The effects of a short training in the use of a rehearsal strategy on memory for words and pictures in children with Down syndrome

Glynis Laws
Department of Psychology, University of Surrey, Guildford, U.K.
John MacDonald, Sue Buckley
Department of Psychology, University of Portsmouth, U.K.

This study describes the effects of using a memory training programme with children with Down syndrome at schools for children with severe learning difficulties. The results suggest a small but significant improvement in memory spans for children at schools where they were trained by teachers or teaching assistants. There were no significant differences between auditory or visual stimulus presentation or between manual or verbal responses, but a three-way interaction between assessment point, stimulus presentation and response mode showed that memory and verbal recall of longer words particularly improved. Responses demonstrated a classic word length effect. One further finding was a significant correlation between reading and memory scores after the training.

Acknowledgements
This research was funded by the University of Portsmouth (HEFCE). We would like to thank the children who took part in this research, and the parents, teachers or teaching assistants who worked with them. The authors would also like to thank Joanna Nye for her assistance with assessments.

Down Syndrome Research and Practice
1996 4 (2) 70-78

Introduction
Gaining some understanding of the short term memory problems of children with Down syndrome and producing effective remediation of these problems are important goals. Restricted short term memory not only results in practical everyday problems in the classroom or at home, but also may have serious implications for the development of other language and cognitive abilities. For example, research suggests there may be links between working memory skills and children's acquisition of vocabulary (Gathercole, Willis, Emslie and Baddeley, 1992). Children with poor working memory skills may find learning new words more difficult.

Since single-word knowledge is important for the development of syntax and semantic structures (Barrett, 1989), limitations on the ability to acquire vocabulary may have a pervasive effect on language development. Working memory processes may also be important in reading, language comprehension and speech production (for a review of research on working memory and language see Gathercole and Baddeley, 1993).

Short term memory deficits in children with Down syndrome have been identified in a number of studies (Bilovsky and Share, 1965, Bower and Hayes, 1994; Das, 1985; McDade and Adler, 1980; Marcell and Armstrong, 1982; Marcell and Weeks, 1988; Varnhagen, Das and Varnhagen, 1987). Most studies find slightly better performance in the visual than in the auditory mode, although Bower and Hayes (1994) found no significant difference between auditory and visual short term memory.

Psychologists at the University of Portsmouth have been engaged in a programme of research on training improvements in short-term memory since 1991. This paper reports the results of the most recent study to evaluate the efficacy of a six-week programme to teach a rehearsal strategy to children with Down syndrome.

The theoretical background to this research is provided by Baddeley and Hitch's working memory model (Baddeley and Hitch, 1974; Baddeley, 1986). The principal features of this model include the notion of separate systems for processing visual or spatial material and for processing verbal material - respectively, the visuospatial scratch-pad and the articulatory loop. These systems are controlled by a central executive which also co-ordinates activity of working memory with that of other cognitive systems. Evidence for the articulatory loop suggests that it acts as a limited capacity store of speech-based information. Its capacity is equivalent to as many words as can be repeated in just under 2 seconds which accounts for the fact that more short words can be remembered than long words (Baddeley, Thomson and Buchanan, 1975).

Throughout childhood memory span grows to reach the normal adult span of about 7 items by the age of 16 (Chi, 1977). This increase is normally matched by a corresponding increase in speech rate as articulation skills develop. Although in people with Down syndrome it is rare to find memory spans greater than 2 or 3 (Bower and Hayes, 1994; Hulme and Mackenzie, 1992; Mackenzie and Hulme, 1987; Marcell and Armstrong, 1982; Marcell and Weeks, 1988), research suggests that it is not their speech production difficulties which account for these poor memory spans (Hulme and Mackenzie, 1992). Rather, they are

thought to be due to a failure to rehearse the items to be remembered (Bower, 1977; Hulme and MacKenzie, 1992).

Several authors have reported successfully increasing memory spans by training a rehearsal strategy to those with moderate learning difficulties (Belmont and Butterfield, 1971; Brown, Campione, Bray and Wilcox, 1973) and those with severe learning difficulties including Down syndrome (Bowler, 1991; Broadley, 1994; Broadley and MacDonald, 1993; Comblain, 1994; Hulme and Mackenzie, 1992)

Broadley studied changes in memory capacity in children with Down syndrome before and after a memory training programme (Broadley,1994; Broadley and MacDonald, 1993). The programme consisted of two training blocks in succession; one provided rehearsal training and the other trained organisation skills. Language and memory performance of the children were compared with a group of control children matched on age and non-verbal ability. Both types of training proved effective. Rehearsal training resulted in increased word spans for auditorily presented and for visually presented stimuli requiring a verbal response. Teaching organisation skills resulted in improved performance on tasks such as choosing the "odd one out", category naming and a fluency measure (e.g. "tell me the names of as many animals as you can").

The children were reassessed some eight months after completing the training programme and had maintained the increases in performance (Broadley, MacDonald and Buckley, 1994). However, the skills were not maintained in the longer term. A sample of fourteen of the original group of twenty-five trained children was revisited three years after completing the programme. By this time, performance on the memory tasks had fallen below the level of their post-training performance. Although this was still better than their pre-training scores it was no different to that achieved by children with similar ages and language abilities who had not been trained (Laws, MacDonald, Buckley and Broadley, 1995). This was not surprising since no plans had been made for the children to continue to practise the trained skills in the longer term.

The results of the eight-month maintenance study indicated significant differences between children who had been trained by the experimenter and those who had been trained by a keyworker, i.e. a parent or teacher (Broadley et al, 1994). The keyworker trained group showed superior maintenance of the memory skills. The experimenter had visited the children she trained just twice each week for the short duration of the training sessions. The keyworker trained children had received the same amount of formal training for the project but the keyworker will also have been able to remind them to use the skills in other contexts (e.g. remembering shopping, fetching items or delivering messages) and may have continued using the training routines after the study ended. Continued teaching of the memory skills and an awareness of the need to prompt the child to use memory strategies in everyday life may well be essential to maintain performance and to promote more general use of the skills.

One aim of the project reported in this study was to recruit participants to take part in an initial training programme, similar to that described above, but who would also be prepared to continue with the training by occasional use of the materials. We hoped to investigate whether the children would sustain any improvements over time and possibly continue to make progress in their memory development. If improvement in memory capacity can be maintained, this would also provide an opportunity to investigate whether better memory would have beneficial effects on other language functions such as vocabulary development. For example, if the children generalised their use of rehearsal with the training materials to other tasks, such as learning new words, the expectation would be that they would learn them more easily.

A further aim of the study was to develop and evaluate the use of a new set of teaching materials to be made available to parents and teachers. The materials used by Broadley (1994) included numerous booklets containing sequences of pictures for memory practice. A "windows" device consisting of a cardboard strip with cut out windows behind which strips of pictures could be inserted was also used for rehearsal training. Although successful in use, these would have been rather expensive to reproduce for general use rather than research. The windows device proved a good way to teach rehearsal but to make its use acceptable over a longer period would have required the provision of a great many alternative strips of pictures to avoid the children becoming bored with repeated presentation of the same pictures.

The solution was to produce a more flexible system which consisted of a row of plastic pockets into which individual pictures can be placed. This allows flexibility in the choice of picture sequences, and also in the type of material which can be presented since the pockets can also be used to show numbers, words, colours etc. The materials and their use are described more fully below.

The study reported here is an evaluation of the use of these memory teaching materials for an initial training period of six weeks. The study also compares the children's memory skills for visually and auditorily presented material, and compares performance under conditions requiring a verbal response with those requiring a manual response. Broadley et al (1995) found significant improvements under auditory and visual presentation conditions, but significantly greater gains were made for visual material. Verbal responses were required for both stimulus types in Broadley's study (although there was also a probed condition). In the present study, the main measures used were word span tasks where the stimulus was presented either as a word (auditory condition) or as a word with an accompanying picture (visual condition). Verbal and manual responses to both these stimulus conditions were recorded.

The data collected for the follow-up study mentioned earlier suggested that there may be a relation between learning to read and the development of other language and memory abilities (Laws, Buckley, Bird, MacDonald and Broadley, 1995). The children who were readers at the start of Broadley's (1994) study, or who were readers by time of the follow-up, had maintained their memory performance over time and had also developed superior vocabulary and grammar understanding. The present study included the collection of reading measures to investigate this relationship in the present sample.

Method

Subjects

Three schools for children with Severe Learning Difficulties volunteered to take part in the project. Meetings with parents and teachers at each school were held to explain the purpose of the research, and what participation in the study would involve. Staff at two schools agreed to teach the children at school. Staff at the third school did not feel able to teach the children, but the parents of these children volunteered to work with them at home.

The schools included a total of forty-two children with Down syndrome. Nine of these children did not take part in the study. The parents of one child withheld consent and eight children, mostly the very youngest, could not respond to the measures chosen for study and so were not included in the research (although their teachers were given training materials).

Pre-training measures were collected from thirty-three children. Of these, six were not included in post-training assessments. Three of these children were in classes which included several children with Down syndrome and it would have been difficult for the staff to work with all of them through the training period. Although it was planned that these children would be taught during the following term, the school subsequently decided to use the teaching materials for regular group language work with all the children in each class as a group. One child who had been trained at another school went on holiday while the post-training assessments were taking place. Two other children started training but their parents had encountered reluctance to engage in the work and had given up the teaching.

The results presented are based on pre-training and post-training measures from the remaining twenty-seven children, nineteen taught at school and eight taught at home. The mean age of the children pre-training was 11 years 9 months (s.d.=42 months); the youngest was 5 years and the oldest, 19 years 1 month. The group included six children under 8, twelve from 8 to 12, and thirteen over 12 years old. There were seven boys and twenty girls.

Procedure

All the children were assessed at school before training started and again after the six week training period. The assessments included the language and memory measures listed below. With the exception of the British Picture Vocabulary Scale (BPVS), the Test for the Reception of Grammar (TROG) and Raven's Coloured Progressive Matrices (Matrices) which were used on only one occasion, all other measures were administered before and after training.

Measures

British Picture Vocabulary Scale -short form (BPVS) (Dunn and Dunn, 1982) - a measure of receptive vocabulary.

Test for the Reception of Grammar (TROG) (Bishop, 1983) - a test to measure grammar understanding.

Raven's Coloured Progressive Matrices (Matrices) (Raven, 1963) - a non-verbal test of general cognitive ability.

Kaufman Assessment Battery for Children (K-ABC) (Kaufman and Kaufman, 1983) - some of the subscales from this test were chosen:

Auditory Digits. This was administered and scored according to the procedure specified in the manual but was also used to calculate a digit span, i.e. the longest sequence of digits remembered in the correct order. Visual test materials were prepared using the same sequences of digits presented in the auditory test and used to measure a visual digit span.

Reading Decoding and Reading Comprehension

Faces. This test of memory for faces was included as a recognition memory measure. The child is shown a photograph of a face which he or she then has to recognise in a group of people in the following photograph.

Hand Movements. This test requires the child to watch, remember and reproduce sequences of hand shapes, i.e. visual stimuli with motor responses.

Triangles. This is a measure of non-verbal cognitive ability.

Word Order. This task is most similar to the word span measures described below. After listening to a sequence of words, the child has to point to silhouette pictures of the words in the correct order.

McCarthy Word Fluency (McCarthy, 1972). This test requires the generation of as many examples as possible from each of four categories in a timed period.

Non-word and word repetition. A point was scored for each nonword correctly repeated from a set of 20 one to four syllable non-words devised by Gathercole and Adams (1994). 15 one to three syllable words acquired early in lexical development were also presented.

Sentence Memory. This task required repetition of 16 phrases or sentences of increasing length and grammatical complexity. One point was scored for each word in the sentence correctly repeated.

Word Span measures

Word spans were tested under four conditions: auditory and visual presentation combined with verbal and manual response modes. In the auditory condition the experimenter spoke the words. In the visual condition the experimenter presented picture cards of the objects and said the word as each card was laid down in sequence. On completion of the sequence the pictures were covered up. The children were required either to repeat the words in the correct sequence (verbal response) or to point to pictures on a card showing six pictures, choosing the correct order (manual response). Performance was measured separately for words of one-, two- and three-syllables, providing a total of twelve measured spans.

For each measure, the test procedure started with a sequence of two. If the child successfully recalled the sequence, the tester presented a sequence of three. Testing continued with sequences increasing by one after each successful trial. If the child was not successful, or recalled the words or pictures in the wrong order, up to two more test sequences at that length were presented. Testing continued

in this way and stopped after three failures at a given sequence length. Word span scores were recorded as the longest sequence that the child could recall in the correct order under each condition. A score for the most items recalled regardless of order was recorded separately.

Test sequences were selected at random from a pool of six words/pictures for each syllable length. Each child received a different sequence and this order was used for all four conditions. Test pictures used in assessments were different from those used in the training to ensure that any increases in memory span could not be attributed to practice with the assessment words. To estimate the effect of practice with training words, the children were also tested post-training with a second set of pictures which formed the training set.

Training Materials

The training materials consisted of 36 pictures (measuring 7.5cm by 10.5cm) for use in teaching a cumulative rehearsal strategy, and for practising categorisation skills. The pictures were realistic line drawings and all illustrated words which appear early in the development of normal children's vocabulary. Before use in the study, the pictures were shown to groups of nursery school and primary reception class children to check that they were recognised. The pictures included a range of one-, two- and three-syllable words.

For teaching rehearsal, trainers were provided with a wallet consisting of four clear plastic pockets that can show a sequence of up to four pictures in a row. Two of these devices side by side can be used to present longer sequences. Each of the pockets is covered by a card flap or window that can be turned up to reveal the picture below. The flaps can be moved independently so that the pictures can be shown one at a time.

Full written instructions about how to use the materials accompanied them. The rehearsal training started with just one picture in a pocket. The teacher lifted the flap and named the picture, encouraging the child to name the picture also. The flap was then closed and the child was asked to remember what the picture was. When this was achieved, the procedure was repeated with two pictures, then three pictures etc. As alternative activities, participants were also supplied with a set of cards printed with numbers and a set of colour cards which could be used to practise remembering sequences of numbers or pictures.

The pictures included items from the categories of animals, body parts, fruit, clothing and transport. They were used to teach category names and, once these were known, could be used for a sorting game, an odd-one-out game, and to practise remembering items from the same category.

The training programme

Training took place over six weeks. Three sessions each of approximately 15 minutes duration were held each week.

Results

The way in which the training was implemented was not identical at each school. As mentioned earlier, parents were responsible for training at one school and, at the other two schools, some children were taught by teachers and some by assistants. The data for each school were thus examined separately where appropriate. Table 1 shows the mean ages and mean scores for language and non-verbal cognitive ability of the children at each school.

Although on average the participating children at School 1 were younger, one-way analyses of variance (ANOVA's)

Table 1: Means and standard deviations for age, vocabulary (BPVS), grammar (TROG) and non-verbal ability (Raven's) for children from each school.

	Age (months)			
	Mean	**S.D.**	**Min.**	**Max.**
School (N)				
1 (7)	124.00	42.07	60	197
2 (8)	142.88	55.47	83	229
3 (12)	147.67	42.07	63	140
Whole sample (27)	140.11	47.12	60	229
	BPVS (raw score)			
School	**Mean**	**S.D.**	**Min.**	**Max.**
1 (7)	9.71	4.75	3	16
2 (8)	8.25	3.77	4	15
3 (12)	9.25	2.77	6	16
Whole sample (27)	9.07	3.55	3	16
	TROG (raw score)			
School	**Mean**	**S.D.**	**Min.**	**Max.**
1 (7)	2.29	1.89	0	6
2 (8)	4.13	3.09	0	8
3 (12)	5.17	2.79	2	11
Whole sample (27)	4.11	2.85	0	11
	Ravens (raw score)			
School	**Mean**	**S.D.**	**Min.**	**Max.**
1 (7)	8.43	5.29	2	17
2 (8)	8.5	5.32	0	16
3 (12)	10.2	5.16	2	16
Whole sample (27)	9.22	5.07	0	17

Table 2. Mean pre-training and post-training word spans under conditions of auditory and visual presentation, and manual and verbal responses.

	Auditory Presentation		Visual Presentation	
	Manual	**Verbal**	**Manual**	**Verbal**
Pre-training	2.22 (0.65)	2.06 (0.80)	2.02 (0.65)	2.11 (0.95)
Post-training	2.26 (0.68)	2.30 (0.65)	2.17 (0.70)	2.47 (0.94)
Gain	0.04	0.24	0.15	0.36

show there was no significant differences among the means for age, vocabulary or grammar understanding, or non-verbal cognitive ability for the three groups of children.

Word spans

Word spans under each condition for each of three syllable lengths were recorded as described in the methods section above. Means for each condition across word length were calculated for pre-training and post-training assessment scores and for the additional post-training measures which used words included in the training. A repeated measures ANOVA investigated differences in means between spans attained using assessment words compared with training words. No main effect was found for word set used, and there were no significant interactions between the word set used and presentation conditions or response mode. Measures collected using words for the trained set are therefore not included in any of the analyses which follow.

Table 2 shows the mean word spans achieved under each condition at each of the two assessment points using assessment word stimuli.

The main question of interest is whether the memory training has resulted in an increase in memory scores over time. It is also of interest to know whether there is any difference between memory scores for auditorily or visually presented material, or for conditions requiring a manual or verbal response, and whether these measures show a word length effect. To investigate these questions, a mixed analysis of variance (ANOVA) was used with time of measurement (pre-training versus post-training), mode of presentation (auditory versus visual), response required (manual versus verbal) and word length (one, two or three syllables) as repeated measures. To take account of the possible differences in training mentioned above, school attended was included as a between-groups factor.

The effects of training and school attended

The ANOVA confirms a significant main effect for time ($F=6.82$; $df=1,24$; $p=.015$). Post-training scores are higher than pre-training scores. There was no main effect for school but school attended did interact significantly with time of measurement ($F=3.61$; $df=2,24$; $p=.043$). Although the children from each group did not differ at the outset, the children at schools 1 and 3 show small but significant overall gains on the memory measures after the training whereas the children at school 2 have made no progress. Table 3 shows the gains made by each group. All seven of the children at school 1 and ten out of 12 of the children at school 3 increased their spans post-training; in contrast only three of the 8 children at school 2 showed any improvement and these changes were very small. Since there were no significant differences in the ages or abilities of the children at the start of the study, these factors cannot account for the differences in performance at the schools.

Table 3. Mean difference in word spans achieved after training across presentation conditions and response modes

	Overall Differences in word span			
School	**Mean**	**S.D.**	**Min.**	**Max.**
1	0.39	(0.27)	0	0.83
2	-0.08	(0.24)	-0.58	0.16
3	0.24	(0.45)	-0.5	1.08

Word length effects

There was a highly significant main effect for word length ($F=39.88$; $df=2,48$; $p<.0009$); memory capacity for one-syllable words was greater than that for two-syllable words which was in turn greater than that for three-syllable words. This effect interacted significantly with the between-groups factor, school attended ($F=3.17$; $df=4,48$; $p=.022$). Table 4 shows the mean word spans obtained at each syllable length by children at each school.

Table 4. Mean word span at each syllable length across conditions of presentation, response mode and time of measurement for each school group.

	Word Length		
School	**One-syllable**	**Two-Syllable**	**Three-syllable**
1	2.61 (.87)	2.25 (.84)	1.88 (.72)
2	2.53 (.64)	2.31 (.49)	2.13 (.59)
3	2.23 (.65)	2.08 (.63)	1.95 (.80)
Whole sample	2.42 (.70)	2.19 (.64)	1.98 (.70)

Although separate repeated measures ANOVA's for each school group confirm that they are all individually subject to a word length effect, the interaction could be explained by the more marked word length effect found for children at school 1 than for those at the other two schools. The children at school 1 had an average difference of 0.73 items between the longest and shortest words remembered compared with average differences of 0.4 and 0.28 items for the other groups. Further investigation of this difference is reported below where changes in the use of rehearsal with training is discussed.

Presentation conditions and response mode

There were no main effects for presentation condition or for response mode but there was a significant interaction between these factors ($F=5.09$; $df=1,24$; $p=.033$). Table 5 shows mean word spans across syllable lengths and times of assessment for each of the four conditions.

Table 5. Mean word spans under auditory and visual presentation conditions and manual and verbal response modes, across word lengths and times of measurement.

	Stimulus Presentation	
Response Mode	**Auditory**	**Visual**
Manual	2.24 (0.63)	2.10 (0.61)
Verbal	2.18 (0.67)	2.27 (0.86)

Further analysis using t-tests show there was no significant difference between manual and verbal responses to auditorily presented stimuli, but verbal responses produced significantly more items than manual responses to stimuli presented visually (t=-2,19; df=26; p=.037).

The analysis also revealed a three way interaction between time of assessment and response mode and word length (F=5.27; df=2,48; p=.009). Table 6 shows the mean items remembered for each length of word for manual and verbal responses at each assessment point.

Table 6. Mean word span for each syllable length under each condition of stimulus and response for each assessment time.

	Pre-training		Post-training	
Word Length	**Manual Responses**	**Verbal Responses**	**Manual Responses**	**Verbal Responses**
One-syllable	2.26(.69)	2.30(.93)	2.46(.88)	2.52(.81)
Two-syllable	2.09(.72)	1.92(.96)	2.17(.62)	2.43(.76)
Three-syllable	1.91(.75)	1.77(.90)	2.02(.70)	2.15(.82)

Table 7. Mean starting span and mean highest span achieved.

Word Span	**Mean**	**S. D.**	**Min.**	**Max.**	**N**
Start	3.00	1.21	1.00	5.00	12
Highest	5.25	1.48	4.00	8.00	12

Careful examination of Table 6 suggests the source of this three-way interaction. For one-syllable words, although more items are remembered post-training, there is little difference between manual and verbal responses pre-training (0.04 items) or post-training (0.06). The pattern of results is rather different for two-syllable and three-syllable words. Pre-training, Table 6 shows that slightly fewer of these items were recalled under verbal response conditions than under manual response conditions. However, post-training the direction of these differences in reversed and more two- and three-syllable words are remembered under verbal response conditions.

Changes in the use of rehearsal with training

The analysis suggests that the word length effect was stronger for children at one school. Since the word length effect is generally considered as evidence of rehearsal occurring, this result possibly reflects an underlying difference in the levels of rehearsal used. The more successful the rehearsal training, then the stronger the word length effect found should be.

The greatest gain in word span was achieved by the group of children at school 1 (see Table 3); and one-way analysis of variance of the mean gains confirms a significant effect for school attended (F=3.61; df=2,24; p=.043). However, no correlation was found between the size of the word length effect and the size of overall increase in word span.

Sex and age differences in training effects

Further analysis investigated whether there were differences between the size of gains achieved by boys and girls, or whether children might gain more benefit from the training at different ages. A two-way ANOVA of gender (boys or girls) and age-group (under 8's, 8 to 12 years old or over 12's) with repeated measures for the difference between pre-training and post-training word span scores was calculated. No significant effects were found; the training appears to be of equal benefit to boys and girls and to have similar effects at any age.

Improvements during training

Although the effect of the training has been demonstrated statistically, the average gains found are small. This research is based on assessments carried out by comparative strangers in the classroom, but it is possible that that the children would achieve better memory scores when tested by parents or teachers they know well. Some idea of the performance of the children under such conditions can be gained from the records of progress during the training sessions kept by teachers and parents. These show the activities attempted by the child and record the longest word span achieved at each session. The word spans achieved by each child at the first session and the maximum span achieved by each child in the course of the training were extracted from those records that were returned at the end of the study and means for each measure are shown in Table 7.

The measures show considerable progress across training sessions with one child achieving spans of up to eight for pictures and for digits or colours. Although there is no way to judge the validity of these measures (children may have received some support to reach these spans), they suggest notably better performance during teaching sessions than under test conditions.

Other memory measures

In addition to word span measures, assessments included a number of other memory measures, which would be predicted to improve if the training resulted in increased rehearsal and if the skill generalised to tasks other than the trained task. Pre-training and post-training means for these measures are given in Table 8.

Table 8. Mean scores pre-training and post-training for other memory measures which were expected to improve

	Pre-training	Post-training	Significance of Difference
Auditory Digit Span	2.22 (1.09) range 0-3	2.15 (1.29) range 0-5	n.s.
Visual Digit Span	2.30 (1.44) range 0-5	2.59 (1.50) range 0-5	n.s.
Word Order (score not span)	3.44 (1.74) range 0-7	4.00 (1.98) range 0-9	p=.045
Sentence memory	40.92 (27.65) range 0-90	46.20 (26.28) range 0-94	p=.039
Nonword repetition	7.96 (6.60) range 0-20	7.52 (6.69) range 0-20	n.s.
Kim's game	5.43 (2.66) range 0-9	5.39 (1.88) range 0-9	n.s.

Table 9. Mean scores pre-training and post-training for other memory measures where improvement was not expected

Hand Movements (score not span)	4.07 (2.8) range 0-9	4.29 (2.47) range 0-10	n.s.
Faces memory	5.48 (3.96) range 0-13	7.93 (3.51) range 0-13	p=.002

Table 10. Correlations between memory spans and reading scores at two assessment points

	Memory Scores (pre-training)	Memory Scores (post-training)
Reading (pre-training)	0.35 (n.s.)	0.56 (p=.003)
Reading (post-training)	0.35 (n.s.)	0.55 (p=.004)

The difference between pre-training and post-training scores on these measures was investigated using repeated measures t-tests. Significant increases were found for the Kaufman Word Order task and the sentence memory task, but not for digit spans or nonword repetition. The Word Order task was very similar to the word span task where words were presented auditorily and responses required pointing to pictures. Only one of the stimulus pictures in the Kaufman test represented an object from the word span stimuli; this suggests at least some generalisation of trained performance. It also seems possible that the training has benefited sentence repetition.

Two other memory measures from the Kaufman battery, Hand Movements and Faces, were thought unlikely to benefit from the training. Pre-training and post-training scores are shown in Table 9. Although there was no significant change in the scores for Hand Movements, the mean score for Faces significantly increased after training. It is difficult to explain this improvement; given the children's learning difficulties and the time elapsed between test and re-test it seems unlikely to be a practice effect.

Reading and memory

A previous study showed that a group of children with Down syndrome who were reading had better language and memory scores than a group of non-readers (Laws, Buckley, Bird, MacDonald and Broadley, 1995). The readers were all children able to read any word on the BAS reading test (Elliott, Murray and Pearson, 1978). In the present study, reading skills were assessed using the subscales provided in the Kaufman-ABC. The mean reading decoding score was 10.44 (s.d.=5.28) pre-training and 9.41 (s.d.=5.42) post-training, with scores ranging from 0 to 15. This test is rather different from the BAS reading test which presents only words to read while the first 10 items of the Kaufman require identification of single letters (five are capitals, and five are lower case).

Partial correlations (controlling for age) were calculated between mean memory scores (averaged across stimulus and response conditions and word lengths) and word decoding scores at both assessment points. These are shown in Table 10.

Although there was no significant relationship between reading and memory before training, after training memory scores are significantly correlated with reading scores. This might be explained if there was no difference between readers and non-readers before the training but if readers benefited more from the training, and in proportion to their reading skills, then a relationship between the memory and reading scores could emerge post-training. However, independent t-tests show there was no difference in the level of training gains achieved by readers and non-readers.

Discussion

The analysis of pre-training and post-training memory measures suggests that the training has resulted in a small but significant gain in word span capacity. However, the gains made are somewhat smaller than those reported for Broadley's training project. For example, the mean increases immediately post-training for the fourteen children followed up from Broadley's study (Laws et al, 1995) were 0.57 for auditorily presented stimuli and 1.08 for visually presented stimuli with verbal responses. By the time of follow-up, three years later, the difference was reduced to 0.43 and 0.85 words respectively; an increase which our analyses suggested would be equivalent to that expected in the normal course of development for these children.

The gains for comparable measures from the children in Schools 1 and 3 in this study were 0.30 for auditorily presented stimuli and 0.53 items for visually presented stimuli. Although small, these increases are equivalent to about two thirds of the developmental increase that would be expected over three years according to our earlier estimation, and that change has taken place over just six weeks. These gains should also be considered in the context

of memory development in typically developing children where auditory digit span increases of about 0.5 of an item per year are to be expected. Seen in this light, the effects of the training are encouraging.

There is some evidence that the memory increases are due to rehearsal and not to some other factor such as simple practice with the stimulus words. If practice with the words accounted for the improvements, then assessment measures using the training stimuli should have been superior to assessments using a different set of words and pictures. There were no significant differences between the children's performance on training words and assessment words suggesting that what they have learned is the rehearsal strategy and not just the words.

After the training, responses to two- and three-syllable words were more successful under verbal response conditions than manual conditions, whereas there were no differences in performance under different response modes before the training. Remembering that the stimulus words were only used during assessment and not for training, this suggests that the children may be using rehearsal to remember and successfully articulate these longer words.

A significant word length effect was noted. This depends on the use of the articulatory loop described by the working memory model (Baddeley and Hitch, 1974) and its finding also shows that these children may be using rehearsal. The group with the greatest overall mean memory span gain also happened to be the group showing the widest word length effect. This was interesting although it was also noted that there was no correlation between gain and the size of the word length effect.

It was disappointing to find that not all the children had benefited from the memory training programme. It has not been possible to establish the reasons for the lack of progress for the children at school 2 who were being trained by their parents. It could be that undertaking the work after school when the children may be tired and there are other activities to attract them posed some problems; two parents withdrew from the programme because they found it difficult to motivate the children, others may have done the same but informally. Only one family returned the training record sheets at the end of the study and took up the offer of additional pictures that had been promised to those interested in continuing the training.

In conclusion, results show an encouraging effect of rehearsal training on the development of short term memory spans. More interesting questions are whether the children would continue to increase their spans with further training, and whether improved short term memory function would have the beneficial effect on language and cognitive functions which theory and the extensive research evidence from normal development would predict. Answers to these questions depend on successful transfer of the skills acquired and to continued awareness of the need to enhance the memory skills and development of children with Down's syndrome by whatever means are possible.

References

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

Baddeley, A.D., and Hitch, G. (1974) Working memory. In G. Bower (Ed.) *The Psychology of Learning and Motivation,* (Vol. 8, pp.47-90). New York: Academic Press.

Baddeley, A.D., Thomson, N., and Buchanan, M. (1975). Word length and the structure of short term memory. *Journal of Verbal Learning and Verbal Behaviour*, 14, 575-589.

Barrett, M. (1989). Early language development. In A. Slater and G. Bremner (Eds.) *Infant Development.* Hove, U.K.: Lawrence Erlbaum Associates Ltd.

Bauer, R. (1977). Memory processes in children with learning disabilities: evidence for deficient rehearsal. *Journal of Experimental Child Psychology,*24, 415-430.

Belmont, J.M. and Butterfield, C.E. (1971). Learning strategies as determinants of mental Deficiency. *Cognitive Psychology*, 2, 411-420.

Bird, G. and Buckley, S. (1994). *Meeting the Educational Needs of Children with Down's syndrome.* Portsmouth: University of Portsmouth.

Bishop, D.V.M. (1983). *Test for the Reception of Grammar (TROG).* Department of Psychology, University of Manchester: Chapel Press.

Bower, A. and Hayes, A. (1994). Short term memory deficits and Down syndrome: a comparative study. *Down's syndrome: Research and Practice,* 2, 47-50.

Bowler, D. (1991). Rehearsal training and short-term free recall of sign and word labels by severely handicapped children. *Journal of Mental Deficiency Research,* 35, 113-124.

Broadley, I. (1994). *Teaching Short-term Memory Skills to Children with Down's syndrome* (Unpublished PhD thesis) Portsmouth, U.K.: University of Portsmouth.

Broadley, I. and MacDonald, J. (1993). Teaching short-term memory skills to children with Down's syndrome. *Down's Syndrome: Research and Practice, 1, 56-62.*

Broadley, I., MacDonald, J., and Buckley, S. (1994). Are children with Down's syndrome able to maintain skills learned from a short-term memory training programme? *Down's syndrome: Research and Practice,* 2, 116-122.

Broadley, I.W., MacDonald, J., and Buckley, S. (1995). Working memory in children with Down's syndrome.*Down's Syndrome: Research and Practice*, 3, 3-8.

Brown, A.L., Campione, J.C., Bray, N.W. and Wilcoxon, B.L. (1973). Keeping track of changing variables: effects of rehearsal training and rehearsal prevention in normal and retarded adolescents. *Journal of Experimental Psychology*, 101, 123-131.

Chi, M. (1977). Age differences in memory span. *Journal of Experimental Child Psychology*, 23, 226-281.

Comblain, A. (1994). Working memory in Down's syndrome: Training the rehearsal strategy. *Down's Syndrome: Research and Practice,* 2 (3) 123-126.

Dunn, L.M. and Dunn, L.M.L. (1982). *British Picture Vocabulary Scale (short form). Windsor:* NFER-Nelson Publishing Company.

Elliott, C.D., Murray, D.J. and Pearson, L.S. (1978).*British Ability Scales.* Windsor: NFER Publishing Company Ltd.

Gathercole, S.E. and Baddeley, A.D. (1993). *Working Memory and Language.* Hove: Lawrence Erlbaum Associates Ltd.

Gathercole, S.E. and Adams, A-M. (1994) Children's phonological working memory: Contributions of long-term knowledge and rehearsal. *Journal of Memory and Language,* Vol 33(5) 672-688.

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

Hulme, C. and Mackenzie, S. (1992).*Working Memory and*

Severe Learning Difficulties. Hove: Lawrence Erlbaum Associates Ltd.

Kaufman, A.S. and Kaufman, N.L. (1983). Kaufman Assessment Battery for Children. Minnesota: American Guidance Service.

Laws, G,, Buckley, S., Bird, G., MacDonald, J. and Broadley, I. (1995). The effects of reading instruction on language and memory development in children with Down's syndrome. *Down's Syndrome: Research and Practice,* 3, 2, 59-64.

Laws, G., MacDonald, J., Buckley, S. and Broadley, I. (1995). Long-term maintenance of memory skills taught to children with Down syndrome. *Down's Syndrome: Research and Practice,* 3, 3, 103-109.

McCarthy, D. (1972). *McCarthy Scales of Children's Abilities*. New York: The Psychological Corporation.

Mackenzie, S. and Hulme, C. (1987). Memory span development in Down's syndrome, severely subnormal and normal subjects. *Cognitive Neuropsychology,* 4, 303-319.

Marcell, M.M. and Armstrong, V. (1982). Auditory and visual sequential memory of Down syndrome and non-retarded children. *American Journal of Mental Deficiency*, 87, 86-95.

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

Raven, J.C. (1963). *Coloured Progressive Matrices*. London: H.K. Lewis and Co. Ltd.

Address for correspondence:

Dr Glynis Laws
Department of Psychology
University of Guildford
Surrey
GU2 5XH

The memory training materials used in this research are available from the Sarah Duffen Centre, Belmont Street, Southsea, Hants, PO5 1NG, UK.

Conferences

International Conference on Chromosome 21 and Medical Research on Down Syndrome

14-15 March 1997
Barcelona, Spain

Organised by: Fundació Catalana Síndrome de Down

For: Geneticists, Molecular Biologists, Neuroscientists, Neuropathologists, Radiologists and Paediatricians interested in Down syndrome.

Official language: English with translation to and from Spanish

For more information, contact:
Agustí Serés-Santamaría, M.D.
Fundació Catalana Síndrome de Down
València, 229, pral
08007 Barcelona
SPAIN
Tel: 34-3-215 74 23
Fax: 34-3-215 76 99