72)	[71–130]	104.13[b]	(17.86)	[78–137]
Episodic Buffer									
Recalling Sentences	6.08[a]	(2.57)	[2–12]	9.33[b]	(2.32)	[4–14]	10.47[b]	(1.92)	[6–14]
Visuospatial Sketchpad									
Block Recall	86.46[a]	(17.99)	[57–112]	97.85[b]	(16.62)	[63–125]	90.56	(16.59)	[60–115]
Picture Locations	9.12	(2.88)	[4–15]	10.15	(2.59)	[5–15]	9.37	(2.48)	[4–15]
Executive Functioning									
Backwards Digit Recall	82.46	(10.05)	[66–96]	86.33	(12.89)	[66–112]	89.72	(10.20)	[70–107]

Note. Means in the same row with different superscripts differ significantly at $p < .05$ in the Tukey's HSD comparison. Means without superscripts do not differ from other means in the same row ($p > .05$).

fewer nonwords than the TLD group (p = .004). The mean performance of the RLTs (M = 97.78) was between that of the children with SLI (M = 89.05) and children with TLD (M = 104.13); however, no further significant group differences were found. Correct scores for short (two + three syllable) and long (four + five syllable) nonwords were then compared. The mean raw scores, standard deviations, and ranges of scores for the three groups at each length (maximum score of 20) are displayed in Table 5.

The results of a Language Group (SLI, RLT, TLD) × Syllable Length (short, long) mixed-model repeated-measures ANOVA revealed no significant interaction, $F(2, 86) = 2.09$, $p = .13$, $\eta_p^2 = .05$. However, there was a significant main effect for group, $F(2, 86) = 4.89$, $p = .01$, $\eta_p^2 = .10$, with a medium effect size, and a significant main effect of syllable length with a large effect size, $F(1, 86) = 442.35$, $p < .001$, $\eta_p^2 = .84$. All groups accurately repeated more short nonwords than long nonwords. Univariate ANOVAs revealed significant group differences on the long nonwords, $F(2, 86) = 5.30$, $p = .007$, $\eta_p^2 = .11$, but not on the short nonwords, $F(2, 86) = 2.38$, $p = .10$, $\eta_p^2 = .05$. For the long nonwords, post hoc comparison using Tukey's HSD test showed that the SLI group accurately repeated significantly fewer nonwords than the TLD group (p = .005). However, there was no significant difference between the SLI and RLT groups (p = .16), or the TLD and RLT groups (p = .22).

Episodic Buffer

To examine the hypothesis that significant differences would be found among the three groups on the measure of the episodic buffer (recalling sentences task), a one-way ANOVA was performed, with group as the between-subjects factor. As predicted, a significant large effect of group was found: $F(2, 92) = 27.03$, $p < .001$, $\eta_p^2 = .37$. Post hoc comparisons using Tukey's HSD test indicated that performance of both the RLT ($p < .001$) and TLD ($p < .001$) groups was significantly higher than that of the SLI group, whereas no difference was found between the RLT and TLD groups (p = .09).

Visuospatial Memory

Because the measures of the visuospatial sketchpad were taken from two different standardized test batteries, two separate one-way ANOVAs were conducted. For block recall, the one-way ANOVA yielded a significant overall effect of group: $F(2, 92) = 3.67$, $p = .03$, $\eta_p^2 = .07$. Post hoc comparisons using Tukey's HSD test revealed that the RLT group outperformed children with SLI (p = .03), whereas there was no significant difference between the SLI and TLD groups (p = .64). No difference was found between the RLT and the TLD groups (p = .17). For picture locations, the one-way ANOVA revealed no significant between-group differences: $F(2, 92) = 1.36$, $p = .26$, $\eta_p^2 = .03$.

Central Executive

Performance on the backwards digit recall task was analyzed using a one-way ANOVA. Although the mean standard score for the SLI group was lower than that of the RLT and TLD groups, the between-group difference was not significant and the effect size was small, $F(2, 92) = 2.81$, $p = .06$, $\eta_p^2 = .06$. However, 41.7% of the children with SLI scored at least 1 standard deviation below the mean, as compared to 35.9% of the RLTs and 25% of children with TLD. Two chi-square tests for independence indicated that, compared to children with SLI, a similar number of children with TLD, $\chi^2(1, n = 56) = 1.75$, $p = .19$, and RLTs, $\chi^2(1, n = 63) = 0.21$, $p = .65$, scored more than 1 standard deviation below the mean on this task. All three groups seemed to find this task difficult, suggesting it is not a good discriminatory tool at this age.

Further Analyses

The groups did not differ significantly on nonverbal IQ as measured by the K-BIT Matrices subtest. However, given that nonverbal IQ could contribute to individual performances, analyses using an analysis of covariance (ANCOVA) or a multivariate analysis of covariance (MANCOVA) were conducted to determine if the results held if K-BIT standard scores were included as a covariate in the analyses (see Table 6 for adjusted means and

Table 5. Comparison of 5-year-old children with SLI, RLTs, and children with TLD on the number of short and long nonwords correctly repeated on the CNRep.

	SLI			RLT			TLD		
Syllable Length	*M*	*(SD)*	[Min.–Max.]	*M*	*(SD)*	[Min.–Max.]	*M*	*(SD)*	[Min.–Max.]
Short	13.05	(3.37)	[8–19]	14.11	(2.82)	[7–19]	14.90	(2.98)	[7–20]
Long	4.33^a	(3.44)	[1–11]	6.43	(4.05)	[1–14]	8.13^b	(4.62)	[2–17]

Note. Means in the same row with different superscripts differ significantly at $p < .05$ in the Tukey's HSD comparison. Means without superscripts do not differ from other means in the same row ($p > .05$).

Table 6. Mean standard scores and standard errors for each of the working memory measures, after adjusting for nonverbal IQ.

Measure	SLI *M*	SLI *SE*	RLT *M*	RLT *SE*	TLD *M*	TLD *SE*
Phonological Loop						
Digit Recall	87.01	2.20	96.34	1.75	101.82	1.95
Word List Recall	90.74	3.27	96.82	2.60	99.75	2.89
CNRep	89.01	3.55	97.90	2.72	104.01	2.96
Episodic Buffer						
Recalling Sentences	6.12	0.46	9.28	0.37	10.51	0.40
Visuospatial Sketchpad						
Block Recall	86.79	3.47	97.27	2.77	91.01	3.03
Picture Locations	9.12	2.88	10.15	2.59	9.37	2.48
Executive Functioning						
Backwards Digit Recall	82.55	2.34	86.18	1.86	89.84	2.03

standard errors). The results showed that for the measures of the phonological loop, episodic buffer, and central executive, adjusting for nonverbal cognitive ability did not alter the results. The significant group differences were maintained, with no change to the effect size, on digit recall, $F(2, 90) = 12.93$, $p < .001$, $\eta_p^2 = .22$; CNRep, $F(2, 85) = 5.30$, $p = .007$, $\eta_p^2 = .11$; and recalling sentences, $F(2, 91) = 26.73$, $p < .001$, $\eta_p^2 = .37$, and no significant group differences on word list recall, $F(2, 90) = 2.19$, $p = .12$, $\eta_p^2 = .05$, and backwards digit recall, $F(2, 91) = 2.82$, $p = .06$, $\eta_p^2 = .06$. After adjusting for nonverbal IQ, there were no longer significant between-group differences on measures of the visuospatial sketchpad: block recall, $F(2, 91) = 2.88$, $p = .06$, $\eta_p^2 = .06$; picture locations, $F(2, 91) = 1.06$, $p = .35$, $\eta_p^2 = .02$. That is, the between-group difference found originally on block recall can be attributed to individual children's performance on the K-BIT Matrices task.

Discussion

The purpose of this study was to compare performance on different components of memory, based on Baddeley's working memory model (Baddeley, 1986, 2000), in 5-year-old children with SLI, RLTs, and children with TLD. The RLT and SLI groups were subsets of late talkers identified at age 2. The results are considered in relation to the five hypotheses presented at the end of the Introduction.

Phonological Memory

Inconsistent with Hypothesis 1, there were no significant group differences on word list recall. However, although there was no significant difference between the RLT and TLD groups on digit recall, the children with SLI performed significantly poorer than the RLTs and the children with TLD. The results from the digit recall task support previous findings showing that children with SLI have limited phonological working memory capacity, which has been shown to impact on language development (e.g., Archibald & Gathercole, 2006b, 2007a; Bishop et al., 1996; Gathercole & Baddeley, 1990; Hick et al., 2005). In contrast, despite early language delay, RLTs do not necessarily show deficits in phonological loop capacity at age 5 years. On the basis of impairments relative to chronological age (scores below 1 standard deviation of the population mean), Archibald and Gathercole (2006b) demonstrated deficits in the performance of children with SLI, aged 7 to 11 years, on both digit and word list recall; 60% of the children with SLI in that study scored at least 1 standard deviation below the mean on digit recall; 70% performed similarly on word list recall. This is a much higher percentage than in the present study, with 29.2% of the children with SLI scoring at least 1 standard deviation below the mean on these tasks. Age may explain the different results; there may be more variability in younger children. In the current study, children were approximately 4 years younger than those in the Archibald and Gathercole study. As Luciana and Nelson (1998) argue, memory develops between the ages of 4 and 8 years and verbal span increases, and as variability decreases, group differences may become significant.

The repetition of nonwords requires greater reliance on the temporary storage of phonological representations than words or digits (Archibald & Gathercole, 2007b). Impaired nonword repetition of children with SLI relative to their typically developing peers in the current study supports Hypothesis 2 and adds to previous research that has consistently reported deficits in nonword repetition for children with SLI (e.g., Archibald & Gathercole, 2006c; Briscoe & Rankin, 2009; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Montgomery & Evans, 2009; Redmond, Thompson, & Goldstein, 2011). Also consistent with past research, the SLI group demonstrated significant difficulty repeating the longer nonwords, reflecting limited phonological working memory capacity (Gathercole & Baddeley, 1990). This finding supports a phonological memory deficit in SLI. Although short nonwords are not sufficient to overwhelm working memory span, longer items may surpass phonological working memory resources, resulting in difficulties in encoding phonological representations and maintaining these representations in working memory. However, successful nonword repetition involves a number of processes, including speech perception, phonological encoding and assembly, phonological knowledge, motor planning, and articulation (Coady & Evans, 2008). That is, children hearing a new word must first perceive and encode the sequence and then be able to hold the sequence in a temporary memory store with a robust enough representation to support further processing, articulation, and connection to meaning (Graf Estes, Evans, & Else-Quest, 2007). Children with SLI may experience deficits at any point, or at multiple points in this sequence.

Although the RLT group had a higher mean accuracy in repeating nonwords than the children with SLI and a lower mean accuracy than the TLD group, their performance on the CNRep was not significantly different from either group. Thal and colleagues (2005) found that 4-year-old children with a "history of language delay" had impaired performance on a nonword repetition task. The late talkers in Thal et al.'s study were identified at an earlier age (16 months), and there were differences in group characteristics. As suggested by Ellis Weismer (2007), the age at which late talkers are identified is an important consideration. Both studies used the CDI, but children in the current study were identified as late talkers at 24 months. Furthermore, although children with a history of language delay in Thal et al.'s study did not have impaired language at age 4 years, their performance was significantly lower than that of typically developing children on measures of receptive and expressive language and cognitive processing. In the current study, the RLT and TLD groups did not show significant differences on the CELF–P2 Expressive and Receptive scales, or on the measure of nonverbal cognitive ability, the K-BIT. In summary, the current findings show that despite an early history of language delay, RLTs in our study were performing within the normal limits on measures of phonological memory at 5 years of age.

Episodic Buffer

The SLI group had significantly lower scores than the other two groups on the measure of the episodic buffer, recalling sentences. Poor sentence-recall performance in SLI has been well reported in previous studies (e.g., Laws & Bishop, 2003; Redmond et al., 2011), and it has been suggested as a clinical marker for SLI in both children and adults (Archibald & Joanisse, 2009; Conti-Ramsden et al., 2001; Poll, Betz, & Miller, 2010).

The lack of a significant difference between the RLT and TLD groups provides no evidence for deficits in retaining verbal information while accessing stored linguistic material in RLTs. In a longitudinal study, Rescorla (2002) found that, at age 6 years, late talkers performed significantly poorer than typically developing children on a sentence-imitation task. However, the late talkers in Rescorla's study were not separated into subsamples of RLTs and children with SLI, as in the current study. The late talkers in Rescorla's study continued to have lower scores on most language measures than the comparison children, and 6% to 17% of the late talkers (depending on the criterion used) appeared to manifest SLI.

Visuospatial Memory

The results did not provide support for Hypothesis 4. The SLI and TLD groups did not differ significantly on the visuospatial memory tasks. Although this result was not predicted, findings regarding visuospatial working memory in children with SLI have been mixed. Children with SLI have been found to have impaired performance on visuospatial tasks assessing span (Bavin et al., 2005; Hick et al., 2005), capacity, as in cross-modal verbal-spatial and dual processing tasks (Hoffman & Gillam, 2004), and paired associative learning (Bavin et al., 2005). Children with SLI may follow a different developmental pattern of visuospatial memory than typically developing children. Hick et al. (2005) showed slower development over 1 year on a visuospatial memory task (pattern recall) in children with SLI (ages 3;9 [years; months]), compared to children with TLD.

The current findings are consistent with the findings of Archibald and Gathercole (2006a), who found no significant differences between children with SLI and children with TLD, aged 7 to 12 years, on visuospatial tasks from the PC-based Automated Working Memory Assessment, and Lum and colleagues (2011), who used the Block Recall subtest of the WMTB-C with children aged 10 years. The differences across study findings undoubtedly result from the differences in the nature of the tasks (e.g., involvement of executive functions; Marton, 2008), criteria for identifying SLI, age ranges, and the fact that SLI is a heterogeneous disorder. Three broad subgroups of SLI can be identified: expressive SLI, receptive SLI, and mixed expressive-receptive SLI (Nickisch & von Kries, 2009), and there can be different manifestations, so samples of SLI are not necessarily equivalent.

Although the RLTs seemed to outperform children with SLI on one of the measures of visuospatial memory, block recall, this was not supported when K-BIT scores were used as a covariate. That is, when nonverbal ability was taken into account, children with SLI and RLTs demonstrated similar performance on measures of the visuospatial sketchpad.

Central Executive

No support was found for the fifth hypothesis. The mean score on backwards digit recall for the SLI group was lower than that of the RLT and TLD groups, but there were no statistically significant group differences. Lum and colleagues (2011), with children aged 10 years; Briscoe and Rankin (2009), with children aged 7 years to 9;8; and Archibald and Gathercole (2006b), with children aged 7 to 9 years, found that children with SLI have markedly depressed verbal central executive functioning. However, in the current study, the children were younger than those in the other three studies, and although number knowledge was not tested as such in the current study, it was observed that some of the 5-year-old children from each group did not have a good grasp of basic numbers. Furthermore, successful backwards digit recall requires processing of verbal information (reversing the order of digits) as well as the retention of the digits (Best & Miller, 2010), and the substantial processing load of the task clearly affected the performance of many of the 5-year-old children in the current study, resulting in all three group means falling below the standardized mean.

In a review article, Best and Miller (2010) proposed that the developmental trajectory of the central executive of working memory is linear with continued maturation through adolescence, especially for more complex tasks that require a greater degree of processing, such as the maintenance and manipulation of multiple stimuli. Regardless of the domain (e.g., verbal vs. visuospatial), the developmental course of the central executive depends on the cognitive demands (the amount of processing) of the task, with less demanding tasks being mastered earlier in development. Therefore, 5-year-old children, those with early language delay or typical language development, may have few resources available to successfully allocate attentional resources simultaneously to verbal processing and storage during complex memory tasks. Given the degree of processing, group differences would be expected to emerge with the backwards digit recall task (Best & Miller, 2010). Overall, our findings suggest that backwards digit recall may not be a discriminatory tool at age 5.

Conclusions

The results of the study add further support to the view that sentence recall and nonword repetition serve as markers of persistent language impairment. They also show that despite delayed early vocabulary development, 5-year-olds with language abilities currently within the average limits do not necessarily show memory deficits. Of note, the RLTs had superior performance on measures of the phonological loop and episodic buffer relative to children with SLI. Our results indicate that children with late talking status may be delayed in producing words for different reasons. This may account for why some late talkers resolve and others go on to have persistent language problems, and it may account for differences between our results and those in some of the previous research with RLTs. Late talkers, like children with SLI, constitute a heterogeneous group. For example, those late talkers who catch up may have a history of limited social skills and internalized behavioral problems, such as withdrawal (Desmarais, Sylvestre, Meyer, Bairati, & Rouleau, 2008). The results of this study indicate the need for further research with late talkers to understand the risk factors for later language impairment.

The current research is unique in terms of the sample; the children were recruited from a large community-based sample, rather than from a clinical sample, and thus the results are more generalizable. A feature of previous SLI research is the recruitment of children with SLI from a wide age range. Studies may recruit from a wide age range in order to have sufficient power for statistical analysis, but memory develops throughout childhood and early adolescence, and so an extended age range will undoubtedly include children at different levels of memory development. Therefore, another strength of the present research is the narrow and comparable age range of the children across the three groups. Further research following up a large community-based sample would add to our understanding of the developmental trajectories of working memory for late talkers who resolve by age 5 years and those who go on to be language impaired. Such research could provide valuable information to assist in the development of informed intervention programs for children with delayed language.

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