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Abstract

Background:

Research has consistently documented a relationship between phonological short-term memory skills (STM) and specific language impairment (SLI). This study reports on the development of phonological STM abilities over 3 years in 80 young adolescents with a history of SLI, investigating the nature of the relationship between phonological STM abilities and language and literacy skills, and vice versa.

Methods: Tests of nonverbal ability, expressive and receptive language, reading and nonword repetition were administered at 11 and 14 years of age.

Results:

There was striking longitudinal stability of phonological STM capacity in young people with SLI. This finding was consistent for the group as a whole, for subgroups, and at the individual level. Regression analyses revealed reciprocal relationships between phonological STM abilities and language/literacy measures. In particular, phonological STM abilities contributed significantly to later expressive language skills and basic reading skills contributed to later phonological STM abilities. Poor phonological STM abilities related to Expressive-Receptive profiles of SLI (ER-SLI) and to the presence of reading difficulties.

Conclusions:

Relationships among the processes involved in language, literacy and memory in young adolescents with SLI indicate complex reciprocal interaction across development

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Specific language impairment (SLI) is a relatively common developmental disorder affecting approximately 7% of the population (Tomblin et al., 1997). SLI is still currently defined using exclusionary criteria, that is, a deficit in language in the absence of a number of other diagnostic features such as general cognitive deficits, sensory disorders, neurological damage or autism. This developmental disorder appears to have a strong genetic basis (Bishop, North, & Donlan, 1996; SLI Consortium, 2002).

Increasing evidence suggests a causal relationship between phonological short-term memory skills (phonological STM) and SLI. Gathercole and Baddeley (1989, 1990) were the first to argue that SLI may involve a specific deficit of phonological STM, i.e., the phonological loop component of working memory. This component specialises in the temporary storage and processing of verbal material and, importantly, is capacity limited. In SLI, this capacity is reduced, thus impeding efficient processing and storing of phonological information. Gathercole and Baddeley (1990) found that 8-year-olds with SLI performed on a nonword repetition task substantially below not only age controls but also chronologically younger language controls. Nonword repetition tasks, by minimising semantic demands, are thought to be a 'purer' measure of phonological STM abilities than word repetition tasks. Since Gathercole and Baddeley's initial publications, a number of researchers have examined the phonological STM abilities in children with SLI using nonword repetition tasks (Montgomery, 1995; Dollaghan & Campbell, 1998; Ellis Weismer et al., 2000). Consistently, findings reveal that children with SLI perform poorly, compared to control children.

Evidence that language abilities and nonword repetition performance are associated does not in itself confirm a causal relationship. However, in a longitudinal study of typically developing children, Gathercole and Baddeley (1989) demonstrated that – after controlling for vocabulary at the earlier age point and nonverbal intelligence – performance on nonword repetition at age 4 years accounted for 8% of the variance in vocabulary scores at age 5. In contrast, the investigators found no evidence of a comparable link between nonword repetition and nonverbal intelligence. These results, taken together with the findings of poorer performance on nonword repetition tasks by children with SLI, suggest that some impairment in the storage component of the phonological loop in turn undermines or constrains progress in a crucial component of language development.

Children with dyslexia have also been found to have difficulties with nonword repetition tasks

(Snowling, 1981; Catts et al., 2005). This is particularly interesting as children with SLI have a high incidence of reading difficulties (Botting, Simkin, & Conti-Ramsden, 2006; Conti-Ramsden, Botting, Simkin, & Knox, 2001) and the presence of such difficulties has been related, at least partly, to difficulties with their phonological STM abilities (Catts et al., 2005; Snowling, Bishop, & Stothard, 2000).

Over time, any relationship between phonological STM abilities and language and literacy development is likely to be reciprocal (Baddeley, 2003; Gathercole, Willis, Emslie, & Baddeley, 1992; Laws & Gunn, 2004). For instance, phonological memory may be important in the early and intense periods of vocabulary acquisition during the preschool years, but in later childhood lexical knowledge may facilitate phonological tasks (Laws & Gunn, 2004). These possibilities underscore the need for longitudinal studies of these gradually developing competencies and their interrelationships. In particular, longitudinal studies of children with developmental disorders provide a potentially informative context in which to determine which deficits are constant, or core, and which are secondary (Bishop, 1997).

Among typically developing children, research involving standardisation data for the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) suggests that working memory capacity, as indexed by the phonological loop, visuo-spatial sketchpad and the central executive, develops steadily across childhood and into early adolescence in typically developing children. Generally, it appears that working memory abilities reach adult-like levels by around 14–15 years of age (Gathercole & Alloway, 2006; Gathercole, Lamont, & Alloway, 2006). In the case of SLI, there are currently no available data examining the development of phonological STM abilities in the period leading to the expected plateau of these skills. Do phonological STM abilities of children with SLI develop during early adolescence? Is there evidence of catch-up during this period?

Most aspects of language development have reached mature levels in typically developing individuals by 14–15 years of age, although vocabulary development, mastery of the subtleties of idiomatic expression, and literacy skills continue to improve into adulthood (Menyuk & Brisk, 2005; Nippold, 1998). For young people with a history of SLI, however, language development may still lag behind even in adolescence. Furthermore, subgroups of children with SLI (e.g., expressive-receptive SLI versus expressive SLI) may show different patterns of language and literacy skills across time (Conti-Ramsden & Botting, 1999). As reviewed above, evidence of a relationship between phonological STM abilities and language as well as literacy skills in children with SLI has been forthcoming. What is less clear is the nature of this relationship, in particular the potential bidirectionality of influence (reciprocity) between language and literacy skills and phonological STM abilities.

Within this context, the present study has three related aims: to examine phonological STM development during the transition from childhood (11 years) to early adolescence (14 years) in a large group of children with SLI; to study further the patterns of development in phonological STM ability in subgroups of children with SLI as well as at the individual level; and to replicate and extend the findings of a relationship between phonological STM capacity and language attainment (oral language and literacy) in early adolescence in SLI.

Method

Participants

The adolescents with SLI were originally part of a wider longitudinal study, the Conti-Ramsden Manchester Language Study (Conti-Ramsden & Botting 1999; Conti-Ramsden, Crutchley, & Botting, 1997). This initial cohort of 7-year-olds was recruited from 118 language units attached to English mainstream schools. This resulted in an initial study cohort of 242 children. The age range was 7;5 years to 8;9 years and comprised 186 males and 56 females (females forming 23.1% of the cohort). These children were reassessed at 8, 11, and 14 years of age.

From the original cohort of 242 children, 124 (51%) agreed to take part in the present stage of the study. Of these, 118 (49%) were assessed and 6 (2%) were not assessed due to alterations in family circumstances. Of the remainder of non-consenting adolescents, 55 (23%) refused consent and there was no response from 59 (24%). Four families (2%) in which the child with SLI had been adopted were not contacted, as this stage of the study involved a wider familial/genetic component.

From this pool of 124 consenting adolescents, the sample for the present study was selected on the following criteria: performance IQ (PIQ) of 80 or more and at least one concurrent standardised language test score >1SD below the population mean at one of the longitudinal assessment stages (7, 8, 11 or 14 years); no sensory-neural hearing loss; English as a first language; no record of a medical condition likely to affect language; nonword repetition data available for both 11 and 14 years. This resulted in a sample of 80 adolescents with SLI (58 male/22 female). Mean age at the 11 years phase was 10;10 and at the 14 years phase was 13;8. The children with SLI in this study either currently or historically met criteria for SLI diagnosis. The participants were classed as currently impaired if they met the following criteria for SLI: performance IQ (WISC-III; Wechsler, 1992) of 80 or more and concurrent expressive or receptive language standard score less than 85. Receptive language was measured using the TROG at 11 years and the CELF rls at 14 years. Expressive language was measured using the EVT at 11 years and a composite of the CELF Formulated Sentences and Sentence Assembly subtests at 14 years.

At 11 years, 24/80 (30%) of participants met criteria for SLI; 18/80 (22.5%) demonstrated normal nonverbal and language ability and 36/80 (45% of the total) showed nonverbal and language ability in the impaired range. There were 2/80 (2.5%) participants with impaired nonverbal abilities but normal language scores. Therefore, at age 11 years, a total of 60/80 participants (75%) had current language difficulties indicated by scores at least 1SD below the mean on standardised tests of expressive and/or receptive language.

At 14 years (after accounting for 1 case of missing data), 30/79 (38%) of participants met criteria for SLI; 31/79 (39.2% of the total) showed nonverbal and language ability in the impaired range and18/79 (22.8%) demonstrated normal nonverbal and language ability. There were no participants with impaired nonverbal abilities but normal language scores. Therefore, at age 14 years, a total of 61/79 participants (77.3%) had current language difficulties indicated by scores at least 1SD below the mean on standardised tests of expressive and/or receptive language.

For 17/80 participants (23.1%), the level of maternal education was unknown. Of the remainder with non-missing data, 17/63 (27%) had mothers with no educational qualifications, 21/63 (33.3%) had mothers with GCSE or O-level qualifications, 16/63 (25.4%) had mothers with A-level or college-level qualifications, 7/63 (11.1%) had mothers educated to degree level and 2/63 (3.2%) had mothers educated to postgraduate level.

Normative nonword repetition data for 11-year-olds

Simkin and Conti-Ramsden (2001) employed a sample of one hundred typically developing children randomly selected from six mainstream primary schools: three in inner city areas and the other three in rural areas. Children were excluded from the sample based on current or previous speech therapy provision, current or previous special educational provision, current or previous hearing difficulty and neither parent a native speaker of English. Fifty children attended school in urban areas and 50 children attended school in rural areas. The participants were all in their final year of primary education (year 6) and ranged in age from 10;5 to 11;6 years. There were 49 boys and 51 girls (girls representing 51% of the total). The participants were administered the Children's Test of Nonword Repetition (CNRep; Gathercole & Baddeley, 1996) in order to provide normative guidelines for 11-year-old children on this task. The distribution of the raw scores was negatively skewed, indicating a cluster of scores around the ceiling level. The expected average raw score for this age range on the CNRep was 38 out of 40, which thus equated to the 50th centile. In other words, 50% of typical 11-year-olds would be expected to perform at this level. Therefore 11-year-olds appear to be at the functional ceiling of the test, and consequently additional testing of 14-year-olds was not warranted. This normative sample were only administered the CNRep at 11 years. Hence, the battery of tests described below applies only to the SLI group.

Tests and materials

Psycholinguistic test battery at 11 years. Expressive language was assessed using the Expressive Vocabulary Test (EVT; Williams, 1997). Children are shown a picture and told a key word for this picture by the assessor. The child must then elicit another appropriate word that matches both the picture and the key word. *Receptive language* was assessed using the Test for Reception of Grammar (TROG; Bishop, 1982). This is a multiple-choice test (based on four pictures) designed to assess understanding of grammatical constructions. The child is required to select the picture that illustrates the sentence. *Reading* was assessed using the Basic Reading and Reading Comprehension subtests of the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993). *Performance IQ* was assessed using the full form of the Wechsler Intelligence Scale for Children (WISC-III, Wechsler, 1992). *Phonological short-term memory* (phonological STM) was assessed using two tasks: the Children's Test of Nonword Repetition (CNRep; Gathercole & Baddeley, 1996) and the Digit Span subtest of the WISC-III (Wechsler, 1992). The CNRep test of consists of 40 nonwords, divided equally into two-, three-, four- and five-syllable items. The items were presented using live voice with lips shielded to prevent lip-reading as recommended for working with distractible children (Adams & Gathercole, 1995). In the Digit Span subtest, the examiner reads a series of number sequences to the child, at the rate of one per second. The child is required to repeat each sequence in either the same order as spoken (Digits Forward) or the reverse order (Digits Backward). A total score is calculated by summing the scores from Digits Forward and Digits Backwards.

Psycholinguistic test battery at 14 years. This was identical to the 11-years-old test battery except that receptive (RLS) language was assessed using the full form of the CELF-R (Clinical Evaluation of Language Fundamentals – Revised UK; Semel, Wiig, & Secord, 1987). Expressive language was assessed through a prorated score comprising the Formulated Sentences and Sentence Assembly subtests of the CELF-R but excluding the Recalling Sentences subtest due to the fact that this subtest is thought to also measure short-term memory. In addition, spelling was assessed using the WORD Spelling subtest.

Results

Does phonological STM develop during early adolescence in SLI?

Inspection of nonword repetition raw scores revealed little change over the three-year period. The mean score at 11 years was 26.9 (SD = 8.8, 95% CI = 24.9–28.8) and at 14 years was 28.3 (SD = 8.2, CI = 26.5–30.2). Scores at the two time points were highly correlated (Pearson correlation = .76, $p < .01$). The mean scores at both time points were equivalent to what would be expected of an average 6-year-old. The digit span data revealed a similar pattern.

The mean raw score at 11 years was 10.6 (SD = 3.7, 95% CI = 9.8–11.4) and at 14 years was 11.1 (SD = 3.0, 95% CI = 10.4–11.7). These scores were highly correlated (Pearson correlation = .61, $p < .001$). The mean scores at both time points were also equivalent to what would be expected of an average 6-year-old. At 11 years the Pearson correlation between digit span and nonword repetition was .50 ($p < .001$) and at 14 years was .56 ($p < .001$). Thus, there was little evidence of phonological STM development during early adolescence in children with a history of SLI as a group. In addition, the correlational results suggest that there was stability of the rank order of scores across this developmental period.

Is the pattern of development and stability similar for children with varying degrees of STM ability?

Four further analyses were carried out in order to investigate patterns of potential development and stability in STM ability. Firstly, participants were divided into those with low CNRep scores at 11 years (raw score of 28 or less, equivalent to 5th centile or below) and those with normal CNRep scores at 11 years (raw score of 35 or above, equivalent to 16th centile or above). The low CNRep group ($n = 43$, 30M/13F) had a mean score of 20.6 (SD = 6.9) at 11 years and a mean score of 23.1 (SD = 7.2) at 14 years. Thus, there was some evidence of change between these two time points for the low CNRep group ($t(42) = 2.262$, $p = .029$) In contrast, the normal CNRep group ($n = 21$, 14 M/7 F) had virtually no change evident with a mean score of 36.8 (SD = 1.9) at 11 years and a mean score of 36.7 (SD = 2.9) at 14 years ($t(20) = .174$, $p = .864$). It is important to note that the latter group was close, at both age points, to the functional ceiling found in children with typical development (TD) and this is likely to have influenced the apparent absence of development. Furthermore, in the case of the low CNRep group, it is difficult to evaluate the difference found with regard to what is expected, as most TD 11-year-olds are already at ceiling on the CNRep task by 11 years of age.

Digit span scores provide an opportunity to examine development where ceiling effects for this age range is not an issue. The low CNRep group had a mean digit span score of 9.4 (SD = 3.8) at 11 years and a mean digit span score of 9.6 (SD = 2.4) at 14 years. These scores were equivalent to the 6.6th centile at 11 years and the 6.1st centile at 14 years. There was no significant difference between these two time points, $t(42) = 2.81$, $p = .780$. The normal CNRep group had a mean digit span score of 13.4 (SD = 2.9) at 11 years and a mean digit span score of 13.4 (SD = 2.9) at 14 years. These scores were equivalent to the 40.2nd centile at 11 years and the 27.5th centile at 14 years. Once again, there was no significant difference ($t(19) = 1.743$, $p = .097$). Thus, there was no development over the three-year period for either group. Normative data for the digit span at these ages (WISC-III Technical Manual, Appendix A, Wechsler, 1992) reveal that typically developing children show improving phonological STM abilities during this period, gaining between 1 and 3 raw scores (Mean = 2.1) between 11 and 14 years.

Individual continuity of nonword repetition scores over time were examined for the low CNRep group. Given the functional ceiling effects of the normal CNRep group, data from these children were not included in this analysis. Scores were categorised at 11 years into <2.5th centile, 2.5th to 15.9th centiles and >16th centile using cut-offs derived from typically developing children's data at 11 years (Simkin & Conti-Ramsden, 2001). These 11-year-old norms were also used to classify the children's scores at 14 years into centiles. Thus, the 14-year centile equivalents are likely to be generous. The stability was striking: the majority of children remained in the equivalent banding at 14 years to that in which they were included at 11 years. Of those children with nonword repetition skills less than the 2.5th centile, 77.4% continued to have raw scores at 14 years that were equivalent to this banding. The figure for those remaining between the 2.5th centile and 15.9th centile was 70.4%. Taken together, these analyses reveal a lack of development and remarkable stability of phonological STM capacity in early adolescence in SLI at the individual level.

The relationship between phonological STM and language attainment

The correlations between nonword repetitions and language scores at both time points are presented in Table 1. All measures at all time points were significantly correlated (.278 to .832).

What aspects of 14-year language attainment are predicted by 11-year nonword repetition abilities?

A series of multiple regressions were conducted using language and literacy measures at 14 years as outcome variables and CNRep raw score at 11 years as the independent variable. The regression model was significant, $F(1,78) = 12.204$, $p < .01$. CNRep raw score at 11 years was found to account for 12% of the variance in ELS at 14 years. For RLS at 14 years the regression model was also significant, $F(1,78) = 14.441$, $p < .001$. CNRep raw score at 11 years accounted for 15% of the variance in RLS at 14 years. In terms of literacy measures at 14 years, the regression model for basic reading was significant, $F(1,79) = 34.009$, $p < .001$. CNRep raw score at 11 years accounted for 30% of the variance in basic reading at 14 years. For reading comprehension, the regression model was significant, $F(1,79) = 14.979$, $p < .001$. CNRep raw score at

Table 1 Correlations among measures at 11 and 14 years

	Measures taken at 14 years							
	CNRep	Digit Span	PIQ	ELS prorated	RLS	Basic Reading	Reading Comp	Spelling
Measures taken at 11 years								
CNRep	.764**	.497**	.278*	.368**	.397**	.551**	.401**	.545**
Digit Span	.456**	.607**	.352**	.560**	.544**	.594**	.597**	.588**
PIQ	.287**	.358**	.801**	.557**	.695**	.409**	.670**	.334**
EVT	.338**	.354**	.484**	.560**	.614**	.442**	.582**	.324**
TROG	.314**	.442**	.472**	.576**	.660**	.476**	.616**	.359**
Basic Reading	.555**	.549**	.345**	.567**	.561**	.871**	.630**	.832**
Reading Comp	.514**	.455**	.396**	.621**	.620**	.784**	.724**	.784**

**$p < .001$.

Note: CNRep and Digit Span raw scores for each time point, standard scores for all other measures.

11 years accounted for 15% of the variance in reading comprehension at 14 years. Finally, the regression model for spelling at 14 years was also significant, $F(1,79) = 32.890$, $p < .001$. CNRep at 11 years accounted for 29% of the variance in spelling at 14 years. Thus, nonword repetition at 11 years was most closely associated with literacy (basic reading and spelling) and expressive language at 14 years.

These results were unchanged after controlling for performance IQ at 11 years. After further controlling for autoregressive effects by including language/literacy ability at 11 years for each of the relevant outcome variables examined, the only significant model involved CNRep at 11 years predicting ELS at 14 years. Hierarchical regression was conducted using ELS as the outcome variable. The first block for the regression comprised nonverbal IQ at 11 years and EVT at 11 years. The second block added CNRep at 11 years. The regression model was significant, $F(3,76) = 17.806$, $p < .001$. Adjusted R^2 at step 1 was .382 and at step 2 was .390. Thus, nonword repetition abilities accounted for 1% of additional variance in expressive language abilities at 14 years even when performance IQ and expressive language status at 11 years were controlled for.

Finally, it is known that nonword repetition is a multi-component task that is likely to tap other cognitive processes (e.g., phonological sensitivity, speech-motor output processes) in addition to phonological STM (Archibald & Gathercole, in press). One way forward is to include in the analyses a measure of phonological STM which reduces some of the demands by using familiar lexical items, i.e., digit span. With this in mind, we repeated the regression analysis controlling for digit span at 11 years. If aspects of the nonword repetition task other than phonological STM are responsible for the link between nonword repetition and expressive language, then the regression results should remain unchanged. If phonological STM is indeed specifically related to expressive language, then the results should reveal that the last step of the model, the inclusion of nonword repetition, does not add any further variance, i.e., the adjusted R^2 change should equal zero. The latter was confirmed by the results of the regression (adjusted R^2 went from .440 to .434 so the change was −.006).

What aspects of 11-year language attainment predict nonword repetition ability at 14 years?

To examine the contribution of 11-year language and literacy measures to 14-year nonword repetition ability, hierarchical regression was conducted with CNRep raw score at 14 years as the outcome variable and language and literacy measures at 11 years as the independent variables. The regression model was significant, $F(4,77) = 9.121$, $p < .001$.

Table 2 shows the results of the multiple regression analysis for predicting nonword repetition ability at 14 years. One of the independent variables contributed significantly to outcome: WORD basic reading ($p < .05$). Overall, the model explained 30% of the variance in CNRep ability at 14 years, with basic reading ability at 11 years making the most significant contribution.

These findings remained unchanged after controlling for performance IQ at 11 years. Furthermore, after controlling for both performance IQ and autoregressive effects by including nonword repetition ability at 11 years, basic reading remained a borderline predictor of nonword repetition ability at 14 years ($p = .075$). Hierarchical regression was conducted using CNRep at 14 years as the outcome variable. The first block for the regression comprised nonverbal IQ at 11 years and CNRep at 11 years. The second block added language and literacy measures at 14 years. The regression model was

Table 2 Multiple regression analysis predicting nonword repetition ability at 14 years

Variable	B	SE B	B
TROG at 11 years	−.045	.073	−.079
EVT at 11 years	.068	.057	.147
WORD basic reading at 11 years*	.226	.083	.431
WORD reading comprehension at 11 years	.088	.113	.139

*$p < .05$.
Note: $R^2 = .297$ ($p < .01$).

Table 3 Hierarchical regression analysis predicting nonword repetition ability at 14 years

Variable	B	SE B	B
Step 1			
WISC PIQ at 11 years	.008	.027	.022
CNRep at 11 years	.696	.074	.751**
Step 2			
TROG at 11 years	−.029	.059	−.052
EVT at 11 years	.023	.047	.049
WORD basic reading at 11 years*	.123	.068	.235†
WORD reading comprehension at 11 years	.005	.088	.008

**$p < .01$; †$p = .075$.
Note: $R^2 = .564$ for Step 1 ($p < .01$); $\Delta R^2 = .582$ for Step 2 ($p < .01$).

significant, $F(6,77) = 18.823$, $p < .001$. Table 3 shows the results of the regression analysis. Basic reading at 11 years accounted for 2% additional variance in nonword repetition skills at 14 years even after controlling for performance IQ and nonword repetition abilities at 11 years.

Language, literacy and phonological STM skills

Three analyses were carried out to investigate further the nature of the relationship between language, literacy and phonological STM skills. First, the psycholinguistic profiles at 11 and 14 years of the poor and normal nonword repetition groups were examined (Table 4).

One-way ANOVAs revealed that there were significant differences between groups on all scores at 11 and 14 years (PIQ at 14 years borderline). The normal nonword repetition group consistently outperformed the poor nonword repetition group on tests of cognition, language and literacy. On all the measures, the low nonword repetition group performed on average below 1SD from the mean. In contrast, the normal nonword repetition group performed on average above 1SD from the mean on most measures.

Second, an analysis of subgroups of children with SLI (Expressive-SLI (E-SLI), Expressive-Receptive SLI (ER-SLI), Receptive-SLI (R-SLI) and Resolved-SLI) as they relate to low versus normal nonword repetition ability groups is presented in Table 5. The subgroups were defined using the relevant expressive and receptive language measures for each stage of the study. Impairment was classed as a score falling more than 1SD below the mean and conversely a normal score was classed as one less than 1SD from the mean. E-SLI was defined as normal comprehension with impairment in expressive language. ER-SLI was defined as both scores falling in the impaired range. Those that were classed as R-SLI showed impairment in comprehension but no accompanying expressive difficulty. Finally, the Resolved-SLI subgroup had both scores in the normal range.

These data reveal that at both 11 and 14 years, most children with low nonword repetition abilities had ER-SLI while most children in the normal nonword repetition group had Resolved-SLI.

Third, the psycholinguistic profiles of young people in our sample with and without reading difficulties (as defined by performance <16th centile on WORD basic reading at 11 years) are presented in Table 6. One-way analysis of variance revealed that young people with reading difficulties performed significantly more poorly than those without reading difficulties on tests of cognition, language, phonological STM and wider literacy skills (reading comprehension and spelling).

Amongst the ER-SLI group at 11 years, the majority (28/33, 84.8%) had concurrent literacy difficulties. In contrast, the Resolved-SLI group had just less than half (8/19, 42.2%) with literacy difficulties. This suggests that low CNRep, ER-SLI and literacy difficulties are likely to go together.

Table 4 Profiles at 11 and 14 years of poor and normal CNRep groups at 11 years

	Poor CNRep group ($n = 43$)		Normal CNRep group ($n = 21$)	
	M	SD	M	SD
PIQ at 11**	78.8	21.9	97.5	25.5
TROG at 11*	83.1	12.7	92.9	17.7
EVT at 11**	68.2	17.3	82.3	14.4
WORD basic reading at 11**	75.6	9.8	99.1	16.2
WORD reading comprehension at 11**	72.3	10.6	88.7	12.0
PIQ at 14†	79.3	18.3	89.4	20.9
CELF rls at 14**	71.1	15.4	91.5	22.1
CELF els at 14**	64.4	10.2	78.3	12.6
WORD basic reading at 14**	76.3	14.2	101.2	12.2
WORD reading comprehension at 14**	71.3	14.0	86.8	13.4
WORD spelling at 14**	72.8	12.8	97.8	12.6

*$p < .05$; **$p < .01$; †$p = .052$.

Discussion

This study extended and replicated previous research indicating a relationship between phonological STM abilities and language/literacy impairment in childhood and early adolescence. New evidence as to the potential reciprocal nature of the relationship between language, literacy and phonological STM was obtained. Furthermore, the present study demonstrated that nonword repetition abilities are developmentally stable in SLI from 11 to 14 years of age, with no evidence of catch-up.

Lack of development and stability of phonological STM abilities in SLI

The present study found lack of development and striking longitudinal stability of phonological STM

Table 5 Proportions of children with ER-SLI, E-SLI, R-SLI and Resolved-SLI in each of the low and normal nonword repetition groups at 11 years and 14 years

	Low CNRep group at 11 years	Low CNRep group at 14 years	Normal CNRep group at 11 years	Normal CNRep group at 14 years
ER-SLI	22/43	25/43	5/21	3/21
	51.2	58.1	23.8	14.3
E-SLI	15/43	7/43	6/21	3/21
	34.9	16.3	28.6	14.3
R-SLI	0/43	6/43	0/21	5/21
	0	14.0	0	23.8
Resolved-SLI	6/43	5/43	10/21	10/21
	14.0	11.6	47.6	47.6

Table 6 Profiles at 11 and 14 years of children with a history of SLI with and without reading difficulties at 11 years

	SLI + reading difficulties ($n = 53$)		SLI ($n = 26$)	
	M	SD	M	SD
PIQ at 11*	81.3	24.2	92.4	22.1
TROG at 11**	81.8	13.1	92.6	14.7
EVT at 11†	70.1	14.9	77.4	21.8
WORD basic reading at 11**	73.3	6.8	101.6	10.2
WORD reading comprehension at 11**	71.7	10.2	87.3	11.5
CNRep raw score at 11**	24.9	8.0	30.4	9.5
PIQ at 14*	80.7	18.3	91.9	21.0
CELF rls at 14**	72.7	16.3	87.3	22.1
CELF els at 14**	64.7	9.8	74.5	14.1
WORD basic reading at 14**	75.9	13.0	99.5	12.2
WORD reading comprehension at 14**	72.2	14.0	84.5	12.9
WORD spelling at 14**	73.0	13.2	93.9	14.0
CNRep raw score at 14**	26.2	7.7	32.0	7.8

**$p < .01$; *$p < .05$; †$p = .067$.

capacity in children with SLI from 11 to 14 years of age. This finding was consistent for the group as a whole, for subgroups with low versus normal nonword repetition abilities, and at the individual level (with a large proportion of children retaining their level of deficit across time). Thus, there was little evidence of catch-up in this underlying processing ability in SLI.

The pattern observed in SLI in this study was unlike that observed in typically developing children. In the latter, based on normative data from the digit span task, there was evidence of development of phonological STM capacity throughout early adolescence. Gathercole et al. (2006) provide further evidence for this different pattern of development in typically developing children. These researchers found that all three components of working memory – phonological STM, visuo-spatial memory and central executive as measured by the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) – develop steadily across the primary and secondary school years (from 4 to 15 years), with most children reaching average adult levels by around 14–15 years of age.

The relationship between phonological STM capacity, language and literacy in SLI

The present investigation replicated previous findings of a positive relationship between phonological STM capacity and language abilities (Montgomery, 2002; Gathercole & Alloway, 2006). Our study also included measures of literacy, thus allowing us to replicate previous findings of an association between these and phonological processing (Snowling et al., 2000). It appears that within SLI, those children with poor nonword repetition skills (who constitute the large majority) have worse language/literacy outcomes in early adolescence than those with better (normal) nonword repetition skills (see also Botting & Conti-Ramsden, 2001). Furthermore, our findings on the distribution of subgroups across the poor versus normal nonword repetition groups underline the association between severity of language difficulties and poor phonological STM. We found that the majority of children with poor phonological STM presented with language difficulties across domains (ER-SLI). Furthermore, the majority of ER-SLI children also presented with literacy difficulties (see also Simkin & Conti-Ramsden, 2006). Thus, poor phonological STM abilities, poor language and poor literacy appear to go together in young adolescents with SLI and better phonological STM abilities relate to better outcomes. We found a larger proportion of children with Resolved-SLI in the normal nonword repetition group.

Given the longitudinal nature of our study, we were able to examine in more detail the potential reciprocal relationships among phonological STM abilities, language and literacy. Even after taking performance IQ into account, nonword repetition abilities were a strong and robust predictor of language and literacy outcomes at 14 years (with variance explained varying from 12% for expressive language, to 15% for reading comprehension, to 19% for receptive language and 30% and 29% for basic reading and spelling, respectively). Furthermore, by using a number of additional controls including autoregressive effects and controlling for digit span, we were able to examine a purer estimate of the potential contribution of phonological STM to language/literacy. Nonword repetition contributed uniquely to expressive language abilities between 11 and 14 years, explaining 1% of the variance. In a study involving an earlier developmental period, Gathercole and Baddeley (1989) reported that 8% of the variance in expressive language (as measured by vocabulary) was additionally predicted by nonword repetition scores. Although comparisons across these two studies need to proceed with caution given the differences in samples and instruments, these data are suggestive of a more modest contribution of phonological STM skills to expressive language skills in early adolescence than in early childhood. This highlights the need for investigation of these relationships longitudinally across a wider developmental span.

Our findings point to a reciprocal relationship between language attainment and phonological STM. This potential bidirectionality has been suggested at the theoretical level (Baddeley, 2003) and has also been found empirically in respect of vocabulary development in typical (Gathercole et al., 1992) and atypical populations (Laws & Gunn, 2004). We found that even after taking performance IQ into consideration, language and literacy skills at 11 years (taken together) predicted 30% of the variance in nonword repetition skills at 14 years, with basic reading abilities making the most significant contribution. We examined whether any additional variance could be explained in the developmental period between 11 and 14 years of age once nonword repetition ability at 11 years was controlled for. WORD basic reading contributed uniquely to nonword repetition skills between 11 and 14 years, explaining 2% of the variance.

The above finding is relevant to recent debates regarding the relationship between SLI and dyslexia. Approximately 50% of children with SLI have reading difficulties and vice versa (Catts et al., 2002; McArthur, Hogben, Edwards, Heath, & Mengler, 2000). Some researchers have suggested that dyslexia may be a less severe form of SLI, characterised by the same phonological deficit (Snowling et al., 2000) or that SLI may be a type of 'dyslexia-plus' with children with SLI showing similar phonological deficits (such as nonword repetition) as children with dyslexia but in addition exhibiting language difficulties beyond phonology (Bishop & Snowling, 2004). Catts et al. (2005) have suggested that the deficit in phonological processing is more closely associated with reading difficulties than it is with SLI (i.e., oral language difficulties). These authors argue that it is children with SLI plus reading difficulties who exhibit poor phonological processing skills such as nonword repetition. In contrast, children with SLI only (and not reading difficulties) do not.

The results of the present study partly support Catts et al.'s (2005) argument. In examining the psycholinguistic profiles of the young people in our study with and without reading difficulties, we found overall that those with reading difficulties have poorer phonological STM abilities at both 11 and 14 years. However, findings from the regression analyses suggest that this outcome is not unidirectional, i.e., poor nonword repetition skills affect reading ability in SLI. Indeed, our results suggest that reading skills can affect nonword repetition abilities. Thus, it may be the case that poor literacy skills may cause nonword repetition skills to stall or decline. The evidence provided here spans the period of 11 to 14 years but it is likely that these influences are active earlier in development. Furthermore, it is clear from our and previous findings that phonological STM abilities do influence oral language abilities and expressive language (Dollaghan & Campbell, 1998; Ellis Weismer et al., 2000). Unlike Catts et al. (2005), we continue to find the association of SLI (without reading difficulties) with poor nonword repetition. In this study, children with SLI-only were still performing poorly for their age in the nonword repetition task, with average raw scores equivalent to less than the 10th centile. Altogether, the results of the present study are suggestive of more complex interactions among language, literacy and phonological STM skills across development.

Clinical implications

In many educational systems, young people make the transition from primary to secondary education when they are around 11 years of age. The findings of the present study suggest that assessment of phonological STM skills at this time may well be worth considering. Our findings suggest that tests of phonological STM at 11 years can be used to predict performance in both expressive and receptive language as well as literacy (reading and spelling) at 14 years of age. Although it is not clear that this association is necessarily causal for all these areas of functioning, the above findings have clinical implications in terms of the need for intervention and prioritisation of support services for children who exhibit poor phonological STM skills in late childhood.

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