Working memory and learning difficulties

Dr Joni Holmes from the Cognition and Brain Sciences Unit in Cambridge University, provides an insight into the difficulties faced by learners with poor working memory and discusses interventions designed to improve working memory function.

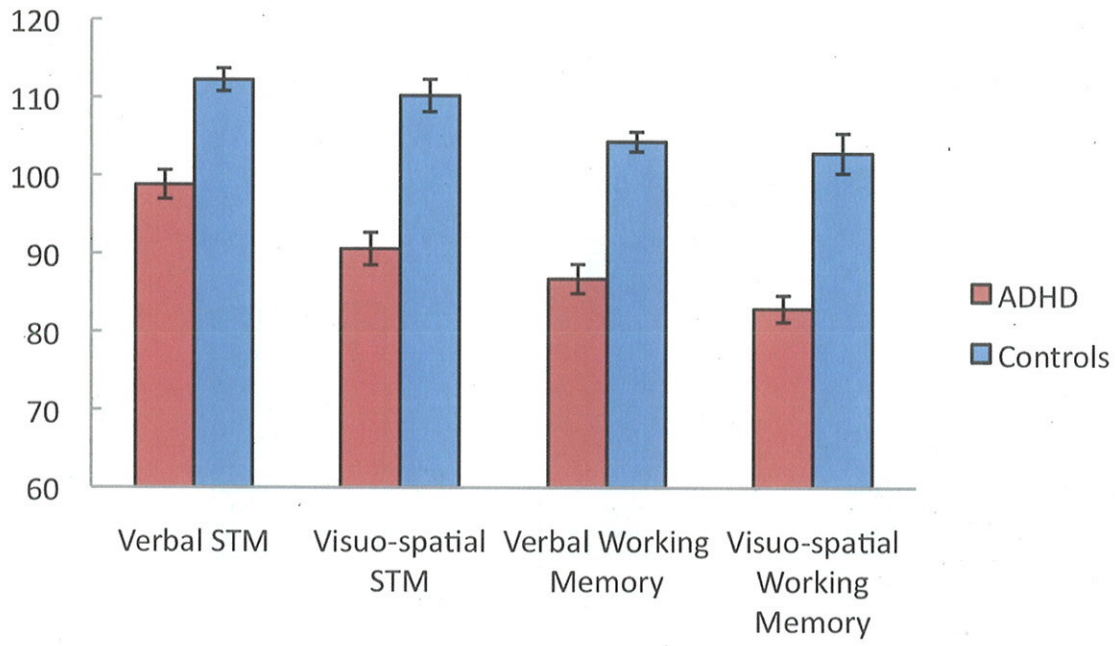
Children struggle to cope with the demands of the classroom for many different reasons, including when they have poor working memory skills. Presenting as an inability to stay on task and complete everyday classroom activities, working memory impairments are relatively common and represent a significant risk factor for educational failure for many children. In this article, I provide an overview of the characteristics of children with working memory difficulties and review current methods for remediating the consequences of poor working memory function.

What is working memory?

Working memory enables us to store information in our minds for short periods of time and use it in our current thinking. It is a kind of mental workspace that we use for many aspects of our everyday life, including reading comprehension, mental arithmetic and planning a series of thoughts or actions. For children, it appears to play a crucial role both in supporting learning and in maintaining focused behaviour in the classroom.

There is an upper limit to the amount of information that we can hold and manipulate in working memory at any given time. This capacity changes across the lifespan and varies greatly between individuals of the same age. For typically developing children, working memory capacity increases steadily up to the age of 14/15 years where it reaches adult levels (Alloway, Gathercole & Pickering , 2006). However, for some children, working memory follows an atypical developmental trajectory that results in a smaller capacity than is typical for their age (e.g. Westerberg, Hirvikoski, Forssberg & Klingberg, 2004). Deficits in working memory are a common feature of a wide range of developmental disorders and specific learning difficulties, including ADHD, dyslexia, specific language impairment, and reading and mathematical difficulties (Archibald & Gathercole, 2007; Geary, Hoard, Byrd-Craven, Nugent & Numtee, 2007; Holmes, Gathercole, Hilton, Place, Alloway, Elliott, 2012; Jeffries & Everatt, 2004; Swanson & Sachse-Lee 2007 – see Figure 1). They can also occur in the absence of any diagnosed disorder, and represent a significant risk factor for poor educational progress (e.g. Gathercole & Alloway, 2008).

Figure 1 *Short-term and working memory scores of children with ADHD compared to an age-matched comparison group, from Holmes et al. 2012.*



What does a child with poor working memory look like and why is it a risk factor for learning difficulties?

Because working memory is used to process and store information during complex and demanding activities, it supports many activities that children routinely engage in at school. Imagine, for example, attempting to read and comprehend a passage of text. The process of reading sentences, holding them in mind and integrating the information to uncover the meaning relies heavily on the ability to simultaneously process and store information over the short term. Similarly, following a set of complex instructions, which a child will often have to do in the classroom, relies on the ability to remember the different parts of the instruction whilst carrying out the various steps to complete the action successfully.

Observations of children in the classroom, combined with teacher reports, have highlighted the major signs of a working memory difficulty. These include: poor academic progress, difficulties following multi-step instructions, failing to complete common classroom activities that require large amounts of information to be held in mind, problems keeping their place in demanding and complex activities such as writing, and high levels of inattentive and distractible behaviour (Gathercole & Alloway, 2008; Gathercole, Alloway, Kirkwood, Elliott, Holmes & Hilton, 2008; Gathercole, Lamont & Alloway, 2006).

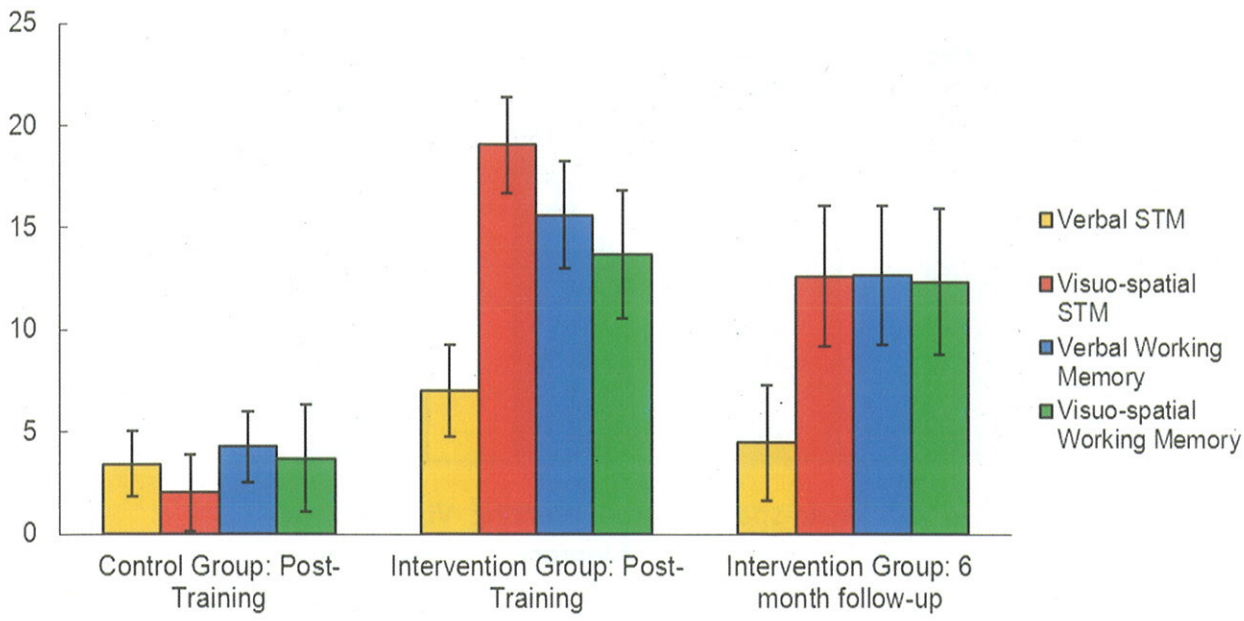
Given the heavy working memory demands of classroom instructions and activities, it is perhaps unsurprising that one of the key characteristics of children with working memory deficits is poor educational attainment (e.g. Gathercole et al., 2008). Learning is a step-by-step process that relies on the successful completion of individual learning activities for the accumulation of knowledge. Children with working memory impairments often fail in the classroom because the working memory loads of each activity exceed their capacities. When the working memory system fails, children forget what they are doing and this can lead to inattentive behaviour. The end result is frequent lost learning opportunities, and consequently slow rates of educational progress (Gathercole & Alloway, 2008).

Interventions

An increased awareness of the negative consequences of working memory difficulties among educational and health practitioners has augmented demand for targeted interventions over recent years. There are currently two approaches; the first focuses on accelerating learning for children with memory problems by adapting the child's environment, and the second attempts to target and train working memory function directly.

The classroom-based approach focuses on increasing teacher awareness of the warning signs of working memory failures and encouraging them to adapt their approach to teaching to reduce memory loads in the classroom. This can be achieved through breaking tasks and instructions down into smaller steps, re-presenting information, using memory aids and fostering an environment in which children feel able to ask if they have forgotten what they should be doing. It also promotes helping children with poor working memory to use strategies to overcome their cognitive weaknesses (see Gathercole & Alloway, 2008 for details). The extent to which the principles of this intervention are implemented predicts children's literacy and mathematical skills, and teachers are typically enthusiastic about the ways in which their understanding and practice has improved as a result of the intervention Specifically, teachers have commented that it is relatively easy to implement within existing curriculum

Figure 1 *Gains in short-term and working memory for children with poor working memory, from Holmes et al. 2009.*



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activities, that it enables them to understand that many task failures are the result of forgetting, and that children benefit from working within their own working memory limits with greater rates of success when the techniques are applied (Elliott, Gathercole, Alloway, Holmes & Kirkwood, 2010). The long-term benefits for learning are not yet known, but this approach offers a practical starting point for practitioners who are keen to support children with poor working memory.

An alternative approach to intervention is to try to improve working memory function directly through practice on working memory tasks. Various computerized training paradigms are available, all of which require individuals to train intensively for a continued period on tasks that adapt to match their current capacity limit. The nature of the training activities differs across programs, with some requiring practice on an array of working memory tasks (e.g. Cogmed, Klingberg et al., 2005) whilst others involve only one type of training task (e.g. N-back, Jaeggi, Buschkuehl, Jonides & Shah, 2011).

There is now substantial evidence that these programmes ameliorate working memory problems in childhood. Enhancements in memory have been found in children with poor working memory, ADHD and cochlear implants (Beck, Hanson, Puffenberger, Benninger & Benninger, 2010; Dunning, Holmes & Gathercole, 2012; Klingberg et al., 2005; Holmes, et al., 2009, 2010; Kronenberger, Pisoni, Henning, Colson & Hazzard, 2011 – see also Figure 2). In a randomised-controlled study, we have shown that improvements in verbal working memory in children with memory impairments are sustained 12 months after training without any additional intervention (Dunning et al., 2012). These training gains are associated with changes in neural activity in areas of the brain important for working memory function (Westerberg & Klingberg, 2007).

The extent to which these improvements in working memory benefit other skills and abilities is currently highly debated (see Klingberg, 2010, Shipstead, Redick & Engle, 2012 and Melby-Lervåg & Hulme, 2012). However, there is at least some preliminary evidence of accelerated learning following training, with significant improvements in maths scores reported several months after training for children with working memory impairments (Holmes et al., 2009) and improvements in reading comprehension reported post-training for children with Special Educational Needs (Dahlin, 2010). In a field trial just completed, we have shown that training administered at the class-level by teachers leads to robust gains in working memory and educationally significant gains in academic performance. Greater progress at school, measured by performance against national targets across the year of the intervention, was found for children with low achievement; in maths for children aged 9-11 years (both Year 5 and Year 6), and in English for children aged 10/11 only (Year 6) (Holmes & Gathercole, 2012).

Although these findings suggest training may have some benefits for academic outcomes, the field of cognitive training is very much in its infancy and we still know very little about how gains resulting from these training programs might, or might not, transfer to meaningful improvements in an individual's daily life. We may find, for example, that gains are mediated by the development of strategies that are specific to the training tasks, which children then fail to apply spontaneously in real-world situations.

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