Working Memory: The Importance of Assessment, Identification and Intervention

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ABSTRACT: Working memory is an important factor in the acquisition of language, literacy and numeracy skills. It is closely linked to learning and achievement.
The purpose of this study was to determine whether or not staff in schools were able to identify working memory difficulties in their students and how pupils with these difficulties were supported. Qualitative and quantitative data was sought from 35 randomly selected primary schools via a questionnaire. Semi-structured follow-up interviews were carried out with SEN Co-ordinators from 10 of the schools. Results revealed that the schools seldom carried out working memory assessment and staff were generally unaware of the characteristics of a poor working memory. Many of the schools within this study were not familiar with the range of assessment tools or resources available for intervention and support. This has significant implications for the provision of training and development of intervention strategies and resources for schools.

Keywords: working memory, short - term memory, dyslexia, DCD

RESUMÉ: le travail de la mémoire est un facteur primordial pour apprendre une langue, apprendre à lire, à écrire et à calculer. C'est un travail étroitement lié à l'apprentissage et aux résultats. Ici, nous avons cherché à savoir si le personnel des établissements scolaires était capable de repérer les problèmes de mémoire auxquels leurs élèves font face et de quelles façons ces derniers étaient aidés. Des données qualitatives et quantitatives ont été demandées à partir d'un questionnaire distribué dans trente-cinq écoles primaires sélectionnées au hasard. Des coordinateurs SEN (en matière de besoins éducatifs spéciaux) ont menés des entrevues semi-structurées de suivi dans dix des écoles. D'après les résultats, les écoles

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n'ont que rarement effectué des évaluations sur le travail de la mémoire et en général, le personnel n'était pas conscient des symptômes des troubles de la mémoire. Cette étude nous apprend que de nombreuses écoles n'étaient pas très au courant de l'ensemble d'outils d'évaluation ou de ressources qu'elles peuvent employer pour intervenir et aider. Cet état de fait présente des répercussions importantes pour fournir aux écoles des formations, des élaborations de stratégies d'intervention et des ressources.

Mots-clés : travail de mémoire, mémoire à court terme, dyslexie, DCD (troubles de l'acquisition de la coordination)

Introduction

Working memory is of great importance to conventional educational attainment from an early age. Early recognition of working memory deficits is vital in helping allowing children with such problems to achieve their full developmental potential.

This study analyses whether schools within the local authority were able to identify any working memory difficulties their pupils might have, using reliable and valid methods, in order to gain a clear profile of their needs. Assuming that schools were able to do this, teacher practice within the classroom could be modified in order to take working memory problems into account. As classroom 'differentiation' might not prove a sufficient response, cognitive training methods may be required as well in order to have the desired impact on pupil achievement. In addition it would be relevant to ask what schools do to support individual pupils with working memory difficulties. It would also be useful to ascertain whether this support is of a generalised (or even ad hoc) nature within the classroom, or of a more specific and structured type.

The main aims of the research were:

- To identify whether schools carried out their own assessment of working memory difficulties
- To identify what the barriers might be to schools carrying out their own assessment

- To identify the assessment tools used by schools and clarify how efficient the schools believe these tools to be in giving them the information they need

The overall focus of the research was on current assessment practice, and whether schools felt this met their needs, rather than on assessment itself and the analysis of assessment methods. In addition to this some qualitative information was sought on current approaches to supporting pupils with working memory difficulties. The main sections of this paper contain

- A review of recent research has been used for contextual purposes and to reinforce the importance of working memory and its links with learning.
- An outline of the methodology used for data collection and analysis
- A synopsis of the results of the data collection
- A discussion of the implications of the results and proposals for the future

A review of recent research and current opinion

'Working memory' is used to describe the ability to hold and manipulate information in the mind for brief periods of time to support "complex cognitive activities" (Gathercole & Pickering, 2000, 178; Alloway 2012; Gathercole & Alloway, 2008). Baddeley (2007, cited in Henry, 2012, p.3) describes working memory as, "a temporary storage system under attentional control that underpins our capacity for complex thought". Alloway (2011) states that short-term and working memory are not the same and explains the difference between the two by giving the example of a pupil in the classroom repeating instructions he has just been given (short-term memory) and then trying to remember those instructions as he carries out the tasks (working memory).

Short-term memory feeds information into the working memory so that it can be held and rehearsed or manipulated for a short period of time. This enables the carrying out of tasks relating to literacy or mathematics and the committing to long-term

memory of information in a form whereby it can be accessed easily when needed in the future. Deficits in short-term and working memory impact on language development as well as on an individual's ability to read, carry out writing tasks and mental maths tasks, follow instructions and enable self organisation (Henry, 2012; Alloway, 2011; Reid, 2009; Gathercole & Alloway, 2008).

Modelling working memory

Working memory is important in that it "appears to play a crucial role both in supporting learning and in maintaining focused behaviour in practical situations" (Holmes, Gathercole & Dunning, 2009, p.146). However, it is demonstrably fragile and a distraction can result in complete loss of the information being held and manipulated. Speed of processing can also affect the working memory (Kyllonen & Christal, 1990, cited in Baddeley, 1996). For example, when instructions are given too quickly, a pupil with working memory difficulties is unlikely to be able to process the information quickly enough, resulting in loss of the information (Kail, 1997, cited in Henry, 2012; Alloway, 2011) and a concomitant slowness in, or inability to, carry out the given task.

The capacity of each person's working memory is different, but research has shown that, while a very young child may be able recall only 1 or 2 items, this improves as the child matures, reaching a peak at around the age of 15 years (Alloway, 2011; Gathercole & Alloway, 2008; Rosser, 1994, cited in Jeffries & Everatt, 2004; Towse et al., 2008).

The working memory model, as originally put forward by Baddeley (1986, cited in Henry, 2012), consisted of three main components (fig. 1).

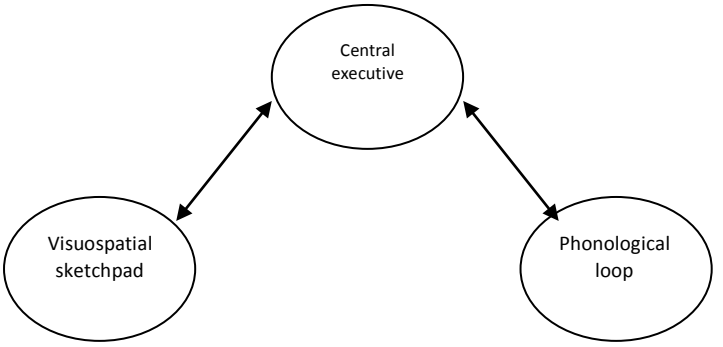

Figure 1: Working memory model (Baddeley, 1986, cited in Henry, 2012)

Within this model information is thought to move between the **central executive** and the **visuospatial sketchpad** ("visuospatial short-term memory", Gathercole & Alloway, 2008, p.11) and between the central executive and the **phonological loop** ("verbal short-term memory", Gathercole & Alloway, 2008, p.11); but not between the visuospatial sketchpad and the phonological loop.

Baddeley later developed the working memory model to include a further component called the **episodic buffer** (Baddeley, 2000 cited in Henry, 2012; Baddeley, 2003 cited in Kelly & Phillips, 2011). Episodic memory relates to our ability to remember details of specific experiences, and can persist for anything between a few hours to several days (Gathercole & Alloway, 2008). The inclusion of this component (fig. 2) explains how these experiences might be stored and interact with information stored within other components, including the **long-term memory**. Long-term memory is defined as "memory of experiences that occurred prior to the immediate past" (Alloway, 2008, p.13), and the **semantic memory** is described as "general knowledge and memory for facts" (Salmond et al., 2008, cited in Henry, 2012, p.288) and a "mental lexicon of language" (Alloway, 2008, p.15).

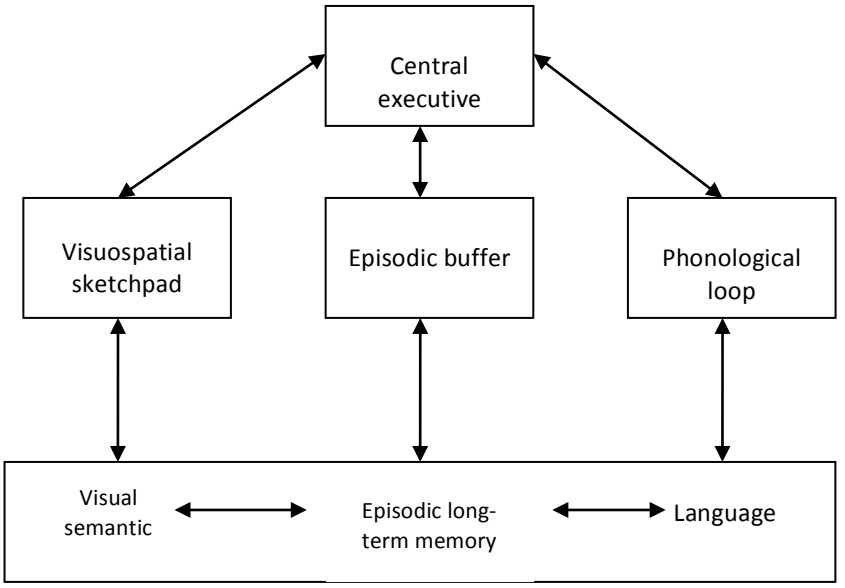

Figure 2: Baddeley's revised model of working memory (2000 cited in Henry, 2012)

Within the phonological loop there are two further components: the phonological store and phonological rehearsal system (Baddeley, 2003; Pickering, 2004; Henry, 2012). Verbal information is only held in the phonological store for a very short period of time before it begins to decay.

The links between working memory and learning

Working memory is closely linked to learning and weaknesses in this area impact substantially on academic achievement (Gathercole, 2008). Research has shown that children with poor working memory are slow to learn in the areas of reading, maths and science, across all key stages (Gathercole & Alloway, 2008; Gathercole & Pickering, 2000; Gathercole et al., 2003; Jarvis & Gathercole, 2003; Rapport et al., 2008).

Writing places a huge burden on the working memory, as children need to focus on the word or sentence they are currently writing, while at the same time recalling what they were intending to write, and planning what is to be written next.

Working memory and reading acquisition

Wagner & Torgesen (1987, cited in Savage et al., 2007) hypothesised that, during reading tasks, phonological codes were temporarily stored in the verbal short-term memory of typically developing readers. Those experiencing reading difficulties, however, were likely to have deficit within the phonological loop and needed support from other components within the working memory model, resulting in slower reading and difficulties with comprehension.

Working memory and the acquisition of language

Understanding a sentence, either heard or read, relies heavily on working memory. Difficulties in this area will result in problems with recalling and using long or more complex sentences and can also result in confusions of tense when speaking. Thus, when vocabulary is too difficult (particularly if new), or sentence structure too long, the memory system will be overloaded (Bristow et al., 1999, cited in Booth, 2009).

Visuospatial memory

The importance of visuospatial memory was reported by Alloway in her 2007 study of children with developmental coordination disorder (DCD). She observed that deficits identified in "measures of visuo- spatial short-term and working memory were significantly worse than in the verbal short- term memory ones" (Alloway, 2007, p.31). This supported findings from earlier studies by Quinn (1994, cited in Alloway, 2007) and Smyth et al. (1988, cited in Alloway, 2007) that visuospatial memory skills were "linked to movement planning and control" (Alloway, 2007, p.31). These studies all inferred that the ability to retain a simple sequence of movements could be seen as closely comparable to the ability to retain verbal information, suggesting that "visuospatial memory parallels verbal memory" (Alloway, 2007, p.31).

Links between working memory deficit and learning difficulties

Alloway (2011) states that working memory deficits are present in a range of learning difficulties, such as dyslexia, DCD and attentional disorders (ADD/ADHD), not as a causal problem,

but as a coexisting problem leading to difficulties in learning. Working memory problems are a major factor in the difficulties faced by pupils with ADD/ADHD. Lervag & Hulme (2013) point out that a number of studies indicate working memory problems impact on attention, impulsive behaviour and self-regulation in those with attentional disorders. Jeffries and Everatt (2004) studied a group of children with special educational needs (SEN), which was sub-divided into groups with dyslexia or with DCD or attention deficits, and further comparing them to a control group without known learning difficulties. Results showed that children in both SEN groups performed poorly on tests of working memory relating to the phonological loop. However, although both SEN groups performed poorly on verbal memory tasks compared to the control, children with dyslexia achieved lower scores on the phonological measures, but performed as well as the control group on the visuospatial sketchpad measures. The dyslexic children achieved the lowest scores of all the study participants on the digit span tests (a sequence of numbers given verbally that the pupil must remember and repeat), particularly the backward digit span (the sequence of numbers must be repeated to the assessor in reverse order) which is indicative of verbal working memory. Children with DCD or attention problems showed more deficits on the visuospatial and motor coordination tasks than those with dyslexia.

Deficits in visuospatial short-term and working memory have been linked to difficulties in mathematics and to mental arithmetic tasks in particular (Alloway, 2011; Chinn, 2000, cited in Reid, 2009).

Working memory function as a predictor of academic progress

It has been suggested that memory is more important than IQ in predicting GCSE results (Riddick, 2002; Gathercole et al., 2004). Also, pupils achieving low SAT scores were "typically found to have extremely poor capacity to store information in working memory" (Gathercole, 2007, p.85). The working memory skills of five year olds were found to be the "best predictor of reading, spelling and math outcomes six years later" (Alloway, 2009, p.92) irrespective of IQ level (Alloway, 2012). Gathercole & Pickering (2000), following their study of the close links between

working memory and attainment on National Curriculum tests at the age of seven years, concluded that assessment of working memory skills in the early years would be a valuable way of screening for children likely to be at risk of poor academic progress.

Assessment of working memory

Gathercole (2008) suggests that working memory can be assessed both indirectly and directly. Indirect assessment involves the use of behaviour rating scales which teachers can use to quantify the frequency of problem behaviours associated with weak working memory. More direct assessment involves the use of batteries of standardised tests.

Awareness and understanding of working memory problems amongst the teaching profession and in the classroom

Studies have shown that some teachers are unsure of what is meant by working memory. As a consequence children with poor working memory were often not identified by their teachers as having such problems (Alloway, 2012; Gathercole et al., 2006; Gathercole & Alloway, 2008) but often described as having a short attention span, or poor listening skills, or were described as 'daydreamers' or easily distractible.

Supportive responses in the classroom

Analysis of the memory load involved in key classroom tasks can help teachers to reduce the demand on memory by relatively slight changes in their practice. Simple classroom strategies such as repeating information, breaking instructions and tasks down into smaller chunks, using simple language structures when giving information and encouraging the pupil to ask for information when needed could be immediately put in place (Gathercole & Alloway, 2007). Memory aids, such as spellings/word mats, number lines and planning tools (e.g. writing frames, mind maps) could be provided and used within the classroom with relative ease.

Improvement of working memory problems through cognitive training

Recent research has shown that working memory can be developed and improved through cognitive training (Klingberg, 2005; Alloway & Warner, 2008). Klingberg, Forssberg & Westerberg (2002) found that not only could working memory be improved by training but that the training also generalised into other tasks, for which participants had not been trained, that required working memory skills.

Meta-analysis of a range of studies into the impact of working memory training revealed "a large variation in results" (Lervag & Hulme, 2013, p2), but that "working memory training has positive effects on tasks similar to those trained" (p4). However, no evidence was found that there was transfer to other areas such as cognitive performance or attainment in reading or arithmetic. Lervag & Hulme (2013) concluded that working memory training programmes could not be recommended as treatment for developmental disorders such as dyslexia and ADHD.

Methodology

Consideration was given as to how optimal data might be collected and it was decided that a survey approach would allow collection of information suitable for analysis, allowing patterns to be identified and facilitating the making of comparisons (Bell, 1993). Munn & Drever (1999) suggest the main advantages of using a questionnaire include efficient use of time, anonymity for the respondent, the possibility of a high return rate and use of standardised questions. The questionnaire consisted of 5 substantive questions plus a question on whether they would be willing to be part of an interview and finally an opportunity for any further comments. The questions were all structured around pupil assessment for working memory, whether the school carried it out and if so the strategies, tools and resources used plus the perceived benefit of training. Follow up interviews were used to clarify a response which can be developed further (Bell, 1993).

Information was gathered using a quantitative and qualitative approach. It was predicted that questionnaire responses from approximately 25 primary schools (10% of the total number of

primary schools within the local authority) would give enough data to work from. Thus, 35 schools (of various sizes ranging from 80 to 200 pupils) were selected at random and sent a questionnaire. All 35 schools responded to the request. All responses were from the Special Educational Needs Co-ordinator SENCo but in 20 cases the SENco was also the Headteacher. Following responses on the questionnaire, regarding willingness to take part in an interview, semi-structured interviews were then arranged within 10 of the participant schools at a mutually agreed time. The interviewees were all in the role of SENCo at their schools.

Four Advisory Teachers, in addition to the researcher, assisted in carrying out interviews within the schools.

Ten schools were selected for interview according to the following criteria:

- Consent to interview
- Schools that carry out some assessment of working memory
- Schools that do not carry out any assessment of working memory

Where there were substantial numbers of one aspect of the criteria random sampling was used.

A mixture of approaches was used in order to analyse the data. There was some statistical analysis in information gained from the questionnaire, for example how many schools carry out assessment of working memory and how many do not. Thematic Analysis has a flexible theoretical freedom (Braun and Clarke 2006) and identifies implicit and explicit ideas within data (Guest 2012). Thus, it was deemed to be the most appropriate qualitative analytic method to apply to the data.

Results

Results revealed that 33 of the 35 schools (94%) responding to the questionnaire did not carry out their own assessment of working memory difficulties. Only two schools carried out their own assessments in this area, through use of classroom observation, digit span tests or the verbal and visual tests contained in the Quest Diagnostic Profile. However, responses from a further six schools showed that, although they had stated that they did not carry out assessment, they did carry out classroom observation. Another school had added to the questionnaire information that the

use of classroom observation and digit span tests was informal, used as a means to discern whether referral to an outside agency, for assessment and advice, would be appropriate.

The majority of schools within the study relied on assessment carried out by outside agencies to identify working memory difficulties of individual pupils; using mainly local authority services i.e. Learning Support Service (LSS) or the Educational Psychology Service (EPS). Two schools also accessed assessment through the Child and Adolescent Mental Health Service (CAMHS) and one of these also used assessment information from the Occupational Therapist (OT) as shown in table 1.

Table 1	LSS only	EPS only	LSS & EPS	CAMHS/OT	No referrals to outside agencies
Number of schools	7	4	19	2	3
Percentage of schools	20	11	54	5.7	8.5
	85%				

Table 1: Working Memory Assessment in schools by outside agencies

Schools carrying out their own assessment indicated they did not refer pupils to the external agencies. In addition to this one school neither carried out their own assessment nor referred to outside agencies. All three schools declined to take part in an interview.

During interview participating schools explained why they did not carry out their own assessment of working memory difficulties. The barriers identified fell into three main themes:

- lack of knowledge or training
- time and
- resources/ funding.

Knowledge or training issues

Lack of knowledge or training meant that teaching staff were not aware of the key characteristics of working memory difficulties, attributing any problems to other causes such as short attention span, poor listening skills or laziness. This is consistent with the misattribution of the signs of poor working memory reported by Gathercole et al. (2006, cited in Alloway, 2012) where teachers explained the problems as 'lacking motivation' or 'daydreaming' (p.141). One interviewee commented that although she would have known a child was having a problem with their work she would not have known the cause of the problem or, therefore, what to do about it. Lack of knowledge of the key characteristics of poor working memory also meant teaching staff were unaware of the assessment tools available to them.

Time

Interviewees commented on time constraints indicating that, due to curriculum pressures, there was little or no time to carry out assessment during the school day.

Resources and funding

Funding was an area of concern for all interviewees. Where no assessment tools were readily available in school, the purchase of such resources would be difficult due to budgeting constraints. School staff needed to know which assessment tools would be the best for them before planning their purchase.

As free access to assessment through local authority services (LSS, EPS) is available to maintained state schools it would appear to be easy to understand why schools would make individual pupil referrals rather than carry out their own assessment. However, interviewees also commented on the referral to external agencies because of the need for specialist knowledge. While school staff may administer a test of working memory, it then depends on their level of knowledge as to how the results of the test would then be interpreted, and what actions identified to be put into place.

Those interviewees who used classroom observation to assist identification of working memory difficulties stated that this was the main assessment tool used in Early Years and Key Stage 1

classrooms. Because school staff were familiar with this method of assessment it was described as easy to use and good at providing practical information that could be acted upon immediately. However, it was also pointed out that interpretation of the observation depended on the teacher's level of knowledge and experience, as that which is observed can be interpreted in different ways and may be open to subjectivity.

According to questionnaire responses a considerable strength of schools was to put in place general classroom strategies to support pupils with poor working memory. Most schools used support strategies such as visual cues, questioning, repetition, planning or writing frames, auditory cues, spelling support and memory games. Less than half of the schools within this study used peer or 'buddy' support systems, although where this strategy had been used it was reported to have worked well. Several schools were able to add further strategies to the general classroom list, as follows:

- Cue cards for numeracy operations
- Brain Gym
- Recording pens and postcards
- Clicker (Crick) – provides auditory feedback, writing frames, word grids etc
- Listening comprehension activities
- Memory support group – games/activities to build memory skills
- Reduction in distance for copying from board – copy placed on desk in front of child
- Activities from Read Write Inc.
- Memory tools:
    - Visualisation
    - Naming
    - Rehearsing
    - Grouping
    - Linking
    - Chunking
    - Mind maps
    - Word maps

In most cases the listed and additional strategies were available to all pupils in the classroom as they were seen to be part of Quality First Teaching, although teachers tended to target specific pupils, differentiating work accordingly. Interviewees stated that commercial resources used were tailored to pupil needs and were found to be very useful, particularly where they were used in 1:1 or small group interventions. However, only one interviewee indicated the school was aware of the need for pre and post intervention assessment to help provide evidence of the impact of these resources, while most schools responded that the SENCo was monitoring the interventions and the progress made, it was not clear exactly how this was done. All interviewees were interested in hearing more about the commercially available resources, with one school commenting that they would be prepared to fund the purchase of recommended resources.

What was not always clear from the combined data was if interventions to develop working memory skills were structured, whether within the classroom, small group or 1:1 situation. General classroom strategies, while supporting the pupils during given tasks, would not necessarily develop or increase working memory capacity.

According to responses 32 schools thought staff training on working memory would be useful. Only one school did not think it would be of use and two schools did not complete that section of the questionnaire. Interviewees all commented that school staff had not had access to training in this area although one commented that the SENCo had accessed some training where working memory was one of the areas covered. Responses throughout the interviews stated that school staff in general were not aware of the impact that working memory difficulties had on learning. Nor were staff aware of the key characteristics of working memory problems and how working memory difficulties might be identified.

All interviewees thought that school staff required training relating to

- the impact of poor working memory on learning,
- what the key characteristics of poor working memory were, in order to aid identification,
- and how to support pupils with working memory difficulties.

These areas were identified by interviewees to be where school staff lacked knowledge, although some staff had already had advice regarding support strategies from external agencies.

Discussion

The importance of the impact of poor working memory on learning is well documented, but this study would suggest that classroom teachers are not fully aware of the implications, particularly in relation to the links between working memory development, behaviour and performance (Klingberg et al., 2002; Holmes et al., 2009; Holmes et al., 2010; Alloway, 2012). It might be suggested that the screening of pupils potentially at risk of poor academic progress (Gathercole & Pickering, 2000) by means of an assessment of working memory function, and prompt intervention designed to develop working memory capacity would seem obvious steps for schools to consider.

Teachers' apparent lack of knowledge with regard to identification of poor working memory, the development of working memory capacity and classroom support strategies has serious implications for teacher training and continuing professional development; particularly if the results of this study are seen to be representative of all schools within the local authority. The present study indicates that information on the importance of working memory, screening and development, seems to be unfortunately slow in reaching those in the classroom.

Lack of time and resources continue to be among the most significant barriers to enhancing teacher knowledge and implementation of new initiatives.

The sharing of information in relation to working memory appears to be somewhat piecemeal both at individual school level and across the local authority. Individual schools within the county may access different training events or take part in 'one off' research studies which raise the knowledge and understanding of staff in one particular school, but this information is not routinely shared with other schools, most probably due to lack of time.

For a number of reasons relating to lack of knowledge, time and resources/funding, most of the schools in the study preferred to refer to external agencies for assessment and advice. The researcher's own experience has shown that schools have tended

not to refer a pupil for assessment and advice solely relating to poor working memory, but for a suite of difficulties, of which working memory is only one part. It is the 'specialist knowledge' that schools appeared to value and the advice relating to the whole context of the pupil's difficulties, not just one isolated area. However, local authority services have tended to be busy and pupils may not be seen immediately by external agencies. Therefore, even an 'informal' assessment of a pupil's working memory carried out by the school could be useful to teaching staff in the interim. Currently local authority services are free to schools, and have been for some time, but this may not always be the case. Changes in funding or service provision in the future, may mean that schools will need to be more self-reliant in terms of assessment and intervention.

Proposals

Although this research is indicative of issues faced by schools it is acknowledged that the study is small scale and limited to one local authority. With this in mind all proposals are framed within this context.

The next steps would appear to be relatively clear in that there is a need for training on working memory for all schools and that this training would be welcomed by most school staff.

A training event would need to include:

- information about the impact made on learning by poor working memory,
- the characteristics of working memory difficulties,
- assessment of working memory, including assessment tools
- general classroom support strategies
- small group/1:1 interventions to develop working memory
- resources
- time for teachers to look closely at assessment tools and resources.

In addition to training opportunities, the development of easily accessible service information sheets for schools and parents would act as a first step to finding out about working memory difficulties for some, or as an *aide memoire* for those who had already accessed training.

Funding for access to training and for purchase of resources and assessment tools has been identified as a barrier for schools.

Conclusions

While current research shows that working memory is closely linked to learning, and that it is crucial that teachers understand the impact of working memory deficit on pupil progress, this study has revealed school staff were generally unaware of the characteristics of poor working memory and seldom carried out working memory assessment, thus, making identification and appropriate support difficult. Without the right intervention pupils will continue to experience difficulties in learning relating to language acquisition, reading, writing and self organisation, impacting, too, on their confidence and self esteem. This study has identified some of the barriers for schools regarding identification, assessment and support of pupils with working memory difficulties and proposes the delivery of training for teachers in these areas. The study also identifies the need for further work on the identification of suitable assessment tools and intervention programmes for schools. Without the opportunity to develop their knowledge and expertise in relation to working memory, teachers cannot identify, support and ameliorate the difficulties experienced by children with a working memory deficit, resulting in the children's lack of academic progress and failure to meet their full potential.

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