Memory and Learning

A programme to support deaf children with their working memory

ndcs
every deaf child

Helping deaf children develop their working memory

SUMMARY
Age range: This is a programme to help deaf children who are aged 5-11 years.
Audience: This programme aims to support primary school teachers in helping their deaf pupils to develop their working memory. Parents can play an important role by helping their children access the web-based games. Parents should work in partnership with their child's teacher, who will introduce the concepts first in school and indicate which games are appropriate at the time.
The programme: The programme consists of three teacher-led games in which the children learn and practice rehearsal skills that are crucial for controlled attention and three web-based games for developing automatic attention, which the children play on the web on their own. The programme is highly individualised so that children progress through the programme at their own pace.
Benefits: Research by Oxford University found that deaf pupils using these materials achieved more on working memory measures when compared with a group of children of the same age and intellectual skills who did not use the materials. Working memory is important because it is a skill which supports a child's progress in literacy and numeracy.

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Introduction

Working memory is the ability to keep information in mind while working on related activities at the same time and is measured in spans. For example, a pupil without the aid of pencil and paper will need to use working memory to add up two numbers spoken to them. Children rely on working memory to follow their teacher's instructions or remembering sentences that they have been asked to write while engaged in the process of writing them.

There are two aspects of working memory: automatic attention and controlled attention, which are important in helping children to memorise and learn. Both of these aspects are important, and many profoundly deaf children have difficulty in these areas. It is therefore important to consider if there are ways in which we can improve the working memory of deaf children. Attention is often stimulated by hearing and can therefore be an area of difficulty for deaf children - even with the latest hearing technologies - in the noisy environment of mainstream class.

The programme is to help improve the working memory of deaf children. It involves exercises for both aspects of working memory which need to be used in coordination with each other.

This document contains a summary of the programme and brief description of the background of the materials which were developed and a research briefing which explains working memory and its impact, describes the activities, outlines how the research was carried out and highlights the outcome that, the more games the children played, the better their working memory when they were retested.

Research summary

What working memory is and why it matters for children's education
Working memory is the ability to keep information in mind and use it to guide behaviour without the support of external cues. In reading, for example, we need to remember what we read at the beginning of a paragraph and keep this information in mind as we continue to read, in order to understand the meaning of the paragraph. In arithmetic, we often have to carry out several steps in a calculation and keep track of the intermediary results. For example, when we calculate 12 x 18, we do it in several stages. We may compute 8 x 2, write down 6, carry the 1, go on to compute 8 x 1, and then have to remember that we carried 1. We may do it in our heads: 10 eighteens are 180, and 2 eighteens more will be 36, plus 180 and we have the answer. These examples illustrate why reading and arithmetic involve working memory.

Working memory tasks involve automatic processes as well as processes that require controlled attention. Automatic processes are related to our ability to attend to any task. Any task that we carry out takes place in an environment where there are objects and people that are not related to the task; the automatic attention processes help us ignore what is not relevant to the task. Tasks that require keeping information in mind and working on it at same time involve a component of working memory that is known as ***the central executive*** because of the role it plays in directing attention and memory. Central executive tasks necessarily involve automatic attention processes but the reverse is not necessarily true. Some children who have basic attention problems have difficulty with automatic attention as well as central executive tasks but some children may have difficulties only with central executive tasks.

Students' performance in working memory tasks is significantly related to their results in reading comprehension as well as in mathematical tasks; this is true of hearing and deaf children, and is also true of deaf children with cochlear implants. This connection

between performance in working memory and educational tasks is important for deaf children's education because many deaf children perform less well in working memory tasks than hearing children of the same age and the same level of intelligence. In order to understand why this is so, we need to think about how working memory is assessed, why deaf children may not achieve results that would be expected from their level of intelligence and what can be done about it.

How is working memory assessed?

In a widely used working memory task, called ***backward digit recall***, children are presented with digits and asked to say them in the opposite order of their presentation. This means that they have to remember the digits and work on the digit information to produce the answer with the digits in the reverse order of their presentation. For example, if I said 7 4 6 2, what would you have to say to get the answer right? Backward digit recall is a task that appears in different standardised assessments of working memory. The digits can be presented in language, oral or signed, or they can be presented in written form. In the latter case, they are covered after presentation, so they have to be reordered and recalled in memory.

Another characteristic of working memory tasks is that they start with fewer items and the number of items increases to make the task progressively more difficult. In the backward digit recall task, the first set of items has two digits, the next set has three, the next four, and so on until the person can no longer cope with the task. The measure of the children's working memory can be expressed either by the number of items that they get correct or the maximum number of digits with which they can cope, which is called the memory span. Working memory develops throughout childhood so the number of items with which children can deal in working memory tasks keeps increasing.

Working memory assessments vary in the way the information is presented, the type of processing people are asked to do, and the

way they are asked to recall the information. In some tasks, as the backward digit recall task, the information is presented in oral form and the answers are given orally. In another task from the *Working Memory Battery for Children* (Pickering & Gathercole, 2001), called ***counting recall***, the children see dots on a page – so the information is presented visually. Their task is to count and recall the number of dots, once the page has been turned – so the children must use some form of language to encode the information. The number of pages increases progressively: the children have to count the dots on one, two, three pages etc. and then recall each number in the order of appearance.

Deaf children's performance in working memory tasks

In a recent study with children in the age range 5 to 12 years, we used three working memory measures with a group of 60 hearing children and 233 deaf children. We explained all the tasks in the language that the children used in school, English or BSL, using the child's preferred language in total communication settings. The tasks were:

1. the ***counting recall task*** from the *Working Memory Battery for Children*, adapted for presentation to deaf children;

2. a ***picture recall task***, in which the children name two pictures that appear simultaneously on a computer screen, and then have to recall the picture that was circled after they had named them. Figure 1 shows an example of an item with three pictures to be recalled; each pair of pictures appears, then one is circled, then the pair disappears and the next pair appears. The three circled pictures are to be remembered in their order of appearance;

3. a ***backward digit recall task***, in which the digits are presented to the children both in language and in print, and the children recall the digits in their preferred language.

Figure 1: A sample item from the picture recall test, span 3

Note that in all of the tasks the stimuli are presented visually; in the first two tasks, the children must encode the information in their preferred language and in the third task the tester presents the digits visually as well as in the child's language of education. In order to compare the children in the different groups, we obtained a combined score based on the three tasks, as they are very strongly related to each other. In this comparison, the children's age is controlled for, because working memory improves with age.

As a group, the deaf children did less well than the hearing children, but the group difference was most noticeable for the profoundly deaf children. The mean score for the profoundly deaf children was significantly lower than the mean score for the hearing children but the means for the children with other levels of hearing loss were not significantly lower statistically. However, this does not imply that only profoundly deaf children did poorly on the working memory tasks: there was a great variation in the results of the children with mild loss and many had scores that were very low indeed. This means that

profoundly deaf children as a group are at risk for learning when a task places heavy demands on working memory but many children with other levels of hearing loss may also be at risk.

What do these results mean for deaf children's education?

We know that working memory is important for learning. We also know that some, but not all, deaf children do not do well on working memory tasks. Some previous research (Mitchell & Quittner, 1996) found that many deaf children (approximately 70%) have low scores in basic attention tasks, and this means that they need to improve their automatic attention mechanisms. Other research (Bebko & Metcalfe-Haggert, 1997) shows that deaf students tend not to rehearse the items in working memory tasks, and this could explain their lower performance. Therefore it would be important to try to help them to improve their working memory using methods that aim at improving basic attention as well as rehearsal skills. In the next section we describe a programme that has been tried out by Teachers of the Deaf with their students and its effectiveness.

A game-based programme to improve deaf children's working memory

The programme has two components: a set of games led by the teacher that aims at teaching rehearsal skills and a set of games played on the web without teacher guidance that aims at promoting basic attention as well as rehearsal. The two sets should be mixed during training, so that the children have the opportunity to learn rehearsal skills and use them on their own during the computer games. We use in this description a mixture of a technical vocabulary, to allow readers to look for more information elsewhere, and a game-specific vocabulary, which relates to the way the materials are presented to the children. For example, in order to talk to the children, we don't use the words "working memory span" (a technical explanation) but the word "level", as they know very well that games vary in level of difficulty. Each game is now described briefly. In order to find out how to run each game, you need to follow the instructions in the "words", "colours" and "digits" sections; this

overview is not sufficient and you will need more detail.

The teacher led games

Listening recall: the Words Game

In this game, the teachers present the children with a sentence in their language of instruction, oral or signed, and the children have to say whether the sentence is true or false of a picture on the screen. The children have to recall the last word in the sentence. The number of sentences increases to represent the new spans or game levels. Verbal or sign rehearsal of the last word should be encouraged by the teacher, depending on the child's preferred language. Visual rehearsal of the number of words to be recalled is encouraged by showing the children that each word or sign can be paired with a finger in order to keep track of how many things they have to recall. The teacher engages in rehearsing with the child at the beginning of each game and allows the child to rehearse alone as the child starts to rehearse spontaneously. Figure 2 shows an example of the Words Game level 2, where the children need to recall two words or signs; in this case, woman and chef.

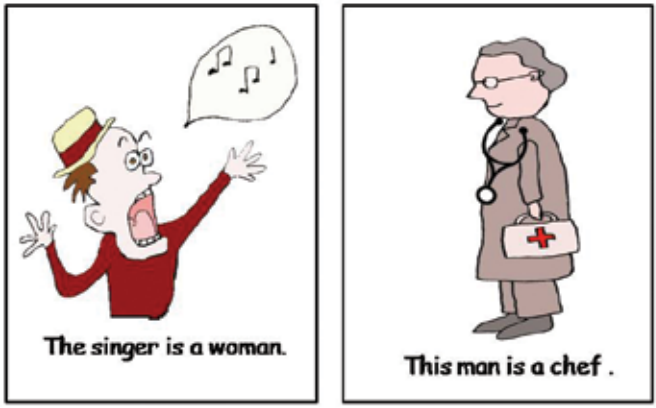

Figure 2: An example of level 2 in the Words Game

Visual-spatial recall: the Colours Game

The children are presented with a colour strip and learn the positions of the colours (as in a rainbow) on the strip. When the game starts, a dragon appears and announces how many colours the child needs to remember. A blank strip then appears and two colours flash in sequence in their positions. When they disappear, the child is asked to name the colours in the reverse order of appearance (deaf children usually say or sign "swap" for reversing the order). The number of colours to be recalled increases over time. Visual rehearsal is encouraged by asking the child to point to the positions of the colours when they name or sign the colours. Figure 3 illustrates a sequence of slides in this game, level 2. The correct answer here would be red, blue (you have to swap the colours).

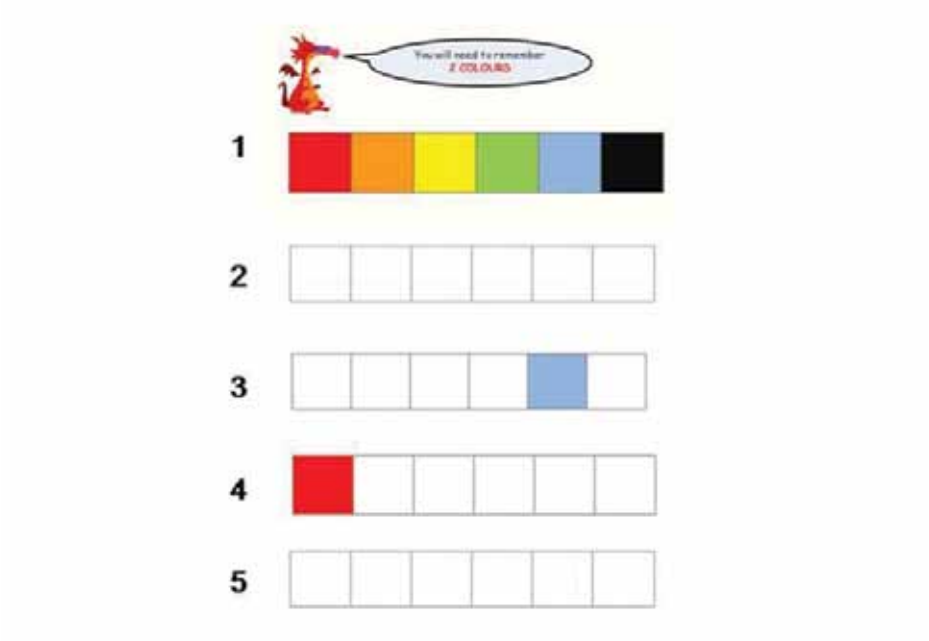

Figure 3: Colour Game level 2

Digit recall: the Missing Digits Game

On each slide, the children see a series of digit strings and name the digits orally or in sign. At random places in the sequence of slides, there is a cue for the children to realise that this is now a recall trial. The last string appears again with the last digits missing, which the children have to recall. The number of digits to be recalled increases over time. Rehearsal in oral or signed language is encouraged. Figure 4 shows an example of the Missing Digits Game, level 1.

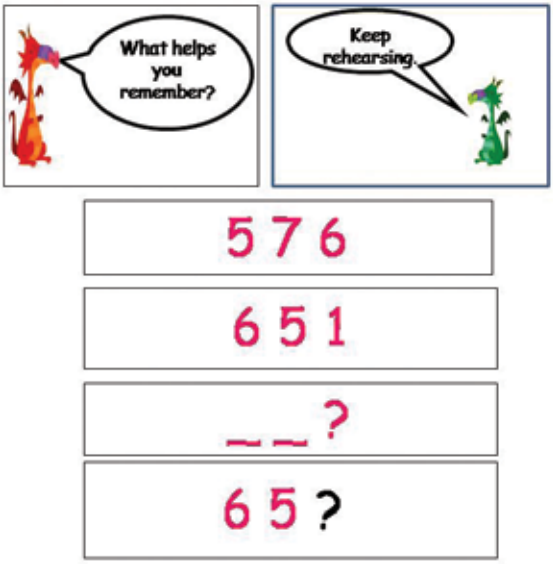

Figure 4: A series of slides showing how the Missing Digits Game works

For all the games, the teachers move the children to the next level of difficulty in the game when the children meet the criterion of four trials correct out of nine. In each session directed by the teacher, the children are expected to play the same game a few times and attain new levels of performance. However, the teacher can move them on to a different game if the children become discouraged by their own lack of progress. The children should play at least two different teacher-led games in each session.

The web-based games

There are three games to be played on the web. The children can access the games in this link: www.education.ox.ac.uk/ndcs/memory_corner.php. The teacher needs to help the children start the session. When the children play the web games for the first time, the teacher should help the child learn how the game works ((there are instructions in the “words”, “colours” and “digits” sections). At any point in time, the teacher should help the child start the game at a level higher than the last one in which the child met the criterion. There is a record sheet for children to keep track of which game level they last passed.

Counting recall: the Animals Game

The children count different animals on sequences of screen presentations, typing in the number of animals on the screen. At the end, the children recall and enter the number of each type of animal into the computer. The task is made more difficult by adding distracters, which are figures that do not have to be counted. This addition of distracters creates an extra attention demand and reinforces basic attention processes. The distracters become more similar to the animals in shape, size and colour as the game proceeds, to reinforce the basic attention process. On alternative games, recall is in the order of presentation or in the reverse order. The number of types of animal to be recalled increases over trials. Figure 5 illustrates this game.

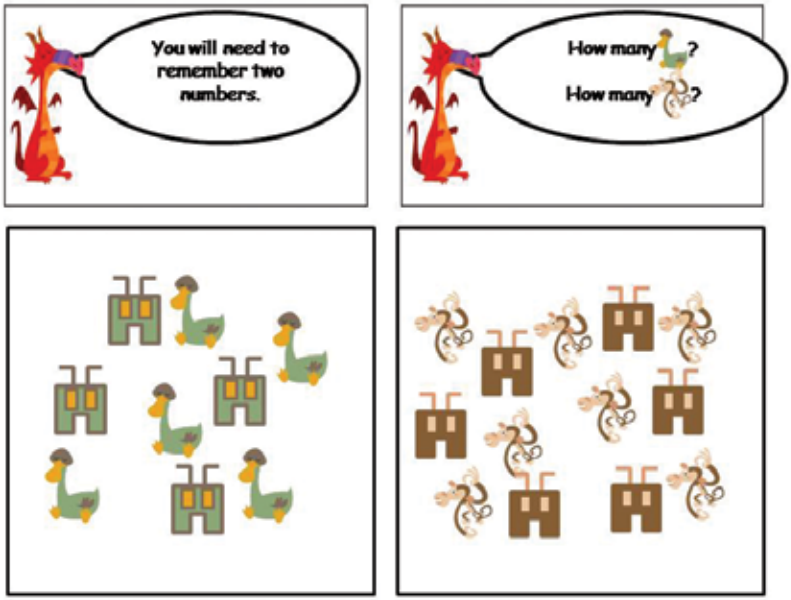

Figure 5: An item with ducks and monkeys and distracters similar to the animals.

Backward digit recall: the Numbers Game

This game gives children the opportunity to practice visual-spatial rehearsal, learned in the teacher-led games. The children learn the position of the nine digits on a 3x3 matrix. During the game, digits appear sequentially in their place in the matrix on the screen and the children type each digit as they appear. At the end of the sequence, a blank matrix appears indicating that it is time for the recall: the children have to recall the digits in the reverse order of appearance. The number of digits to be recalled increases over time, making the game more difficult. Figure 6 shows the initial blank matrix, a sequence of two digits, and the blank matrix as the cue to recall. The correct answer is 8 3 (you have to swap the numbers).

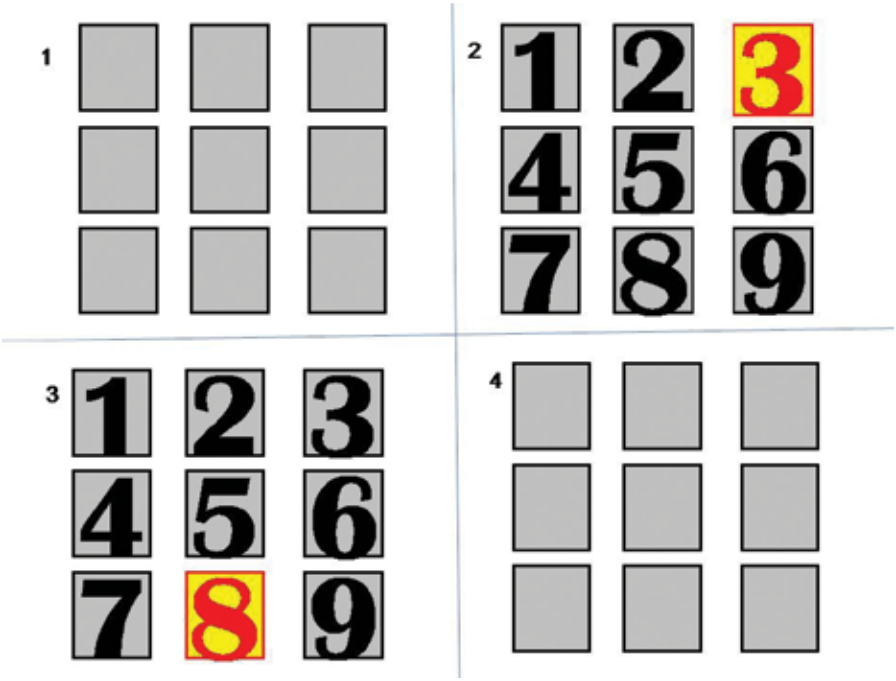

Figure 6 illustrates the web-based Numbers Game.

Backward letter recall: the Letters Game
This game gives children another opportunity to practice visual-spatial rehearsal strategies. The procedure is similar to the previous game but the letters A to I are used instead of digits. It is more difficult because the sequence of digits is usually better known by the children than the sequence of letters. The recall is in reverse order of appearance. As in the other games, the level of difficulty is increased by having the child recall a larger number of letters.

The children's participation in the web games is automatically recorded. When they attain a certain level of success, they are led to some bonus games, where they can choose one of four other games

to play. These games are rather different and give them another opportunity to enjoy themselves without having to remember more than the instructions. The children should be told that getting to these extra games shows that they have played the memory games really well.

Did the children perform better in the working memory tests after playing the games?

We compared the 73 children who participated in this game-based programme with a group of 77 children who did not participate in the programme, which we called the comparison group. Both groups were assessed twice in working memory tasks with about the same interval between the assessments; the teaching tasks were the same ones described in games section of this booklet. For the children in the project, the first assessment was before they started on the games programme and the second assessment took place after they had played the games. The children in the comparison group were participating in another study that did not aim to improve their working memory. Figure 7 shows the means for each group and the variation of scores around the means (shown by the lines). It is quite clear that the two groups were different after the project group had participated in the games; the best scores in the comparison group do not approach the mean score for the project group.

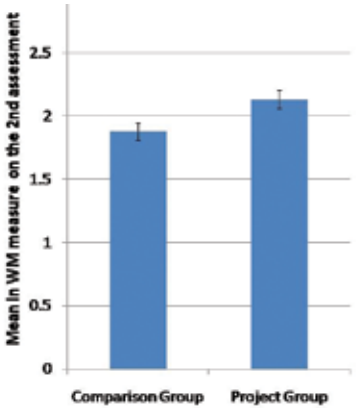

Figure 7: Mean on the working memory measure for each group on the second assessment

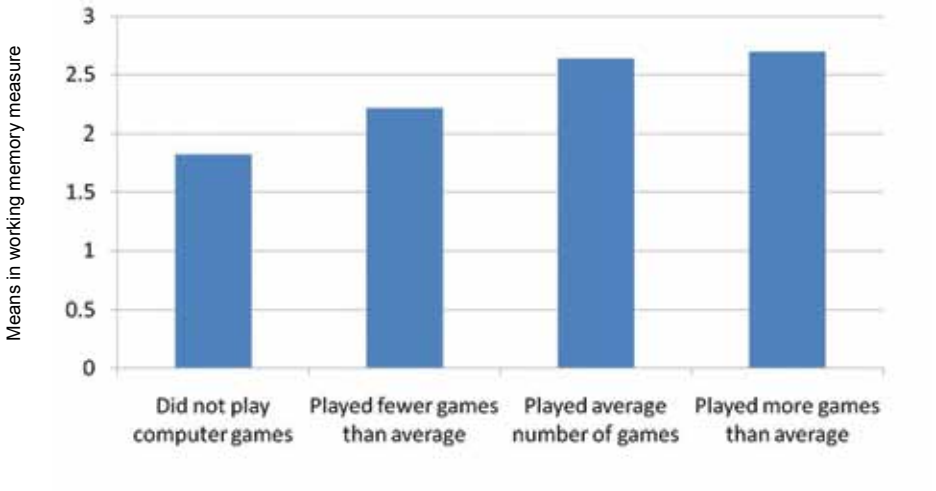

Figure 8: Working memory means at second test by number of web-games played

There was a huge variation in the number of web-based games that the children played during the programme. We had an automatic record of the number of games that the children played on the web because they had to login in order to play the games. We grouped the children by the number of games that they had played on the web, forming four groups, as indicated in Figure 8. The figure shows the project children's mean scores at post-test by the number of games played on the web.

The figure clearly shows that the children benefited from playing more web games, which reinforced the basic attention processes and gave them opportunities to rehearse more.

Summary and conclusions

Children's working memory plays an important part in how well they do and learn in school. Many deaf children do not do as well as hearing children of the same age and level of intelligence in working memory tasks. However, working memory can be improved through teaching. This research briefing describes a game-based teaching programme that was effective in improving the working memory performance of a large group of children whose teachers used the programme with them. Teachers of the Deaf and parents can use these materials and work together to improve children's working memory.

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- A Freephone Helpline 0808 800 8880 (voice and text) offering clear, balanced information on many issues relating to childhood deafness, including schooling and communication options.
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- Specialist information, advice and support (including representation at hearings if needed) from one of our appeals advisers in relation to the following types of tribunal appeals: education (including disability discrimination, special educational needs (SEN) and, in Scotland, Additional Support for Learning (ASL)); and benefits.
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- A quarterly magazine and regular email updates.
- An online forum for parents and carers to share their experiences at www.ndcs.org.uk/parentplace.
- A website for deaf children and young people to get information, share their experiences and have fun at www.buzz.org.uk.

NDCS is the leading charity dedicated to creating a world without barriers for deaf children and young people.

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