Short-term memory and vocabulary development in children with Down syndrome and children with specific language impairment

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A longitudinal comparison was made between development of verbal and visuo-spatial short-term memory and vocabulary in children with Down syndrome (DS), children with specific language impairment (SLI), and typically developing children as a control group. Participants were 12 children with DS (6 males, 6 females; mean chronological age 9y 9mo [SD 2.8mo], range 8y 6mo to 11y 4mo); nine children with SLI (4 males, 5 females; mean chronological age 3y 9mo [SD 4.8mo], range 3y 3mo to 4y 5mo); and 12 typically developing children (5 males, 7 females; mean chronological age 4y 4mo [SD 3.9mo], range 3y 3mo to 4y 3mo). Participants were matched on mental age (mean mental age 4y 3mo). All participants completed verbal short-term memory, visuo-spatial short-term memory, and expressive and receptive vocabulary tasks on three occasions over 1 year. Similarities were seen in the clinical groups for verbal short-term memory. There was some evidence of difficulty in visuo-spatial short-term memory in the children with SLI relative to the other groups, but all three groups showed overlap in visuo-spatial short-term memory performance. At the final time-point vocabulary performance in the clinical groups was similar; the typically developing children showed higher vocabulary abilities than both clinical groups.

Down syndrome (DS) arises from the presence of an extra chromosome 21 and occurs in approximately 1 per 1000 live births (Steele 1996). In addition, there is, usually, some degree of learning difficulty (though there can be considerable individual difference: Carr 1985, Sloper et al. 1990), DS has been associated with particular language and verbal short-term memory difficulties. Children with DS can show deficits in expressive grammar and vocabulary, over and above difficulties based on chronological or mental age (Fowler et al. 1994, Chapman et al. 1998, though see Laws and Bishop 2003, discussed below). Receptive vocabulary is often less impaired in children with DS (Fowler et al. 1994, Miller 1999).

Compared with typically developing individuals matched for mental age, children and adults with DS consistently display difficulties in verbal short-term memory (Jarrold and Baddeley 1997, Seung and Chapman 2000), and in receptive vocabulary (Hulme and Mackenzie 1992, Jarrold et al. 2002, Laws 2002), and compared with individuals with other types of learning difficulty (Bower and Hayes 1994; Wang and Bellugi 1994; Jarrold et al. 1999, 2000; Seung and Chapman 2000). Such findings suggest that difficulties with verbal short-term memory in individuals with DS are over and above more general cognitive or language difficulties in this group.

In contrast, visuo-spatial short-term memory abilities in individuals with DS often show an advantage compared with verbal short-term memory skills (Jarrold and Baddeley 1997, Jarrold et al. 1999, Laws 2002, although see Vicari et al. 1995).

Physical impairments in children with DS can make language and verbal short-term memory difficulties more likely. Many individuals with DS have varying degrees of hearing impairment (Pueschel and Sustrova 1996). However, the level of hearing loss does not reliably correlate with the degree of language difficulties in DS (Marcell and Cohen 1992, Chapman et al. 1998), nor does hearing loss adequately explain verbal short-term memory difficulties in this clinical group (Marcell and Cohen 1992, Jarrold and Baddeley 1997, Seung and Chapman 2000, Jarrold et al. 2002). Many individuals with DS have articulation difficulties (Cody and Kamphaus 1999) which can affect speech production and intelligibility (Hamilton 1993, Gunn and Crombie 1996). Removing or reducing the verbal response requirement of verbal short-term memory tasks does not improve memory in individuals with DS (Marcell and Weeks 1988, Laws et al. 1996, Jarrold et al. 2002). Jarrold et al. (2000) found no difference in articulation rates of individuals with DS and individuals with moderate learning difficulties, despite significantly poorer digit span performance in the individuals with DS. This suggests that speech production difficulties may not be the root of verbal short-term memory difficulties in this population.

Children with specific language impairment (SLI) fail to develop language normally, despite normal non-verbal intelligence, no hearing impairment, no frank neurological damage, nor peripheral oro-motor or sensory deficits, and no signs of autism. The pattern of language and verbal short-term memory difficulties described in children with DS is in many ways similar to the difficulties found in children with SLI, at least at some developmental time-points. Studies indicate delay in vocabulary acquisition in children with SLI (Rice 1991, Conti-Ramsden and Jones 1997, Leonard 1998, Hick et al. 2002) and difficulties with experimental expressive vocabulary learning tasks (Dollaghan 1987, Rice et al. 1990). Children with SLI show poor verbal short-term memory when compared with

language-matched, typically developing children (Gathercole and Baddeley 1990, Montgomery 1995, Bishop et al. 1996, Dollaghan and Campbell 1998, Conti-Ramsden et al. 2001a). Low performance on verbal short-term memory tasks is also seen in children with SLI in tasks that remove the need for a verbal response (Gillam et al. 1998).

Laws and Bishop (2003) compared expressive and receptive vocabulary in children with SLI and children with DS, and found vocabulary performance of children with SLI to be poorer than both children with DS and typically developing children matched for non-verbal mental age. The children with DS showed a similar vocabulary performance to the typically developing children. In contrast, Laws and Bishop demonstrated similar verbal short-term memory difficulties in children with SLI and children with DS: both clinical groups showed poorer performance than the typically developing children.

Interestingly, the visuo-spatial short-term memory abilities of children with SLI and children with DS have not been directly compared. There is increasing evidence to suggest that the difficulties experienced by children with SLI may not be completely language-specific (see Johnston 1999 for a review). Children with SLI, despite demonstrating normal non-verbal abilities overall, show poor performance on certain cognitive tasks, for example, mental rotation (Johnston and Ellis Weismer 1983, Kamhi et al. 1984); hierarchical planning (Cromer 1983, Kamhi et al. 1995); and hypothesis testing (Nelson et al. 1987, Ellis Weismer 1991). Some believe children with SLI may have a general limitation in processing (e.g. Ellis Weismer 1991, Johnston 1994, Ellis Weismer and Evans 2002), and/or an inability to coordinate limited processing resources (Hoffman and Gillam 2004) and that such limitations could be responsible for the pattern of language, verbal memory, and cognitive difficulties evidenced in children with SLI. Therefore, it is not inconceivable that the difficulties of children with SLI may extend to visuo-spatial short-term memory.

The current study compared development of short-term memory and vocabulary in children with DS, children with SLI, and typically developing children matched for non-verbal mental age. The main focus was to provide novel information on visuo-spatial short-term memory abilities of children with SLI. The study also aimed to compare visuo-spatial short-term memory in children with DS and children with SLI. A longitudinal design was undertaken. One possibility was that the clinical groups developed at a similar rate to typically developing children, albeit at a lower level. For the children with DS, the disparity between their chronological and mental ages (see Method) suggested slower development over time compared with typically developing children. However, certain tasks could show different developmental trajectories in this population. A developmental comparison has not been performed between children with DS and children with SLI. Although the study was exploratory, several hypotheses were put forward. It was predicted that the clinical groups would show similar levels of performance on verbal short-term memory, both showing difficulties relative to typically developing children. Both clinical groups were expected to show little verbal short-term memory improvement over time. For visuo-spatial short-term memory, it was predicted that the children with DS would show a similar performance to the typically developing children. The children with SLI were predicted to show similar performance to the other two groups initially, but a greater improvement over time than the children with DS. For vocabulary, based on the study by Laws and Bishop (2003), it was expected that the children with SLI would show the lowest performance. It was thought that the children

Table I: Participant characteristics at Time 1

Characteristics	*Children with DS*	*Children with SLI*	*TD children*
Mean mental age, mo	54	48	52
Range, mo	42–60	42–60	42–60
SD, mo	5.79	7.46	6.28
Mean chronological age, mo	117	45	46
Range, mo	98–136	39–53	39–51
SD, mo	12.80	4.80	3.94
Number of males, *n*	6	4	5
Number of females, *n*	6	5	7

DS, Down syndrome; SLI, specific language impairment; TD, typically developing.

Table II: Mean task and standard error of the mean (SEM) scores for three groups at Time 1

Task	*Children with DS (n=12)*		*Children with SLI (n=9)*		*TD children (n=12)*	
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*
Digit Span	2.58	0.15	2.33	0.24	3.92	0.38
Word Span	2.5	0.15	2.22	0.22	3.92	0.31
Pattern Recall	9.50	1.17	8.44	1.68	10.42	1.07
BPVS-II	38.00	2.84	26.22	4.86	42.08	1.99
EVT	43.67	1.71	35.89	2.93	47.42	1.68

DS, Down syndrome; SLI, specific language impairment; TD, typically developing; BPVS-II, British Picture Vocabulary Scale II; EVT, Expressive Vocabulary Test.

with SLI would also show the least improvement in vocabulary development.

Method

PARTICIPANTS

The present study was approved by the University of Manchester Committee on the Ethics of Research on Human Beings. All potential participants received information detailing the purpose and procedures involved in the study. Parents provided written consent for their children's participation.

Participants included: 12 children with trisomy 21 DS, nine children with SLI, and 12 typically developing children (with no known educational difficulties or history of speech and language difficulties). All children were matched for non-verbal mental age using the Leiter International Performance Scale (Leiter 1969). Groups were matched for non-verbal mental age to account for differences in performance between the children because of disparity in general non-verbal ability. Participants of a previous study comparing children with DS and children with SLI were matched on this basis (Laws and Bishop 2003). The three groups did not differ significantly on mental age (analysis of variance [ANOVA]: $F[2,30]=2.33$, $p=0.11$), but the children with DS were of a significantly higher chronological age than the other two groups ($F[2,30]=273.89$, $p<0.001$). Both the typically developing children and children with SLI had age-appropriate non-verbal abilities. Participant details for the three groups (recorded at Time 1) are given in Table I. As the figures indicate, matching was close but not exact, reflecting the heterogeneity of both clinical groups. Preliminary analyses indicated that covarying out differences in mental age did not affect group performance differences. No children had any reported hearing difficulties, and all were monolingual speakers of English. All children lived in the northwest of England during the study. Children with DS were recruited through the Greater Manchester Down Syndrome Association. All the children with DS received varying degrees of special educational provision, with five attending mainstream schools. Type of schooling did not affect results when covaried in preliminary analyses. Children with SLI were recruited through speech and language therapy services in the northwest of England. Typically developing children were recruited from two Manchester primary schools.

At the start of the investigation, the children with SLI all scored at least 1 standard deviation (SD) below the mean (<16th centile) on the Reynell Developmental Language Scales III Expressive section (Edwards et al. 1997). Six out of nine participants also scored lower than 1SD on the receptive section (with the three other participants having demonstrated significant difficulties on the receptive language section in a study 6 months before the current investigation: see Hick et al. 2002). None displayed any signs of autism (Autism Screening Questionnaire; Berument et al. 1999) and none had any frank neurological damage or history of seizures. All children with SLI were receiving speech and language therapy at the time of the study. Speech and language therapists confirmed that the children were demonstrating persistent impairments specific to language. Participant numbers for the children with SLI were slightly smaller owing to difficulties identifying and recruiting children of the required age who fitted the SLI criteria used in this investigation.

PROCEDURE

All participants were seen at three time-points, with a 6-month interval between each data collection point. A single researcher (RH) visited each child individually either at home or at school, depending on parental preference. The following assessments were administered to all children at each visit.

Digit Span

This is from the British Ability Scales (BAS; Elliot et al. 1978). It measures verbal short-term memory ability. Participants repeat lists of digits, beginning with two digits. There are five items in blocks 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 items are presented. If any items are failed the child moves back another block, until a whole block is repeated correctly. The test is discontinued when all five items in a

Table III: Mean task scores, standard error of the mean scores (SEM), and confidence intervals (CI) for three groups at all time-points

Task		*Time 1 (0mo)*			*Time 2 (6mo)*			*Time 3 (12mo)*		
		Mean	*SEM*	*CI*	*Mean*	*SEM*	*CI*	*Mean*	*SEM*	*CI*
Digit Span	DS	2.58	0.15	2.26–2.91	2.5	0.15	2.17–2.83	2.42	0.15	2.09–2.74
	SLI	2.33	0.24	1.79–2.88	2.89	2.00	2.43–3.35	3.22	0.22	2.71–3.74
	TD	3.92	0.38	3.08–4.75	4.5	0.31	3.81–5.19	4.58	0.36	3.80–5.37
Word Span	DS	2.50	0.15	2.17–2.83	2.33	0.14	2.02–2.65	2.58	0.15	2.26–2.91
	SLI	2.22	0.22	1.71–2.74	2.56	0.24	2.00–3.11	3.22	0.22	2.71–3.74
	TD	3.92	0.31	3.23–4.61	4.17	0.24	3.64–4.70	4.33	2.56	3.77–4.90
Pattern Recall	DS	9.50	1.17	6.94–12.06	11.67	1.21	9.01–14.33	12.58	1.19	9.97–15.20
	SLI	8.44	1.68	4.58–12.31	8.33	2.13	3.43–13.24	9.78	2.39	4.27–15.29
	TD	10.42	1.07	8.06–12.77	13.42	0.78	11.69–15.14	15.42	0.80	13.65–17.18
BPVS-II	DS	38.00	2.84	31.76–44.24	44.17	2.60	38.44–49.39	43.50	3.59	35.59–51.41
	SLI	26.22	4.86	15.01–37.43	30.44	4.84	19.29–41.60	37.78	3.79	29.03–46.52
	TD	42.08	1.99	37.70–46.46	52.83	1.87	48.72–56.95	60.25	2.63	54.46–66.04
EVT	DS	43.67	1.71	39.90–47.40	47.33	1.89	43.17–51.50	46.42	1.86	42.32–50.52
	SLI	35.89	2.93	29.13–42.65	38.56	2.87	31.94–45.17	42.00	3.06	34.96–49.05
	TD	47.42	1.68	43.70–51.10	54.75	2.33	49.63–59.87	59.92	2.68	54.03–65.81

DS, Down syndrome; SLI, specific language impairment; TD, typically developing; BPVS-II, British Picture Vocabulary Scale II; EVT, Expressive Vocabulary Test.

block of numbers have been failed. The greatest length at which at least three out of five items were repeated correctly was the child's digit span. This task has been used successfully with children with DS (see Jarrold and Baddeley 1997, Seung and Chapman 2000) and children with SLI (see Gillam et al. 1998).

Word Span

This task has been used previously in a study on the development of language in preschoolers with SLI. (See 'read me' file on Childes database for details on data from this test for children in the Manchester SLI group [Joseph et al. 2002].) Words used were: *man, hat, toe, cup, bin*. These monosyllabic nouns are considered to be part of a child's spoken vocabulary by age 2 years, and so were judged suitable for all children in the study. The child begins by repeating three lists of two words. If successful on at least two out of three occasions, they progress to three lists of three words, and so on, with five words being the maximum list length measured. Word Span is the greatest list length the child can repeat back from at least two out of the three lists administered.

Pattern Recall

This task was based on work by Jarrold et al. (1999) and devised by the first author (RH) to provide a visuo-spatial short-term memory measure. Pictures of sharks are presented over paper grids coloured to represent the sea. Half the squares of 'sea' have sharks over the top, which 'disappear' after a short presentation. The child has to remember where the sharks were, responding by pointing to the correct square of sea. Twenty trials are presented, five trials at four levels: five 2×2 grids with two sharks, five 2×3 grids with three sharks, five 2×4 grids with four sharks, and five 2×5 grids with five sharks. Two practice trials are administered before the task commences. In these trials the child is shown a 2×2 sea grid with one shark. The investigator ensures the child can see and identify the shark. The child is told the shark is going to hide in the sea and they have to remember where it was. After 2s the shark is flipped over (out of sight of the child), and the child is asked to point to the square of sea where the shark was. Once two practice trials are successfully completed, the task begins. Sharks are presented as in the practice trials. The child scores one point for each set of sharks correctly recalled, giving a total score out of 20.

British Picture Vocabulary Scale II (BPVS-II; Dunn et al. 1997)

This task measures children's receptive vocabulary. The child is shown four pictures and is required to point to the picture named by the investigator. Stimuli are divided into sets of 12 items. The test begins with items deemed appropriate for the child's age (or language level). If a child is incorrect on any of these items then the preceding set of items are administered until a basal level of one or no errors out of 12 items is reached. The task finishes when the child makes eight or more errors in a set. The BPVS-II has been used successfully with children with DS (see Jarrold et al. 2000, Laws et al. 2000) and with children with SLI (see, Gathercole and Baddeley 1990, Hick et al. 2002).

Expressive Vocabulary Test (EVT; Williams 1997)

This assesses expressive vocabulary and word retrieval, using labelling and synonyms to elicit vocabulary. Initially, the children are shown a picture and asked to name it. If they continue to answer correctly they move to the synonym section, where they are presented with a picture and a spoken word and asked to provide another word for the picture. Children start at a point deemed suitable for their age (or language level) and then go forward or backward until a basal score of five consecutive correct items is reached. The test is stopped after five consecutive incorrect items. The EVT has been used successfully in other studies involving children with SLI (see Conti-Ramsden et al. 2001b).

Results

To consider differences between the groups in task performance over time, raw data were analyzed using mixed ANOVAs, with

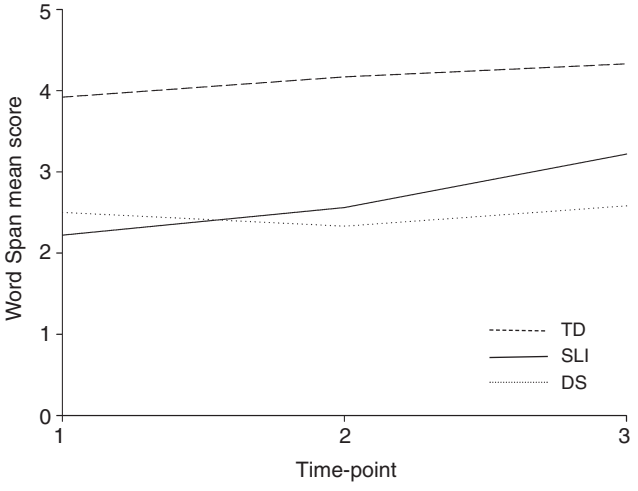

Figure 1: *Mean Word Span scores for three groups over time. TD, typically developing; SLI, specific language impairment; DS, Down syndrome.*

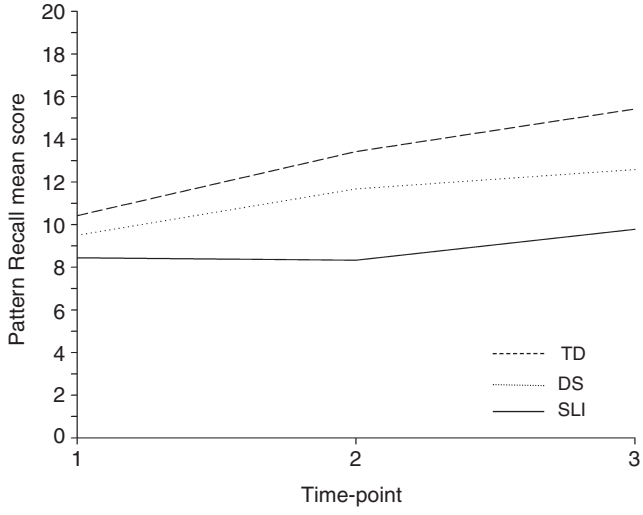

Figure 2: *Mean Pattern Recall scores for three groups over time. TD, typically developing; DS, Down syndrome; SLI, specific language impairment.*

group as the independent measure and time as the repeated measure.

Significant time × group interactions occurred for all tasks except pattern recall, although the interaction was approaching significance (Digit Span: $F[4,60]=5.67$, $p=0.001$; Word Span: $F[4,60]=3.49$, $p=0.013$; Pattern Recall: $F[4,60]=2.16$, $p=0.08$ not significant; BPVS-II: $F[4,60]=10.72$, $p<0.001$; EVT: $F(4,60)=7.58$, $p<0.001$). Therefore, for the verbal short-term memory tasks and the vocabulary tasks there were some differences between the groups with regard to performance over time. Mean scores for all three groups at time 1 are presented in Table II. Table III shows the mean scores, confidence intervals, and standard error scores for all groups on all tasks at the three time-points. Figures 1 and 2 plot mean scores for the three groups for word span and pattern recall respectively, as these tasks exemplify the pattern of results.

For verbal short-term memory (Digit Span and Word Span), the typically developing children scored higher than the other two groups at all three time-points. However, the children with SLI made progress over time which was not seen in the children with DS.

For vocabulary (BPVS-II and EVT), the children with SLI began with lower scores than the children with DS. The children with SLI made progress over time. In contrast, although the children with DS improved, their scores showed a plateau between times 2 and 3.

For visuo-spatial short-term memory (Pattern Recall), the children with SLI showed the least positive development of all three groups, and thus, the gap in scores between the children with SLI and the other groups widened over time. There was also high variation in the scores of the children with SLI for this task compared with the other two groups of children.

Discussion

For verbal short-term memory, results indicated some similarities in the clinical groups. Both clinical groups scored significantly lower than the typically developing children throughout the test. This confirms previous studies documenting difficulties in verbal short-term memory in individuals with DS (e.g. Hulme and Mackenzie 1992, Jarrold and Baddeley 1997, Seung and Chapman 2000, Jarrold et al. 2002, Laws 2002) and in children with SLI (Gathercole and Baddeley 1990, Montgomery 1995, Bishop et al. 1996, Dollaghan and Campbell 1998, Conti-Ramsden et al. 2001a). Despite performance similarities, the children with DS showed less improvement in verbal short-term memory over the course of the investigation than the children with SLI.

For vocabulary, initially the children with DS showed some advantage in both expressive and receptive vocabulary, relative to the children with SLI. However, this advantage was not maintained. The children with SLI improved on vocabulary over time, but also showed a wide variation in vocabulary abilities. At the end of the study, the typically developing children showed significantly higher vocabulary scores than both clinical groups. The children with DS appeared to plateau in their vocabulary performance between the second and third time-points. In summary, when children with DS and children with SLI were compared over time using BPVS-II and EVT vocabulary measures, they did not show similarities in performance at all time points.

Researchers have found similarities between the language of children with DS and children with SLI, based on expressive grammar measures (Bol and Kuiken 1990, Scarborough et al. 1991). This suggests language performance similarities in these clinical groups may be restricted to grammatical ability, and may not extend to vocabulary. Laws and Bishop (2003) found differences between children with DS and children with SLI in terms of vocabulary performance. However, they also found that children with DS showed similar levels of vocabulary to typically developing children matched for non-verbal mental age. This was only the case at time 1 in the current study. This further highlights the importance of longitudinal investigation when investigating clinical group abilities on any task. Similar levels of performance may be a transient feature rather than a consistent pattern, when considered developmentally.

Findings from the visuo-spatial short-term memory task (Pattern Recall) warrant further consideration. Overall, the three groups showed similar levels of performance over time. However, results suggested that some children with SLI were scoring low on visuo-spatial short-term memory, and showing little improvement, compared with the other two groups. This is interesting, as it might be expected that the children with SLI would show most typical development on a non-verbal short-term memory task, and slower improvements on verbal tasks. The visuo-spatial short-term memory findings are in line with the suggestion that children with SLI have of difficulties in areas other than language and verbal short-term memory (see Johnston 1999), and also of more general cognitive/processing difficulties in SLI (Ellis Weismer 1991, Johnston 1994, Ellis Weismer and Evans 2002). They may further suggest that the short-term memory difficulties of children with SLI are not limited to verbal tasks. Further research is needed to confirm this finding, particularly as not all the children with SLI were showing difficulties with the visuo-spatial short-term memory task.

Throughout the study the children with DS showed levels of pattern recall performance similar to that of typically developing children. This supports the advantage of visuo-spatial memory over verbal short-term memory in individuals with DS (Jarrold and Baddeley 1997, Jarrold et al. 1999, Laws 2002). As standard scores and/or centiles were not available for all tasks, performance was not compared directly. However, data indicated some disparity between verbal short-term memory and visuo-spatial short-term memory abilities in children with DS. Broadley et al. (1995) support the idea that children with DS will use visual support where they can to compensate for poorer verbal short-term memory abilities. Further research into the relationships between short-term memory and language in individuals with DS is warranted. In particular, a larger sample than that in the current study would be useful, and would enable correlation analysis of short-term memory and vocabulary relationships.

Several clinical extrapolations can be made from the current findings. The study adds to evidence suggesting that visually based intervention approaches in education for children with DS are likely be successful. Evidence also suggests verbal short-term memory can improve in children with SLI. Novel information is provided on visuo-spatial short-term memory in SLI, indicating that some children in this clinical group may have difficulties in this area. Practitioners working with children with SLI should be aware that despite overall 'normal' non-verbal abilities, skills such as visuo-spatial short-term memory might also be affected in this population. Additionally, some children with SLI may be less able to exploit their visual short-term memories to assist with language learning.

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