Effective screening tools for children with working memory impairments

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Abstract

The term ‘working memory’ refers to the capacity to store and manipulate information for a brief period. There is now extensive evidence that working memory predicts current and subsequent scholastic attainments of children across the school years in both literacy and numeracy. Early identification of poor working memory skills is clearly desirable given the links between memory abilities and learning in the classroom. This paper discusses two different tools for effectively identifying children with poor working memory skills. The first is the Automated Working Memory Assessment (AWMA; Alloway, 2007), a culture-fair, computerised battery for educators to effectively screen individuals between 4 and 22 years for working memory problems. The second tool is the Working Memory Rating Scale (Alloway et al., 2008), a teacher checklist based on key behavioural characteristics that children with working memory impairments exhibit. Data from children with low and average working memory skills on both these screening tools and comparisons with other standardised memory assessments (such as the WISC-IV Memory Index) will be presented. Benefits of these screening tools include minimal training required, high face validity, and a quick and cost effective means of alerting teachers to the warning signs of memory deficits that will impair learning will also be discussed.

Working memory: A definition

The term 'working memory' refers to the capacity to store and manipulate information in mind for brief periods of time. It provides a mental workspace that is used in many important activities in everyday life. Working memory capacity is measured by complex span tasks that require simultaneous short-term storage of information while processing additional information. One example is listening recall, in which the participant makes judgments about the semantic properties of sentences while remembering the last word of each sentence in sequence.

Working memory and learning

Working memory is a relatively pure measure of a child's learning potential. As it is not strongly influenced by the child's prior experiences such as pre-school education, or their socio-economic background (e.g., maternal educational level), it tells us about a child's capacity to learn (Alloway, Gathercole, Willis, & Adams, 2004; Dollaghan, Campbell, Needleman, & Dunlosky, 1997; Weismer et al., 2000). In contrast, school-based assessments or even IQ tests measure knowledge that the child has already learned.

There is now extensive evidence that working memory capacity constrain children's academic achievements. Studies have also reported close associations between working memory capacity and pupils' performance on national assessments in literacy and numeracy across all three key stages: Key Stage 1 and 2 (Alloway, Gathercole, Adams, Willis, Eaglen, & Lamont, 2005; Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegmann, 2004); and Key Stage 3 (Alloway, Banner, & Smith, 2008; Jarvis & Gathercole, 2005).

Working memory is also linked to learning difficulties in children identified on the Special Needs register commensurate to the severity of needs (Alloway, Gathercole, Willis, & Adams, 2005). Deficits in working memory performance were more marked in children with statements of special needs than those at earlier stages of recognition of the need for educational support. It is suggested that this difficulty may underpin their failures to make normal educational progress. Poor working memory skills have also been found to predict learning two years later in children with learning difficulties, independent of their IQ (Alloway, in press).

Students with working memory impairments struggle in the classroom because they are unable to hold in mind sufficient information to allow them to complete the task. Losing crucial information from working memory will cause them to forget many things: instructions they are attempting to follow, the details of what they are doing, where they have got to in a complicated task, and so on. Because those with working memory impairments fail in many different activities on many occasions due to these kinds of forgetting, they will struggle to achieve normal rates of learning and so typically will make poor general academic progress (Gathercole & Alloway, 2008).

Research has shown that 10-15% of children in a mainstream classroom will suffer from working memory impairments that will jeopardise their academic success. Common failures for children with working memory impairments include forgetting lengthy instructions, place-keeping errors (for example, missing out letters or words in a sentence), and failure to cope with storing and manipulating information (Alloway, Gathercole, Kirkwood, & Elliott, in press-a; Alloway & Gathercole, 2006).

Automated Working Memory Assessment (AWMA)

Early identification of poor working memory skills is clearly desirable given the links between memory and scholastic excellence. I have recently developed the Automated Working Memory Assessment (AWMA, Alloway, 2007), a computer-based assessment of working memory skills, with a user-friendly interface. This tool provides a practical and convenient way for educational professionals and psychologists to screen for significant working memory problems, in individuals aged between 4 and 22 years. The AWMA provides a detailed profile of working memory skills necessary for targeting early intervention strategies. It is convenient for teachers as it requires minimal training for administration: test scores are calculated automatically by the computer programme and the child's profile is generated upon completion.

The development of the AWMA was based on a dominant conceptualization of working memory as a system comprising multiple components whose coordinated activity provides the capacity for the temporary storage and manipulation of information in a variety of domains. According to the Baddeley (2000) revision of the influential Baddeley and Hitch (1974) model, working memory consists of four limited capacity elements. The central executive is a domain-general component responsible for the control of attention and processing that is involved in a range of regulatory functions including the retrieval of information from long-term memory (Baddeley, 1996). The temporary storage of information is mediated by two domain-specific stores: the phonological loop provides temporary storage of verbal material, and the visuo-spatial sketchpad is specialized for the maintenance and manipulation of visual and spatial representations (see Baddeley & Logie, 1999, for a review). The fourth component, the episodic buffer, is responsible for binding information across informational domains and memory sub-systems into integrated chunks (Baddeley, 2000). This model has been supported by evidence from studies of children (e.g., Alloway, Gathercole, & Pickering, 2006; Alloway, Gathercole, Willis, & Adams, 2004; Bayliss, Jarrold, Gunn, & Baddeley, 2003), adult participants (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004), neuropsychological patients and neuroimaging research (Jonides, Lacey, & Nee, 2005).

The AWMA provides three measures each of verbal and visuo-spatial aspects of short-term memory and working memory. In line with a substantial body of prior evidence, verbal and visuo-spatial working memory were measured using tasks involving simultaneous storage and processing of information, whereas tasks involving only the storage of information were used to measure verbal and visuo-spatial short-term memory. In tests of verbal short-term memory (tapping the phonological loop), the participant is required to recall sequences of verbal material such as digits, words, or nonwords. Visuo-spatial short-term memory tests (tapping the visuo-spatial sketchpad) involve the presentation and recall of material such as sequences of tapped blocks, or of filled cells in a visual matrix. More complex memory tasks have been designed to assess the central executive/attentional control aspect of the working memory. In these working memory tasks, the individual is typically required both to process and store increasing amounts of information until the point at which recall errors are made. One example of a verbal working memory task is counting recall, in which the participant counts the number of target items in each of a series of successive arrays and then recalls the totals for each array in the original sequence (Case, Kurland, & Goldberg, 1982). Analogous visuo-spatial working memory tasks include rotating images and recalling their locations.

The multiple assessments of each memory component in the AWMA taken for a large sample of children between four and eleven years provided the opportunity to investigate the underlying structure of working memory using confirmatory factor analyses (Alloway et al., 2006). The findings confirmed that in line with the working memory model outlined above, the processing aspect of both the verbal and visuo-spatial working memory tasks was controlled by a centralised component (i.e., the central executive), while the short-term storage aspect was supported by a domain-specific component—the phonological loop for verbal information and the visuo-spatial sketchpad for visuo-spatial information. The underlying cognitive structure for working memory was in place even for those in the youngest age group, who were 4 and 5 years old.

AWMA & Learning outcomes
The AWMA is the first standardized tool for non-specialist assessors such as classroom teachers to screen their pupils for significant working memory problems quickly and effectively. To date, the AWMA has been used to screen over 4000 in schools in the UK (Alloway et al, in press-a). The suggestion that the AWMA is a valid screening tool is consistent with the finding that low working memory skills constitute a high risk factor for educational underachievement. In a large-scale study of children identified with working memory deficits using the AWMA, only 2% of them achieved scores in the average range in standardized assessments of reading and math.

AWMA & Developmental disorders
The AWMA has also been used in children with Dyslexia, Specific Language Impairments, Developmental Coordination Disorder, Attention Deficit and Hyperactive Disorder, Developmental Dyscalculia, and Autistic Spectrum Disorder. It provides a useful 'snapshot' of how their impairments and memory skills impact learning (see Alloway et al., 2008a).

Reliability and Validity
Findings from a recent study indicate that working memory skills in children with poor working memory remained relatively stable over the course of the school year (Alloway, Gathercole, Kirkwood, & Elliott, in press-b). The data in the present study also indicates that the AWMA also has good diagnostic validity as evidenced by the high classification accuracy of the WISC-IV Working Memory Index.

Application
The practical implications of these findings are that educators have access to a tool to facilitate identification of poor working memory skills in children. Two major obstacles to the effective identification and management of working memory needs in the classroom at present are firstly, that working memory problems are difficult to detect from casual observation alone, and secondly, that there is an absence of suitable assessment tools that can be used by teachers to identify working memory problems. The AWMA provides an easy and effective method for assessing working memory in the classroom that has the potential to overcome both of these obstacles. It provides age-related cut-off scores that indicate typically low, average or high working memory skills (see Alloway, 2007 for further details). This will enable teachers to identify children who are likely to experience particular problems in carrying out complex tasks that required both memory storage and effortful processing, such as writing, counting, and remembering instructions, in order to provide timely and effective management of this source of future learning difficulties. The AWMA has been translated in over 10 languages and has been used internationally to identify and support children with working memory problems.

Details of the AWMA can be found here:
http://www.harcourt-uk.com/awma

Working Memory Rating Scale (WMRS)
The Working Memory Rating Scale (WMRS; Alloway, Gathercole, & Kirkwood, 2008) consists of 20 short descriptions of problem behaviours that differentiate children with low and average working memory abilities. The teacher rates how typical each behaviour is of the child on a scale ranging from *not typical at all* (0) to *very typical* (3). The behaviours are described in statements such as i) *Does not volunteer answers in group situations*, ii) *To move on to the next step in an activity, needs frequent prompts by teaching staff,* and iii) *Mixes up material inappropriately, e.g., incorrectly combines parts from two sentences rather than reading each one accurately*. It is particularly valuable for teachers who do not wish to use more formal assessments of working memory, but do want to provide a more systematic evaluation of the potential working memory problems than can be provided by information observation alone.

The WMRS has a number of merits. It takes no longer than 5 minutes to complete, and is easy to score and interpret, requiring no psychometric training. It is valuable not only as a diagnostic screening tool for identifying children at risk of poor working memory, but also in illustrating both the classroom situations in which working memory failures frequently arise, and the profile of difficulties typically faced by children with low working memory. The rating scale will also enable teachers to use their informal knowledge of the child to produce an indicator of how likely it is that the child has a working memory problem. It provides a valuable first step in detecting possible working memory failures. Identification can then be followed up by examination of the individual's detailed profile of working memory strengths and weaknesses using standardized measures, such as the Automated Working Memory Assessment (AWMA).

Reliability and Validity
The WMRS is negatively correlated with all four memory composite scores and processing scores in the AWMA (see Alloway et al., 2008b). This indicates that higher (i.e., more problematic) teacher ratings on the WMRS were associated with lower memory scores on the AWMA. We also investigated how well the WMRS teacher ratings differentiated the low and average working memory groups. In total, 76% of children with poor working memory and 80% of the average working memory children were correctly identified. This establishes that the WMRS is effective at discriminating children in the two working memory groups, with higher scores typically characterising the children with working memory deficits.

In a recent study, we compared the relationship between working memory and attention problems using teacher ratings on the WMRS with the Conners Teaching Rating Scale (CTRS, Conners, 2001) and BRIEF (Gioia et al., 2000) in low WM children (Alloway et al., 2008c). There was a strong relationship between the WMRS score and the working memory subscale in the BRIEF and the Cognitive problems/Inattention subscale of the CTRS. The children's WMRS score was also significantly linked with the number of commission errors, but not omission ones, in a cognitive measure of sustained attention, the Continuous Performance Test (Conners, 2004). When compared with a typically-developing group, the WMRS identified a greater proportion of children with working memory problems than both the BRIEF and CTRS. These data suggest that working memory, as measured by the WMRS, is linked to some aspects of attention; however, it separable from other aspects linked with inhibition and self-regulation.

Details of the WMRS can be found here:
`http://www.harcourt-uk.com/wmrs`

References

Alloway, T. P. (2007). *Automated Working Memory Assessment.* London: Harcourt Assessment.

Alloway, T.P. (in press). Working memory, but not IQ, predicts subsequent learning in children with learning difficulties. *European Journal of Psychological Assessment.*

Alloway, T.P., Banner, G., & Smith, P. (2008). Working memory and cognitive styles in adolescents' attainment. *Manuscript submitted for publication.*

Alloway, T.P. & Gathercole, S.E. (2006). How does working memory work in the classroom? *Educational Research and Reviews, 1,* 134-139.

Alloway, T.P., Gathercole, S.E., Adams, A.M., & Willis, C., Eaglen, R., & Lamont, E. (2005). Working memory and other cognitive skills as predictors of progress towards early learning goals at school entry. *British Journal of Developmental Psychology, 23*, 417-426.

Alloway, T.P., Gathercole, S.E., & Kirkwood, H. (2008). *The Working Memory Rating Scale*. London: Pearson Assessment.

Alloway, T.P., Gathercole, S.E, Kirkwood, H.J., & Elliott, J.E. (2008b). Reliability and validity of the Working Memory Rating Scale. *Learning and Individual Differences*.

Alloway, T.P., Gathercole, S.E, Kirkwood, H.J., & Elliott, J.E. (in press-a). The cognitive and behavioural characteristics of children with low working memory. *Child Development*.

Alloway, T.P., Gathercole, S.E, Kirkwood, H.J., & Elliott, J.E. (in press). Evaluating the validity of the Automated Working Memory Assessment. *Educational Psychology*.

Alloway, T.P., Gathercole, S.E., & Pickering, S.J. (2006). Verbal and visuo-spatial short-term and working memory in children: Are they separable? *Child Development, 77*, 1698-1716.

Alloway, T.P., Gathercole, S.E., Willis, C., & Adams, A.M. (2004). A structural analysis of working memory and related cognitive skills in early childhood. *Journal of Experimental Child Psychology, 87,* 85-106.

Alloway, T.P., Gathercole, S.E., Willis, C., & Adams, A.M. (2005). Working memory and special educational needs. *Educational and Child Psychology, 22,* 56-67.

Alloway, T.P., Gathercole, S.E., Holmes, J., Place, M., & Elliott, J. (2008c). A comparison of sustained attention and behavioral problems in children with ADHD and children with poor working memory. *Manuscript submitted for publication.*

Alloway, T.P., Rajendran, G., & Archibald, L.M. (2008a). Working memory profiles of children with developmental disorders. *Manuscript submitted for publication.*

Baddeley, A. D. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49A,* 5-28.

Baddeley, A. D. (2000). *The episodic buffer: A new component of working memory? Trends in Cognitive Sciences, 4, 417-423.*

Baddeley A. D., & Hitch G. (1974). Working memory. In G. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, 47-90. New York: Academic.

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 28-61). New York: Cambridge University Press.

Bayliss, D. M., Jarrold, C., Gunn, D. M., & Baddeley, A. D. (2003). The complexities of complex span: Explaining individual differences in working memory in children and adults. *Journal of Experimental Psychology: General, 132,* 71-92.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Working memory capacity as long-term activation: An individual differences approach. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19,* 1101-1114.

Conners, K. (2001). *Conners' Teacher Rating Scale-Revised (S*). New York: Multi-Health Systems Inc.

Dollaghan, C., Campbell, T., Needleman, H., & Dunlosky, G. (1997). Reducing bias in language assessment: A processing-dependent measure. *Journal of Speech, Language and Hearing Research, 40,* 519-525.

Gathercole, S.E. & Alloway, T.P. (2008). *Working memory & learning: A practical guide.* London: Sage Press.

Gathercole, S. E., & Pickering, S. J. (2000). Assessment of working memory in six- and seven-year old children. *Journal of Educational Psychology, 92,* 377-390.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 15 years of age. *Applied Cognitive Psychology, 18,* 1-16.

Gioia, G.A., Isquith, P.K., Guy, S.C., & Kenworthy, L. (2000). *Behavior Rating Inventory of Executive Function.* Florida, USA: Psychological Assessment Resources, Inc.

Jonides, J., Lacey, S. C., & Nee, D. E. (2005). Processes of working memory in mind and brain. *Current Directions in Psychological Science, 14,* 2-5.

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working-memory capacity: A latent-variable approach to verbal and visuo-spatial memory span and reasoning. *Journal of Experimental Psychology: General, 133,* 189-217.

Weismer, S. E., Tomblin, J. B., Zhang, X., Buckwalter, P., Chynoweth, J. G., & Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research, 43,* 865-878.