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

Rachel Hick, Nicola Botting & Gina Conti-Ramsden

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Abstract

A longitudinal comparison was made between development of verbal and visuo-spatial short-term memory and vocabulary in children with Down syndrome and children with specific language impairment (SLI), including typically developing children as a control group. Participants were twelve children with Down syndrome (mean chronological age 9;9 years; 6 males, 6 females), nine children with SLI (mean chronological age 3;9 years; 4 males, 5 females) and twelve typically developing children (mean chronological age 4;4 years, 5 males, 7 females). Participants were matched on mental age (mean mental age 4;3 years). All completed verbal short-term memory, visuo-spatial short-term memory and expressive and receptive vocabulary tasks on three occasions over a year. Similarities were seen in the clinical groups with respect to 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 of children showed overlap in visuo-spatial short-term memory performance. At the final time-point vocabulary performance in the clinical groups was similar, and the typically developing children showed higher vocabulary abilities than both clinical groups.

Introduction

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

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

In contrast, visuo-spatial short-term memory abilities in individuals with Down syndrome are often advantageous compared with verbal short-term memory skills (Jarrold & Baddeley, 1997; Jarrold et al., 1999; Laws, 2002; though see Vicari et al., 1995).

Physical impairments in children with Down syndrome can make language and verbal short-term memory difficulties more likely. Many individuals with Down

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

Children with specific language impairment (SLI) fail to develop language normally despite normal non-verbal intelligence, no hearing impairment, no frank neurological damage, no 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 Down syndrome is in many ways similar to the difficulties evidenced in children with SLI, at least at some developmental time-points. Studies indicate delay in vocabulary acquisition in children with SLI (Conti-Ramsden & Jones, 1997; Hick et al., 2002; Leonard, 1998; Rice, 1991) and difficulties with experimental expressive vocabulary learning tasks (e.g. Dollaghan, 1987; Rice et al., 1990). Children with SLI

show poor verbal short-term memory when compared with language matched typically developing children (Bishop et al., 1996; Conti-Ramsden et al., 2001; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Montgomery, 1995). Low performance on verbal short-term memory tasks is also seen in children with SLI with 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 Down syndrome, finding vocabulary performance of children with SLI to be poorer than both children with Down syndrome and typically developing children matched for non-verbal mental age. The children with Down syndrome showed 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 Down syndrome: both clinical groups showed lower performance than the typically developing children.

Interestingly, the visuo-spatial short-term memory abilities of children with SLI and children with Down syndrome have not been directly compared. There is increasing evidence to suggest difficulties of 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 & 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; Ellis Weismer & Evans, 2002; Johnston, 1994), and/or an inability to coordinate limited processing resources (Hoffman & 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 Down syndrome, children with SLI and typically developing children, matched on non-verbal mental age. A 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 Down syndrome 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 Down syndrome, their disparity between chronological and mental age (see method section for details) 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 currently been undertaken with children with Down syndrome and children with SLI. Though the study was exploratory, a number of predictions were made. 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 Down syndrome would show 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 Down syndrome. For vocabulary, based

on Laws and Bishop (2003), it was expected that the children with SLI would show the lowest performance. It was thought that the children with SLI would also show the least improvement in vocabulary abilities.

Method

Participants

Participants were: 12 children with Trisomy 21 type Down syndrome, 9 children with SLI, and 12 typically developing children (with no known educational difficulties or history of speech and language difficulties). All children were matched on non-verbal mental age using the Leiter International Performance Scale (Leiter, 1969). Groups were matched on non-verbal mental age to account for differences in performance between the children due to disparity in general non-verbal ability. A previous study comparing children with Down syndrome and children with SLI matched on this basis (Laws & Bishop, 2003). The three groups did not differ significantly on mental age (ANOVA: F (2,30) = 2.33, p = 0.11), but the children with Down syndrome 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 1. 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 North West of England during the study. Children with Down syndrome were recruited through the Greater Manchester Down Syndrome Association. All the children with Down syndrome 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 North West. Typically developing children were recruited from two Manchester primary schools.

INSERT TABLE 1 ABOUT HERE

The children with SLI all scored at least 1 standard deviation below the mean (below the 16th centile) on the Reynell Developmental Language Scales III expressive section (Edwards et al., 1997) at the start of the investigation. Six out of nine participants also scored lower than 1 standard deviation 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). None displayed any signs of autism (Autism Screening Questionnaire; Berument et al., 1999), nor 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 the children were demonstrating persistent impairments specific to language. Participant numbers for the children with SLI were slightly smaller due to difficulties identifying and recruiting children of the required age who fitted SLI criteria used in this investigation. All parents of participants

gave written consent for participation and the University of Manchester ethics committee approved the study.

Procedure

All participants were seen at three time-points, with a six-month interval between each data collection point. A single researcher 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: From the British Ability Scales (BAS; Elliot et al., 1978). This 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 block of numbers have been failed. A span score was derived, taking the greatest length at which at least three out of five items were repeated correctly as the child's digit span. This task has been used successfully with both children with Down syndrome (e.g. Jarrold & Baddeley, 1997; Seung & Chapman, 2000) and children with SLI (e.g. Gillam et al., 1998).

Word span: This task has been used previously in a study on the development of language in preschoolers with SLI.[1] 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, hence were judged suitable for all children in the study. The child begins by repeating

[1] See 'read me' file on Childes database for details on data from this test for children in the Manchester SLI corpus (Joseph et al., 2002).

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 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 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: 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. Two practice trials are administered before the task commences. In these trials the child is shown a 2x2 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 2 seconds 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; 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 1 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 has been used successfully with children with Down syndrome (e.g. Jarrold et al., 2000; Laws et al., 2000) and with children with SLI (e.g. Gathercole & 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 child is shown a picture and asked to name it. If they continue to answer correctly the child moves 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 (e.g. Conti-Ramsden et al., 2001).

Results

INSERT TABLE 2 AND TABLE 3 ABOUT HERE

To consider differences between the groups in task performance over time, raw data were analysed using mixed ANOVAs, with group as the independent measure and time as the repeated measure.

Significant time x group interactions occurred for all tasks except pattern recall, though 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 n/s; BPVS: 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 respect to performance over time. Mean scores for all three groups at time 1 are presented in table 2. Table 3 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 the mean scores for the three groups for word span and pattern recall respectively, as these tasks exemplify the pattern of results.

INSERT FIGURES 1 AND 2 ABOUT HERE

For verbal short-term memory (digit span and word span), the typically developing children scored highest at all three time-points. However, the children with SLI made progress over time that is not seen in the children with Down syndrome.

For vocabulary (BPVS and EVT), the children with SLI began with lower scores than the children with Down syndrome. The children with SLI made progress over time. In contrast, although the children with Down syndrome improve on vocabulary, their scores show a plateau between times 2 and 3.

For visuo-spatial short-term memory (pattern recall), the children with SLI show the least positive development of all three groups, and thus the gap in scores between the children with SLI and the other groups widens over time. There was also high

variation in the scores of the children with SLI for this task, compared to the other two groups of children.

Discussion

With respect to verbal short-term memory, results indicated some similarities in the clinical groups. Both clinical groups scored significantly lower than the typically developing children throughout. This confirms previous studies documenting difficulties on verbal short-term memory in individuals with Down syndrome (e.g. Hulme & Mackenzie, 1992; Jarrold & Baddeley, 1997; Jarrold et al., 2002; Laws, 2002; Seung & Chapman, 2000) and in children with SLI (e.g. Bishop et al., 1996; Conti-Ramsden et al., 2001; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Montgomery, 1995). Despite performance similarities, the children with Down syndrome 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 Down syndrome were showing 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 Down syndrome appeared to plateau in their vocabulary performance between the second and third time-points. In summary, when children with Down syndrome and children with SLI were

compared over time using BPVS 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 Down syndrome and children with SLI, based on expressive grammar measures (e.g. Bol & Kuiken, 1990; Scarborough et al., 1991). This suggests language performance similarities in these clinical groups may be restricted to grammatical ability, and not extend to vocabulary. Laws and Bishop (2003) found differences between children with Down syndrome and children with SLI in terms of vocabulary performance. However they also found children with Down syndrome to show 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 some children with SLI were scoring low on visuo-spatial short-term memory, and showing little improvement, compared to 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 proposals of difficulties in children with SLI in areas other than language and verbal short-term memory (e.g. Johnston, 1999), and also more general cognitive/processing difficulties in SLI (Ellis Weismer, 1991; Ellis Weismer & Evans,

2002; Johnston, 1994). 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 Down syndrome showed levels of pattern recall performance similar to the typically developing children. This supports an advantage for visuo-spatial memory, relative to verbal short-term memory, in individuals with Down syndrome (e.g. Jarrold & 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 the children with Down syndrome. Broadley et al. (1995) support the idea that children with Down syndrome 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 Down syndrome is warranted. In particular, a larger sample than the one in the current study would be useful, and would enable correlational analysis of short-term memory and vocabulary relationships.

A number of clinical extrapolations can be made from the current findings. The study adds to evidence suggesting visually-based intervention approaches in education for children with Down syndrome 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 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.

References

Baddeley, A. (1986) *Working Memory*. Oxford: Oxford University Press.

Baddeley A, Gathercole S, Papagno C. (1998) The phonological loop as a language learning device. *Psychol Rev*105: 158-173

Baddeley A, Hitch G. (1974) Working memory. In: Bower G, editor. *The Psychology of Learning and Motivation.* New York: Academic Press. p 47-90.

Berument S, Rutter M, Lord C, Pickles A, Bailey A. (1999). Autism Screening Questionnaire: Diagnostic validity. *Br J Psychiatry*175: 444-451.

Bishop D, North T, Donlan C. (1996) Nonword repetition as a behavioural marker for inherited language impairment: evidence from a twin study. *J Child Psychol Psychiatry*37: 391-403.

Bol G, Kuiken F. (1990) Grammatical analysis of developmental language disorders: a study of the morphosyntax of children with specific language disorders, with hearing impairment and with Down's syndrome. *Clin Linguist Phon*4: 77-86.

Broadley I, MacDonald J, Buckley S, (1995) Working memory in children with Down syndrome. *Down Synd Res Pract*3: 3-8.

Buckley S, (1999b) Improving the speech and language skills of children and teenagers with Down syndrome. *Down Syndrome News and Update*1: 111-128.

Buckley S, Bird G, (1993) Teaching children with Down's syndrome to read. *Downs Synd Res Pract*1: 34-39.

Carr J. (1985) The development of intelligence. In: Lane D, Stratford B, editors. *Current Approaches to Down's Syndrome* London: Holt, Rinehart and Wilson. p 167-186.

Chapman R, Hesketh L, Kistler D. (2002) Predicting longitudinal change in language production and comprehension in individuals with Down syndrome: hierarchical linear modelling. *J Speech Lang Hear Res*45: 902-915.

Chapman R, Seung H.-K, Schwartz S, Kay-Raining Bird E. (1998) Language skills of children and adolescents with Down syndrome: II. Production deficits. *J Speech Lang Hear Res*41: 861-873.

Cody H, Kamphaus R. (1999) Down Syndrome. In: Goldstein S, Reynolds C. editors. *Handbook of Neurodevelopmental and Genetic Disorders in Children.* New York: The Guildford Press. p 385-405.

Conti-Ramsden G, Botting N, Faragher B. (2001) Psycholinguistic markers for specific language impairment (SLI). *J Child Psychol Psychiatry*42: 741-748.

Conti-Ramsden G, Botting N, Simkin Z, Knox E. (2001) Follow-up of children attending infant language units: outcomes at 11 years of age. *Int J Lang Commun Disord*36: 207-219.

Conti-Ramsden G, Jones M. (1997) A comparison of verb use in children with SLI and their younger siblings. *First Language*17: 165-193.

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

De Renzi E, Nichelli P. (1975) Verbal and nonverbal short-term memory impairment following hemispheric damage. *Cortex*11: 341-354.

Dollaghan C. (1987) Fast mapping of normal and language-impaired children. *Journal of Speech and Hearing Disorders*52: 218-222.

Dollaghan C, Campbell T. (1998). Nonword repetition and child language impairment. *J Speech Lang Hear Res*41: 1136-1146.

Dunn L, Dunn L, Whetton C, Burley J. (1997) *British Picture Vocabulary Scale II.* Windsor: NFER-Nelson.

Duyck W, Szmalec A, Kemps E, Vandierendonck A. (2003) Verbal working memory is involved in associative word learning unless visual cues are available. *Journal of Memory and Language*48: 527-541.

Edwards S, Fletcher P, Garman M, Hughes A, Letts C, Sinka I. (1997) *Reynell Developmental Language Scales III.* University of Reading Edition. Windsor: NFER-Nelson.

Elliot C, Murray D, Pearson L. (1978) *British Ability Scales.* Windsor: NFER-Nelson.

Ellis Weismer S. (1991) Hypothesis testing abilities of language-impaired children. *J Speech Hear Res*34: 1329-1338.

Farrand P, Jones D. (1996) Direction of report in spatial and verbal serial memory. *Q J Exp Psychol*49A: 140-158.

Fowler A, Gelman R, Gleitman L. (1994) The course of language learning in children with Down syndrome. In: Tager-Flusberg H, editor. *Constraints on Language Acquisition: Studies of Atypical Children.* Hilsdale, NJ: Erlbaum. p 91-140.

Gathercole S. (1995) Is nonword repetition a test of phonological memory or long-term knowledge? It all depends on the nonwords. *Mem Cognit*23: 83-94.

Gathercole S, Adams A. (1993) Phonological memory in very young children. *Dev Psychol*29: 770-778.

Gathercole S, Baddeley A. (1989) Evaluation of the role of phonological STM in the development of vocabulary in children: a longitudinal study. *Journal of Memory and Language*28: 200-213.

Gathercole S, 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, Baddeley A. (1993) *Working Memory and Language.* Hove: Erlbaum.

Gathercole S, Hitch G, Service E, Martin A. (1997) Phonological short-term memory and new word learning in children. *Dev Psychol*33: 966-979.

Gathercole S, Willis C, Emslie H, Baddeley A. (1992) Phonological memory and vocabulary development during the early school years: a longitudinal study. *DevPsychol*28: 887-898.

Gillam R, Cowan N, Marler J. (1998) Information processing by school-age children with specific language impairment: evidence from a modality effect paradigm. *J Speech Lang Hear Res*41: 913-926.

Gunn P, Crombie M. (1996) Language and speech. In: Stratford B, Gunn P, editors. *New Approaches to Down Syndrome.* London: Cassell. p 249-267.

Hamilton C. (1993) Investigation of articulatory patterns of young adults with Down's syndrome using electropalatography. *Down's Synd Res Prac*1: 15-28.

Hick R, Joseph K, Conti-Ramsden G, Serratrice L, Faragher B. (2002) Vocabulary profiles of children with specific language impairment. *Child Language Teaching and Therapy*18: 165-180.

Hoffman L, Gillam R. (2004) Verbal and spatial information processing constraints in children with specific language impairment. *J Speech Lang Hear Res*47: 114-125.

Hulme C, Mackenzie S. (1992) *Working Memory and Severe Learning Difficulties.* Hove: Erlbaum.

Jarrold C, Baddeley A. (1997) Short-term memory for verbal and visuospatial information in Down's syndrome. *Cognitive Neuropsychiatry*2: 101-122.

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

Jarrold C, Baddeley A, Hewes A. (2000) Verbal short-term memory deficits in Down syndrome: a consequence of problems in rehearsal? *J Child Psychol Psychiatry*40: 233-244.

Jarrold C, Baddeley A, Phillips C. (2002) Verbal short-term memory in Down syndrome: A problem of memory, audition or speech? *J Speech Lang Hear Res*45: 531-544.

Johnston J. (1994) Cognitive abilities of children with language impairment. In: Watkins R, Rice M, editors. *Specific Language Impairments in Children.* Baltimore. Paul H. Brookes. p 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, Ellis Weismer S. (1983) Mental rotation abilities in language-disordered children. *J Speech Hear Res*26: 397-403.

Joseph K, Serratrice L, Conti-Ramsden G. (2002) Development of copula and auxiliary BE in children with specific language impairment and younger unaffected controls. *First Language*22: 137-172.

Kamhi A, Catts H, Koeing L, Lewis B. (1984) Hypothesis testing and nonlinguistic symbolic abilities in language impaired children. *Journal of Speech and Hearing Disorders*49: 169-176.

Kamhi A, Ward M, Mills E. (1995) Hierarchical planning abilities in children with specific language impairments. *J Speech Hear Res*38: 1108-1116.

Laws G. (2002) Working memory in children and adolescents with Down syndrome: evidence from a colour memory experiment. *J Child Psychol Psychiatry*43: 353-364.

Laws G, Bishop D. (2003) A comparison of language abilities in adolescents with Down syndrome and children with specific language impairment. *J Speech Lang Hear Res*46: 1324-1339

Laws G, Byrne A, Buckley S. (2000) Language and memory development in children with Down syndrome at mainstream schools and special schools: a comparison. *Educational Psychology*20: 448-457.

Laws G, MacDonald J, Buckley S. (1996) The effects of short training in the use of a rehearsal strategy on memory for words and pictures in children with Down syndrome. *Down Synd Res Pract*4: 70-78.

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

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

Marcell M, Cohen S. (1992) Hearing abilities of Down syndrome and other mentally handicapped adolescents. *Res Dev Disabil*13, 533-551.

Marcell M, Weeks S. (1988) Short-term memory difficulties and Down's syndrome. *Journal of Mental Deficiency Research*32: 153-162.

Michas I, Henry L. (1994) The link between phonological memory and vocabulary acquisition. *British Journal of Developmental Psychology*12: 147-164.

Miller J. (1999) Profiles of language development in children with Down syndrome. In: Miller J, Leddy M, Leavitt L, editors. *Improving the Communication of People with Down Syndrome.* Baltimore, MD: Paul H. Brookes Publishing. p 11-40.

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

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

Pueschel S, Sustrova M. (1996) Visual and auditory perception in children with Down's syndrome. In: Rondal J, Perera J, Nadel L, Comblain A, editors. *Down's Syndrome: Psychological, Psychobiological and Socio-educational Perspectives.* London: Whurr. p 53-63.

Rice M. (1991) Children with specific language impairment: towards a model of teachability. In: Krasnegor N, Rumbaugh D, Schiefelbusch R, Studdert-Kennedy M, editors. *Biological and Behavioural Determinants of Language Development.* Hillsdale, NJ: Erlbaum. p 447-480.

Rice M, Buhr J, Nemeth M. (1990) Fast mapping and word-learning abilities of language-delayed preschoolers. *Journal of Speech and Hearing Disorders*55: 33-42.

Scarborough H, Rescorla L, Tager-Flusberg H, Fowler A, Sudhalter V. (1991) The relation of utterance length to grammatical complexity in normal and language-disordered groups. *Applied Psycholinguistics*12: 23-45.

Seung H-K, Chapman R. (2000) Digit span in individuals with Down syndrome and in typically developing children: temporal aspects. *J Speech Lang Hear Res*43: 609-620.

SLI Consortium (2002). A genomewide scan identifies two novel loci involved in specific language impairment. *Am J Hum Genet*70: 384-398.

Sloper P, Cunningham C, Turner S, Knussen C. (1990) Factors relating to the academic attainments of children with Down's syndrome. *Br J Educ Psychol*60: 284-298.

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

Steele J. (1996) Epidemiology: incidence, prevalence and size of the Down's syndrome population. In: Stratford B, Gunn P, editors. *New Approaches to Down Syndrome.* London: Cassell. p 45-72.

Vicari S, Carlesimo G, Caltagirone C. (1995) Short-term memory in persons with intellectual disabilities and Down's syndrome. *J Intellect Disabil Res*39: 532-537.

Wang P, Bellugi U. (1994) Evidence from two genetic syndromes for a dissociation between verbal and visual-spatial short-term memory. *J Clin Exp Neuropsychol*16: 317-322.

Van der Lely H, Howard D. (1993) Children with specific language impairment: linguistic impairment or short-term memory deficit? *J Speech Hear Res*36: 1193-1207.

Williams K. (1997) *Expressive Vocabulary Test.* Minnesota: AGS.

Table 1: Participant characteristics at time 1

	Children with DS	Children with SLI	TD children
Mean mental age	54 mths (4;6 yrs) (range = 42-60 months)	48 mths (4 yrs) (range = 42-60 months)	52 mths (4;4 yrs) (range = 42-60 months)
SD (mths)	5.79	7.46	6.28
Mean chronological age	117 mths (9;9 yrs) (range = 98-136 months)	45 mths (3;9 yrs) (range = 39-53 months)	46 mths (3;10 yrs) (range = 39-51 months)
SD (mths)	12.80	4.80	3.94
No. of males	6	4	5
No. of females	6	5	7

Table 2: Mean task scores and standard error scores (SES) for the three groups at time 1

	Children with DS (N=12)		Children with SLI (N=9)		TD children (N=12)	
Task	Mean	SES	Mean	SES	Mean	SES
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	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

Table 3: Mean task scores, standard error scores (SES) and confidence intervals (CI) for the three groups at all time-points

Task		Time 1			Time 2			Time 3		
		Mean	SES	CI	Mean	SES	CI	Mean	SES	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	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

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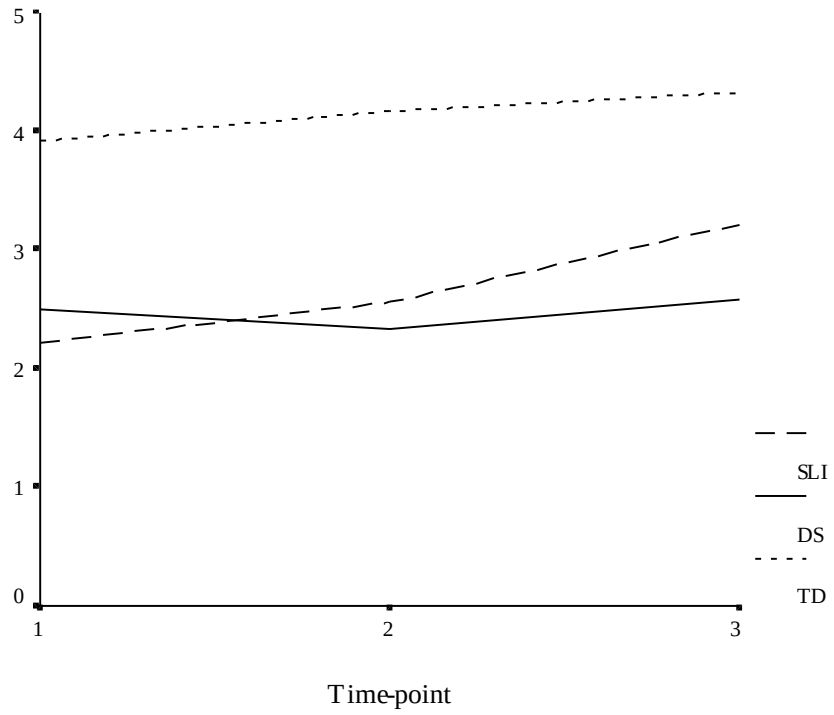
Figure 1: Mean word span scores for the three groups over time

Figure 2: Mean pattern recall scores for the three groups over time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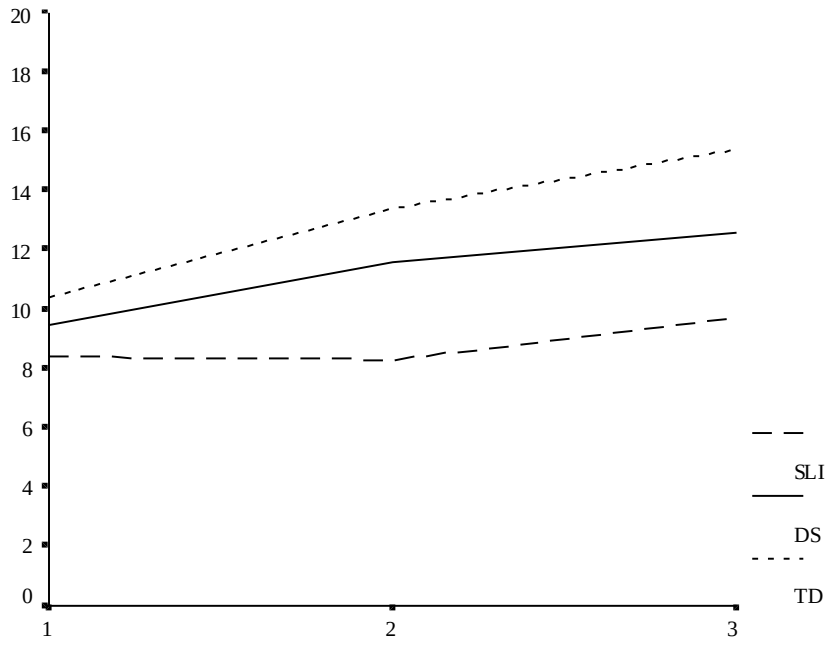
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