Cognitive abilities in children with specific language impairment (SLI): Consideration of visuo-spatial skills

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Abstract

Background: The current study concerns the cognitive abilities of children with specific language impairment (SLI). Previous research has indicated that children with SLI demonstrate difficulties with certain cognitive tasks despite normal non-verbal IQ scores. It has been suggested that a general processing limitation might account for the pattern of language and cognitive difficulties seen in children with SLI (e.g. Ellis Weismer and Evans, 2002). In the current study, performance on a visuo-spatial short-term memory task and a visuo-spatial processing task was considered in a group of young children with SLI. Verbal short-term memory was also measured.

Aims: To identify whether children with SLI demonstrate difficulties with visuo-spatial memory as well as verbal short-term memory. To see whether a visuo-spatial processing task without short-term memory requirements is problematic for children with SLI. To consider performance on these tasks over time.

Methods: Nine children with SLI (mean age 3;9 yrs at study outset) and nine typically developing children (mean age 3;9 yrs at study outset), were visited on three occasions over the period of a year. Verbal short-term memory, Visuo-spatial short-term memory and visuo-spatial processing tasks were administered to the children and performance over time was compared between the two groups.

Results: The children with SLI performed at a lower level than the typically developing children on the verbal short-term memory task. Both groups showed similar development on the verbal short-term memory task and the visuo-spatial processing task over time. Only the visuo-spatial short-term memory task showed slower development over time in the children with SLI relative to the typically developing children.

Conclusions: Children with SLI demonstrated slower development on a visuo-spatial short-term memory task, relative to typically developing children of the same chronological age. This finding has implications for speech and language therapists and other professionals working with children with SLI. It may mean that only certain types of visual support are suitable, and that children with SLI will have difficulty with tasks requiring a high level of processing, or a number of mental manipulations.

Background:

The language abilities of children with specific language impairment (SLI) have been studied at length, in terms of theoretical speculation concerning language acquisition, and in order to glean information on language profiles and prognosis in SLI (see Leonard 1998 for a summary). Certain areas of cognitive ability have also been considered in children with SLI, often with a view to identifying difficulties in areas other than language that could be contributing to the language problems of this clinical group.

Despite the requirement of normal non-verbal intelligence in order for a child to be diagnosed as having SLI, there is a growing amount of research suggesting that the difficulties of children with SLI may not be completely ‘language specific’. For example, children with SLI have shown difficulties with spatial processing (Kamhi et al. 1988), hierarchical planning tasks (Cromer 1983, Kamhi et al. 1995) and hypothesis testing (Nelson et al. 1987, Ellis Weismer 1991). Johnston (1999) gives a good overview of the literature on the cognitive abilities that have been investigated in SLI. Due to the large variety of research into this area, the current paper considers further only the research on cognitive abilities in SLI most relevant to the present investigation.

Verbal short-term memory is one area of cognitive ability widely researched both in typically developing children and also in children with SLI (e.g. Gathercole and Baddeley 1990, Gathercole 1995, Montgomery 1995, Bishop et al. 1996, Dollaghan and Campbell 1998, Henry et al. 2000, Gathercole et al. 2001). Consistently, children with SLI have been found to show difficulties with verbal short-term memory tasks such as digit span and non-word repetition. Some researchers have speculated that verbal short-term memory difficulties may be one causal factor in the language impairments seen in children with SLI (e.g. Gathercole and Baddeley 1990, but see Snowling et al. 1991, Van der Lely and Howard 1993 for an alternative view).

There is less research into the short-term memory abilities of children with SLI for non-verbal/visuo-spatial items, for example using tasks such as pattern span (Phillips and Christie 1977, Wilson et al. 1987) or Corsi blocks (De Renzi and Nichelli 1975). A study by Hick et al. (submitted), compared visuo-spatial short-term memory in children with SLI, children with Down syndrome and typically developing children. This study found some evidence of lower visuo-spatial short-term memory abilities in children with SLI relative to both of the other groups of children, though only the difference between the children with SLI and typically developing children was significant. To the knowledge of the authors, there is no other information currently on the visuo-spatial short-term memory abilities of children with SLI.

Despite a dearth of research on visuo-spatial short-term memory, other cognitive tasks without verbal output requirements have been considered in children with SLI. Mental imagery ability has received attention, due in part to the postulated relationship between this representational skill and language ability (Inhelder 1963). Kamhi (1981) found children with SLI (mean age 5 years) to show lower levels of performance on a 'haptic recognition' mental imagery task (the child feels a shape and then points to the corresponding picture), compared with typically developing children matched for mental age. Johnston and Ellis Weismer (1983) documented slower mental rotation abilities in children with SLI compared with chronological age matched typically developing children. The children with SLI demonstrated difficulties with image generation, maintenance and interpretation, rather than transformation. This pattern suggested that the children with SLI were able to produce mental visual images, but might not have maintained or utilised them as well as typically developing children of a similar age. Kamhi et al. (1984) considered the relationship between mental imagery and language ability, finding a positive correlation between vocabulary comprehension and performance on mental imagery tasks in children with SLI.

Ellis Weismer (1991) has speculated that the difficulties seen in children with SLI with language and also with performance on certain cognitive tasks, reflect less efficient processing strategies that affect both verbal and non-verbal domains. Johnston (1994, 1999) also considered the view that children with SLI may have limitations in processing, either in terms of efficiency or capacity. A general explanation based on processing limitations could account for difficulties in both language and cognitive skills. However, as Johnston discussed, the generality of this explanation, although advantageous in the sense that it can explain performance in a variety or different skill areas, is also its main weakness. It is difficult to reconcile an explanation based on an overall general processing difficulty or limitation, with the specific pattern of findings seen in many children with SLI. For example, children with SLI do show a discrepancy between performance on verbal and non-verbal tasks, and not all non-verbal tasks are affected in SLI. Furthermore, specific aspects of language appear more problematic than others (see Leonard 1998 for details). Hence, any explanation of SLI based on processing has to account for these patterns of ability and difficulty.

Aims:

The current study aimed to consider performance on three types of cognitive task in children with SLI, relative to their typically developing peers. This study reports further findings from the work presented in Hick et al. (submitted). The focus of the Hick et al. paper was primarily a comparison between the performance of children with SLI and children with Down syndrome on vocabulary and short-term memory tasks. However, the analysis also showed some evidence of difficulties in the children with SLI on visuo-spatial memory, relative to typical developing children, who were included in the comparison for a control measure. The current paper uses data collected from the same typically developing children and children with SLI as the Hick et al. study, but discusses previously unreported findings.

Performance on verbal short-term memory, visuo-spatial short-term memory, and visuo-spatial processing (without any memory factor) was compared in children with SLI and typically developing children of the same age. Furthermore, the study was conducted longitudinally over the period of a year, to track any developmental differences between the groups on these tasks. Relationships were considered between performance on the three cognitive tasks in the two groups of children. This analysis aimed to tease apart the various memory and processing factors contributing to performance on the cognitive tasks.

A visuo-spatial processing measure was included in the study to try to ascertain whether any cognitive difficulties observed in the children with SLI were specific to tasks with memory elements. Although a difficulty with visuo-spatial short-term memory (or general short-term memory) might not explain all the different types of cognitive difficulties documented in the SLI literature, it could certainly be a factor in tasks such as mental imagery and other visual processing tasks that require mental manipulations of material. Hence, if difficulties were seen in the children with SLI on the verbal short-term memory and visuo-spatial short-term memory tasks only, then it may be a general short-term memory difficulty that is underpinning much of the difficulty seen in cognitive performance in children with SLI.

Alternatively, if one subscribes to the view that children with SLI have general difficulties with processing of information, such impairment may affect verbal short-term memory, visuo-spatial short-term memory and also visuo-spatial processing performance. Hence, if difficulties were seen in the children with SLI in all three areas, then these may be due to processing demands, rather than the memory difficulties.

As well as theoretical benefits, knowledge of the visuo-spatial memory and processing skills of children with SLI is likely to be of interest to practitioners working with children with SLI, particularly those involved with the design of effective intervention.

Methods:

Participants

Two groups of children participated in the study: nine children with SLI and nine typically developing children. Participant characteristics of both groups are given in table 1.

INSERT TABLE 1 ABOUT HERE

Children with SLI:

Nine children with SLI participated in the study, with a mean age of 3 years 9 months (sd = 5 months) at the outset of the study. These children were recruited from speech and language therapy services in the North West of England and were all receiving therapy throughout the study. All speech and language therapists reported that these children had persistent difficulties specific to language. Screening measures confirmed this view. All the children with SLI had normal non-verbal IQ (all within 7 months of their chronological age) as measured by the Leiter International Performance Scale (Leiter, 1969), and did not differ significantly from the typically developing children in terms of mental age (SLI = 48.1 months (sd = 7.5); TD = 49.0 months (sd = 4.5); Mann Whitney U = 35.5, exact p = 0.67).

None of the children demonstrated any autistic tendencies, based on the Autistic Screening Questionnaire (ASQ; Berument et al. 1999) nor did they have any hearing difficulties, neurological abnormalities, oro-motor abnormalities, nor motor difficulties, according to both therapist and parental report. The children with SLI were all scoring at least 1 standard deviation (SD) below the mean (below the 16th percentile) on the Reynell Developmental Language Scales III expressive section (Edwards et al. 1997), and six out of nine participants were also scoring lower than 1 SD below the mean on the receptive section (with the three other participants having demonstrated significant difficulties on the receptive language section in a study 6 months previous to the current investigation, see Hick et al. 2002 for details). Table 2 presents the Reynell percentile scores for each participant in the SLI group.

INSERT TABLE 2 ABOUT HERE

Typically developing children:

Nine typically developing children also participated, by way of a control group. The typically developing children were recruited from nursery units attached to local authority schools in South Manchester. The children had a mean age of 3;9 (sd = 4 months) at the outset of the study. The typically developing children had no known educational difficulties or history of speech and language difficulties, no hearing or other sensory impairments, nor any reported motor impairments. The typically developing children were matched for mental age with the children with SLI, hence also demonstrated normal non-verbal abilities (Leiter 1969; no more than 4 months lower than chronological age) and they did not display any autistic tendencies (ASQ; Berument et al. 1999)

Procedure

After the initial screening, all participants were visited on three occasions, with a six-month interval between each data collection point. Children were all seen individually by a single researcher, either at home or at school, depending on parental preference. Written consent was gained from parents of all children. Three tasks were administered to all children at each visit. The order of presentation was the same for all children: verbal short-term memory task (digit span); visuo-spatial short-term memory task (pattern recall); visuo-spatial processing task (block construction). The tasks are described below:

Verbal Short-Term Memory Task: Digit span. Taken from the British Ability Scales (BAS; Elliot et al. 1978).

This task measures verbal short-term memory. It was chosen as it has been consistently used successfully with both typically developing children (e.g. Gathercole and Adams 1993) and also children with SLI (e.g. Gillam et al. 1998).

Participants repeat auditorily presented lists of digits, beginning with items of two digits in length. There are five items in each block of numbers (blocks are from two to nine digits in length). If the first item is passed the child moves onto the next block until an item is failed. Once an item is failed the child moves back a block and all the items are presented. If any of these items are failed then the child moves back a block again, until a whole block is repeated correctly. The test is discontinued when all five items in a block of numbers have been failed. A span score was derived in the current study, taking the greatest length at which at least three out of five items were repeated correctly as the child's digit span.

Visuo-Spatial Short-Term Memory Task: Pattern recall.

This task was designed to provide a visuo-spatial short-term memory measure, based on a measure devised by Jarrold et al. (1999). An appropriate standardised measure was not available for the children in the current study. A Corsi measure of visuo-spatial short-term memory was not administered, due to the young age of many of the participants in the study. Jarrold et al.'s task requires the child to recall the positions of frogs on lilypads, presented on computer. In the current study, a computer was not available for use. Instead a paper version of the pattern recall task was designed. In this task, computerised pictures of sharks are presented on acetate over paper grids which are coloured to represent the sea. Half the squares of 'sea' have sharks over the top, the sharks then 'disappear' after 2 seconds. The child's task is to remember where the sharks were, responding by pointing to the correct square of sea. The number of sharks increases progressively from two to five. With each increase in number of sharks, the number of squares of sea also increases by two. Twenty trials are presented to each child: 5 trials at 4 levels: five 2x2 grids with 2 sharks; five 2x3 grids with 3 sharks; five 2x4 grids with four sharks and five 2x5 grids with 5 sharks. Each sheet of sharks is presented to the child with a 'sea' grid (printed on paper from a computer drawing) underneath. These acetates and grids are in a ring binder which is presented to the child horizontally as an easel, so they can only see one side. Two practice trials are administered before the task commences. In these trials the child is shown a 2x2 sea grid with one shark on an acetate sheet over the top. The investigator initially ensures that the child can see and identify the shark. The child is told that the shark is going to hide in the sea and that they have to try to remember where it was. After 2 seconds the acetate sheet is flipped over to the other side of the ring binder (out of sight of the child), and the child is asked to point to the square of sea where the shark had been. Once the child has successfully completed two practice trials they are told there will now be two sharks that are going to hide and that they need to try to remember where they were. The main part of the task then commences. The sharks are presented to the child as they are in the practice trials. The child scores one point for each set of sharks correctly recalled, giving a total score out of 20.

Visuo-Spatial Processing Task: Block Construction. Taken from the NEPSY: A Developmental Neuropsychological Assessment: (Korkman et al. 1998).

This task was chosen for use as it is designed to assess a child's ability to integrate visuo-spatial processing and motor skills as well as planning abilities, but does not have a visuo-spatial memory element as the model is available at all times. An equivalent task was not available in the BAS battery. The participant is required to copy a three-dimensional block construction from a three-dimensional model and subsequently from two-dimensional pictures. The task is timed with bonus points being scored for fast performance in the later tasks. In the current study, the timed element was removed from the task and groups were compared on raw scores only, with no bonuses given for faster performance. It was thought that this would be a fairer comparison of visuo-spatial skills per se between the two groups, rather than adding a speeded motor-coordination element to the task. There have also been suggestions that children with SLI have some limitations in speed of processing (Kail 1994, Miller et al. 2001).

Results:

Because of the nature of the data and number of participants, non-parametric tests have been used throughout. All analyses were done on raw scores. The main over-time analyses are presented initially. For the verbal short-term memory task (digit span) there was a main effect of time in both the SLI and the typically developing (TD) group (Friedman: SLI = $\chi^2(2) = 11.12$, $p = 0.004$; TD = $\chi^2(2) = 9.58$, $p = 0.008$), and a significant group difference with all three time points combined (3 time-scores summed, Mann Whitney = 11.0, exact $p = 0.008$). These results indicated that for the digit span task, performance was significantly higher in the typically developing group but that performance of both groups was improving over time, suggesting no major interaction effects.

Likewise, for the visual processing task (block construction) there was a significant effect of time for both groups (Friedman: SLI = $\chi^2(2) = 11.66$, $p = 0.003$; TD = $\chi^2(2) = 8.82$, $p = 0.012$), but no significant effect of group when time points were collapsed (Mann Whitney = 28.5, exact $p=0.30$). This suggested a similar level of performance and similar development in both the SLI and TD groups for the block construction task.

For pattern recall, a different finding emerged. For the SLI group, no significant change over time was found (Friedman: SLI = $\chi^2(2) = 1.45$, $p = 0.49$) whilst for the TD group, the effect of time was significant (Friedman: TD = $\chi^2(2) = 8.67$, $p = 0.013$). This may suggest an interaction between the rate of development and group. However although the children with SLI performing lower overall on the pattern recall task, the group comparison (with time point scores summed) was not statistically significant (Mann Whitney = 28.5, exact $p=0.30$).

Mean and median task scores and ranges for the two groups of children at each time-point can be seen in table 3. The children with SLI had larger range of performance at all time-points on both the block construction and pattern recall tasks than the typically developing children.

INSERT TABLE 3 ABOUT HERE

Spearman Rho correlations were then calculated for all the tasks at time 3 for the children with SLI and typically developing children separately. Due to small participant numbers, very high coefficients were required in order for correlations to be significant. Nevertheless some patterns were evident, in particular, that only the children with SLI showed significant relationships between tasks. Coefficients are presented in table 4.

INSERT TABLE 4 ABOUT HERE

Discussion:

Results supported previous findings of difficulty with verbal short-term memory in children with SLI, relative to typically developing (e.g. Gathercole and Baddeley 1990, Gathercole 1995, Montgomery 1995, Bishop et al. 1996, Dollaghan and Campbell 1998, Henry et al. 2000, Gathercole et al. 2001). However, although the children with SLI were performing at a lower level on the verbal short-term memory task (digit span), their rate of development over time on the task was similar to the typically developing children. Hence, although the children with SLI did the verbal short-term memory task problematic, they were able to improve their performance throughout the study.

Concerning the visuo-spatial processing task (block construction), there was no significant difference between overall group performance. However, there was more variability in performance in the children with SLI on the block construction task, as indicated by the larger range of scores in this group. As with the digit span task, development over time on block construction was similar in the children with SLI and typically developing children.

The visuo-spatial short-term memory task (pattern recall) showed difficulties in the children with SLI relative to the typically developing children in terms of development over time. This supports the suggestion that children with SLI may have some cognitive difficulties, despite normal non-verbal abilities overall (e.g. Kamhi 1981, Cromer 1983, Johnston and Ellis Weismer 1983, Kamhi et al. 1984, Nelson et al. 1987, Kamhi et al. 1988, Ellis Weismer 1991, Kamhi et al. 1995). It further suggests that problems with short-term memory in children with SLI may not be restricted to verbal short-term memory tasks. It also emphasises the need to examine skills over time.

The correlational analysis was interesting, as different relationships were seen in the children with SLI, compared with the typically developing children. This finding may suggest an increased involvement of more general processing in the performance of the children with SLI on the cognitive tasks, compared with that of the typically developing children. However, due to the small numbers of children involved in the current study, future investigation is necessary to replicate the correlational findings.

Findings from previous research on cognitive abilities in children with SLI may help to explain the current results. Evidence has indicated difficulties with mental imagery in children with SLI (e.g. Kamhi 1981, Johnston and Ellis Weismer 1983, Johnston 1999). The visuo-spatial short-term memory task utilised in the current study (pattern recall) requires skills similar to those involved in mental imagery tasks (e.g. an image of the position of the sharks needs to be generated, stored temporarily and then retrieved and reproduced by the child). Therefore, it could be possible that a mental imagery deficit is affecting performance on the visuo-spatial short-term memory task, as well as any concurrent short-term memory difficulty. Such compounding difficulties may account for the poorer performance of the children with SLI over time on the visuo-spatial short-term memory task, relative to the other two cognitive tasks.

Processing limitations in SLI, as postulated by Ellis Weismer (1991) and Ellis Weismer and Evans (2002) can, to some degree, explain the difficulties seen in the children with SLI on all three tasks administered in the current study. However, general processing difficulties cannot fully explain why the visuo-spatial short-term memory task did not show developmental improvements in the children with SLI.

More research is required to identify whether a particular aspect of the pattern recall task is problematic for children with SLI, or whether it is simply that the task requires 'more' processing in some way.

The lower language level of the children with SLI could have contributed to their delays in performance. Language difficulties are likely to impinge on most tasks to a certain degree, even where verbal instruction or response is not required.
As Johnston stated:

'Whenever (verbally-based) mental strategies lead to simpler solutions than nonverbal strategies, the child with a language impairment would be at a developmental disadvantage.' (Johnston 1994, page 111).

Due to the expressive language requirements of a verbal memory task such as digit span, it might be reasonable to expect a language impairment to affect performance to some degree. However, previous research suggests that verbal output difficulties are not the only factor contributing to difficulties on digit span tasks in children with SLI. For example, Gillam et al. (1998) found difficulties in children with SLI, compared with typically developing children, on a digit span task that utilised visual presentation and required a non-verbal pointing response. They suggested that the typically developing children were able to translate the pictorial information into its verbal form, whereas the children with SLI were relying upon a less efficient visual code in order to recall the digits.

It could be possible that the language difficulties of the children with SLI restrict the skill base they can draw upon in order to perform the visuo-spatial short-term memory task (and, in some children with SLI, the visuo-spatial processing task). If, for example, participants were using some type of counting strategy for the visuo-spatial short-term memory task, the children with SLI might have been disadvantaged.

However, verbal rehearsal is thought to be very limited in typical development before the age of around 7 years (Gathercole et al. 1994). Alternatively, it may have been that the typically developing children were using verbal coding of the positions of the sharks as well as visuo-spatial information, but the children with SLI were relying upon visual short-term memory processes only. However, there are two factors that suggest the typically developing children were unlikely to have been using verbal coding. Firstly, the age of the participants. Evidence from typical development suggests that verbal coding of visual items in memory may not occur spontaneously in children of this age (Hitch and Halliday 1983). Secondly, aspects such as position are much more difficult to verbally recode than a visually presented digit, which has an established lexical label and phonological representation. Hence, language difficulties alone may not be a complete explanation for the performance of the children with SLI in the current study.

It may be that speech and language therapy occurring during the time of the study contributed to improvements in verbal short-term memory. This may offer some explanation for the increases seen in verbal short-term memory relative to visuo-spatial short-term memory in the children with SLI. However, it is less easy to attribute the improvements on the visuo-spatial processing task directly to speech and language intervention. As the visuo-spatial processing task involved a degree of motor skill, development of more sophisticated motor abilities in both groups of children over time might have contributed to improvements on this task throughout the study.

Though the small sample size restricts analysis and interpretation, some implications can be drawn from this study, particularly in terms of future investigations and therapeutic intervention. Firstly, it is clear that research into the cognitive abilities of children with SLI should continue. It should not be assumed that because a child demonstrating primary language impairments is scoring normally on non-verbal cognitive measures, that their performance will be age-appropriate in all cognitive areas. Evidence from the current study suggests some children with SLI may have difficulties in the area of visuo-spatial processing, and particularly visuo-spatial tasks where memory is involved. This is something that requires replicating in future work with this population.

In terms of clinical implications, although limitations in terms of visual processing/memory may not be a priority target area for a speech and language therapist, an awareness that children with SLI may require simple visual support, may be limited in memory for visually presented items or position of items, and may not be able to translate the visual into the verbal as easily as typically developing children, is likely to assist in the planning of effective interventions. Furthermore, based on the current work and also some of the previous research, children with SLI may show detrimental performance in all tasks with high processing loads, for example, lots of different transformations, a range of factors to consider/hold in mind simultaneously- anything where a degree of mental manipulation of material is required, be it verbal or visual. Such knowledge is of relevance to both speech and language practitioners, and also all educational professionals involved in planning curriculum activities for children with SLI.

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References

BERUMENT, S., RUTTER, M., LORD, C., PICKLES, A. and BAILEY, A. (1999). Autism Screening Questionnaire: Diagnostic validity. British Journal of Psychiatry, **175,** 444-451

BISHOP, D., NORTH, T. and DONLAN, C. (1996). Nonword repetition as a behavioural marker for inherited language impairment: evidence from a twin study. Journal of Child Psychology and Psychiatry, **37**, 391-403.

BRISCOE, J., BISHOP, D., and NORBURY, C.F. (2001). Phonological processing, language and literacy: A comparison of children with mild-to-moderate sensorineural hearing loss and those with specific language impairment. Journal of Child Psychology and Psychiatry, **42**, 329-340.

CROMER, R. (1983). Hierarchical planning disability in the drawings and constructions of a special group of severely aphasic children. Brain and Cognition, **2,** 144-164.

DE RENZI, E. and NICHELLI, P. (1975). Verbal and nonverbal short-term memory impairment following hemispheric damage. Cortex, **11**, 341-354.

DOLLAGHAN, C. and CAMPBELL, T. (1998). Nonword repetition and child language impairment. Journal of Speech, Language and Hearing Research, **41**, 1136-1146.

EDWARDS, S., FLETCHER, P., GARMAN, M., HUGHES, A., LETTS, C. and SINKA, I. (1997). Reynell Developmental Language Scales III. (Windsor, UK: NFER-Nelson.)

ELLIOT, C., MURRAY, D. and PEARSON, L. (1978). British Ability Scales. (Windsor, UK: NFER-Nelson.)

ELLIS WEISMER, S. (1991). Hypothesis testing abilities of language-impaired children. Journal of Speech and Hearing Research, **34**, 1329-1338.

ELLIS WEISMER, S. and EVANS, J. (2002). The role of processing limitations in early identification of specific language impairment. Topics in Language Disorders, **22**, 15-29.

FAZIO, B. (1997). Learning a new poem: Memory for connected speech and phonological awareness in low-income children with and without specific language impairment. Journal of Speech and Hearing Research, **40**, 1285-1297.

GATHERCOLE, S. (1995). Is nonword repetition a test of phonological memory or long-term knowledge? It all depends on the nonwords. Memory and Cognition, **23**, 83-94.

GATHERCOLE, S. and ADAMS, A. (1993). Phonological memory in very young children. Developmental Psychology, **29**, 770-778

GATHERCOLE, S. and BADDELEY, A. (1990). Phonological memory deficits in language disordered children: is there a causal connection? Journal of Memory and Language, **29**, 336-360.

GATHERCOLE, S. and BADDELEY, A. (1996). The Children's Test of Nonword Repetition. (London, UK: The Psychological Corporation.)

GATHERCOLE, S. ADAMS, A. and HITCH, G. (1994). Do young children rehearse? An individual differences analysis. Memory and Cognition, **22**, 201-207.

GATHERCOLE, S., WILLIS, C., EMSLIE, H. and BADDELEY, A. (2001). The influences of syllables and wordlikeness on children's repetition of nonwords. Applied Psycholinguistics, **12**, 349-367.

GILLAM, R., COWAN, N. and MARLER, J. (1998). Information processing by school-age children with specific language impairment: evidence from a modality effect paradigm. Journal of Speech, Language and Hearing Research, **41**, 913-926.

HENRY, L., TURNER, J., SMITH, P. and LEATHER, C. (2000). Modality effects and the development of the word length effect in children. Memory, **8**, 1-17.

HICK, R., JOSEPH, K., CONTI-RAMSDEN, G., SERRATRICE, L. and FARAGHER, B. (2002). Vocabulary profiles of children with specific language impairment. Child Language Teaching and Therapy, **18**, 165-180.

HICK, R., BOTTING, N., and CONTI-RAMSDEN, G. (submitted). Short-term memory and vocabulary development in children with Down syndrome and children with specific language impairment. Developmental Medicine and Child Neurology.

HITCH, G. and HALLIDAY, M. (1983). Working memory in children. Philosophical Transactions of the Royal Society, Series B, **302**, 324-340.

INHELDER, B. (1963). Observations sur les aspects opératifs et figuratifs de la pensée chez des enfants dysphasiques. Problèmes de Psycholinguistique, **6**, 143-153.

JARROLD, C. (2001). Applying the working memory model to the study of atypical development. In J. Andrade (Ed.) Working Memory in Perspective. (Hove, Sussex. Psychology Press), pp 126-150.

JARROLD, C., BADDELEY, A. and HEWES, A. (1999). Genetically dissociated components of working memory: evidence from Down's and Williams syndrome. Neuropsychologica, **37**, 637-651.

JOFFE, V. (1998). Rhyming and related skills in children with specific language impairment. Current Psychology of Cognition, **17**, 479-512.

JOHNSTON, J. (1994). Cognitive abilities of children with language impairment. In R. Watkins and M. Rice (Eds.) Specific Language Impairments in Children. (Baltimore. Paul H. Brookes), pp 107-121.

JOHNSTON, J. (1999). Cognitive deficits in specific language impairments: decisions in spite of uncertainty. Journal of Speech-Language Pathology and Audiology, **23**, 165-172.

JOHNSTON, J. and ELLIS WEISMER, S. (1983). Mental rotation abilities in language-disordered children. Journal of Speech and Hearing Research, **26**, 397-403.

KAIL, R. (1994). A method of studying the generalized slowing hypothesis in children with specific language impairment. Journal of Speech, Language and Hearing Research, **37**, 418-421.

KAMHI, A. (1981). Nonlinguistic symbolic and conceptual abilities of language-impaired and normally-developing children. Journal of Speech and Hearing Research, **24**, 446-453.

KAMHI, A., CATTS, H., KOEING, L. and LEWIS, B. (1984). Hypothesis testing and nonlinguistic symbolic abilities in language impaired children. Journal of Speech and Hearing Disorders, **49**, 169-176.

KAMHI, A., LEE, R.F., and NELSON, L. (1985). Word, syllable and sound awareness in language-disordered children. Journal of Speech and Hearing Disorders, **50**, 207-212

KAMHI, A., CATTS, H., MAUER, D., APEL, K. and GENTRY, B. (1988). Phonological and spatial processing abilities in language and reading impaired children. Journal of Speech and Hearing Disorders, **53**, 316-327.

KAMHI, A. WARD, M. and MILLS, E. (1995). Hierarchical planning abilities in children with specific language impairments. Journal of Speech and Hearing Research, **38**, 1108-1116.

KORKMAN, M., KIRK, U. and KEMP, S. (1998). NEPSY: A Developmental Neuropsychological Assessment. (San Antonio, TX: The Psychological Corporation).

LEITER, R. (1969) The Leiter International Performance Scale. (Chicago, IL: Stoelting Company).

LEONARD, L. (1998). Children with Specific Language Impairment. (Cambridge, MA: MIT Press).

METSALA, J. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. Journal of Educational Psychology, **91**, 3-19

MILLER, C., KAIL, R., LEONARD, L. and TOMBLIN, J. (2001). Speed of processing in children with specific language impairment. Journal of Speech, Language and Hearing Research, **44**, 416-433.

MONTGOMERY, J. (1995). Examination of phonological working memory in specifically language impaired children. Applied Psycholinguistics, **16**, 355-378.

NELSON, L., KAMHI, A. and APEL, K. (1987). Cognitive strengths and weaknesses in language impaired children: one more look. Journal of Speech and Hearing Disorders, **52**, 36-43.

PHILLIPS, W. and CHRISTIE, D. (1977). Interference with visualisation. Quarterly Journal of Experimental Psychology, **29**, 637-650.

SNOWLING, M., CHIAT, S. and HULME, C. (1991). Words, non-words and phonological processes: some comments on Gathercole, Willis, Emslie and Baddeley. Applied Psycholinguistics, **12**, 369-373.

VAN DER LELY, H. and HOWARD, D. (1993). Children with specific language impairment: linguistic impairment or short-term memory deficit? Journal of Speech and Hearing Research, **36**, 1193-1207.

WILSON, J., SCOTT, J. and POWER, K. (1987). Developmental differences in the span of visual memory for pattern. British Journal of Developmental Psychology, **5**, 249-255.

Table 1: Participant characteristics

	Children with SLI	Typically developing children
Mean mental age SD (mths)	48 mths (4 yrs) (range = 42-60 months) 7.5	49 mths (4;1 yrs) (range = 42-54 months) 4.5
Mean chronological age SD (mths)	45 mths (3;9 yrs) (range = 40-53 months) 4.7	45 mths (3;9 yrs) (range = 39-49 months) 3.6
No. of males	5	5
No. of females	4	4
Mean ASQ SD	5.86 3.72	5.75 1.91

Table 2: Reynell percentile scores for children with SLI

Participant code	Reynell Percentile Score	
	Expressive	Receptive
A	1	1
B	9	75
C	1	1
D	8	7
E	1	1
F	1	1
G	1	89
H	13	84
I	1	1

Table 3: Mean and median scores and ranges for the three time-points

	Children with SLI				Typically developing children			
Task	Mean	SD	Median	Range	Mean	SD	Median	Range
Time 1:-								
Digit span	2.33	0.71	2	2	3.67	1.23	3	4
Block construction	5.22	1.64	5	6	6.22	1.09	7	3
Pattern recall	8.44	5.03	9	18	9.22	3.27	10	9
Time 2:-								
Digit span	2.89	0.60	3	2	4.33	1.12	4	3
Block construction	5.56	2.46	6	9	6.56	0.53	7	1
Pattern recall	8.33	6.38	10	18	12.22	1.65	13	5
Time 3:-								
Digit span	3.22	0.67	3	2	4.34	1.23	4	3
Block construction	6.56	2.24	7	8	7.34	1.12	7	4
Pattern recall	9.78	7.17	14	19	14.44	2.3	15	6

Table 4: Correlations at time three using Spearman Rho:

Children with SLI:

	Digit span	Pattern recall	Block construction
Digit span	-		
Pattern recall	0.75*	-	
Block construction	0.85**	0.94**	-

*p<0.05 **p<0.001

Typically Developing Children:

	Digit span	Pattern recall	Block construction
Digit span	-		
Pattern recall	- 0.54	-	
Block construction	-0.19	0.63	-

All NS at p=0.05