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Title: Cogmed Working Memory Training: To what extent is it supported by research and theory?

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Cogmed Working Memory Training: To what extent is it supported by research and theory?

Cogmed is a computerised working memory training programme, which claims to improve working memory capacity and provide a ‘cascading effect of improvements’ (http://www.cogmed.com/how-it-works) on wider cognitive abilities. On the Cogmed website, we are told that the programme ‘is implemented by healthcare professionals around the world,’ combines ‘cognitive neuroscience with innovative computer game design,’ and that ‘whoever you are, Cogmed training will challenge your brain and improve it,’ (http://www.cogmed.com/) This academic critique aims to investigate such claims and assess the effectiveness of Cogmed, by considering the theory and empirical research underpinning and surrounding the intervention. Based on the findings and conclusions drawn, implications for Educational Psychologists (EPs) will be discussed.

Working Memory

Working memory can be defined as ‘a brain system that provides temporary storage and manipulation of the information necessary for … complex cognitive tasks,’ (Baddeley, 1992, p556). Baddeley and Hitch’s 1974 model of working memory proposed a three-component structure. The Central Executive controls our attention to information and coordinates the other two parts. The Phonological Loop or ‘inner ear’ holds and processes information in speech-based form and the Visuospatial Sketchpad or ‘inner eye,’ deals with visual data. Baddeley (2000) added an ‘Episodic Buffer’ which holds integrated chunks of information in a multidimensional code, linking the components together and with long term memory.

Many theorists and educational professionals believe that working memory deficits impinge the learning process (e.g. Alloway, Gathercole, Adams and Willis, 2005). Working memory capacity is thought to be one of the best predictors of academic success, above factors such as IQ (Alloway, 2009). Cogmed relies on this theory, claiming that ‘working memory is the engine for learning’ (http://www.cogmed.com/). It is this link between working memory abilities and educational outcomes that drives much of the research in the area; with researchers searching for the best ways to improve or support children’s working memory, in the knowledge that this is likely to help their progress. Gathercole (2008) proposes that ten percent of children experience working memory problems, highlighting the potential impact of successful interventions.

Two main approaches to supporting children with working memory difficulties include the environmental approach (e.g. Alloway and Gathercole, 2008), involving the adaptation of the classroom environment and curriculum delivery and the within-child approach, which can involve teaching the child new skills to be able to cope with the demands of the classroom (e.g. Engle, Carullo and Collins, 1991) or training the child’s working memory capacity to increase it, (e.g. St-Clair-Thompson, Stevens, Hunt and Bolder, 2010). This final idea is the theory behind Cogmed. There is much debate about which strategy is likely to be most effective and whether or not working memory capacity can in fact be changed.

The traditional opinion was that working memory had a fixed or limited capacity (e.g. Baddeley and Hitch, 1974); this was an ‘essentially defining characteristic’ of the model (Apter, 2012, p259). Others suggest that there is a fixed capacity but this is not fully developed until late adolescence (Gathercole, Pickering, Ambridge and Wearing, 2004), which could support the use of training during childhood. A number of researchers now suggest that training can increase working memory capacity, for example, Chein and Morrison (2010) concluded that following a five-week adaptive training programme, participants had developed larger working memory capacities, as demonstrated by increased working memory test scores. The Cogmed website dedicates a page to ‘neuroplasticity,’ the ‘idea that an individual’s brain can reorganise itself and change,’ (http://www.cogmed.com /neuroplasticity).

The Cogmed Programme

It can be seen therefore, that Cogmed rests on two main theories: that working memory impacts upon wider cognitive functioning and that working memory capacity can be increased through training. Cogmed computerised working memory training was first conceptualised in 1999 by Dr Torkel Klingberg, a Swedish neuroscientist. The first paying customers received Cogmed training in Sweden in 2003 and in 2009, the first British researchers, including Holmes, Gathercole and Dunning (2009), began to evaluate the effectiveness of the programme. Although this study found that ‘adaptive training that taxed working memory to its limits was associated with substantial gains in working memory’ (p9), Cogmed’s inventory of professionals and practices offering the programme indicates that there are still none available in the UK in 2014. The programme was purchased by Pearson in 2010 and is now marketed worldwide.

Cogmed involves twenty-five sessions, one each weekday for five weeks, with each session lasting for thirty to forty-five minutes. Cogmed-qualified coaches help users to complete the training and provide feedback about progress. There are three different versions of the computer programme. The 'JM' version for preschoolers embeds working memory tasks within roller coasters and bumper cars. The school age 'RM' version has a robot and space-age theme and increased levels of difficulty come from more complex tasks and longer sequences. The adult 'QM' version of the programme uses mostly the same exercises as the RM version, but has a simpler, less themed interface. Activities include presenting clients with a number of three dimensional blocks that light up in a sequence that is then recalled by clicking on the correct blocks in order. Another involves hearing a sequence of numbers and recalling them in the reverse order by clicking on them. It is thought that tasks such as the first one challenge visuospatial working memory whilst the latter taps auditory abilities, indicating an influence from the multi-component working memory model.

Cogmed training is 'adaptive;' the level of difficulty of each successive task automatically adjusts depending on whether the user has been successful in the previous activity. Cogmed explains that 'the highly fine-tuned calibration means that every Cogmed user will always be training at the very edge of his or her cognitive capacity,' (http://www.cogmed.com/how-it-works). Holmes, Gathercole and Dunning (2009) used Cogmed with children with low working memory capacities. The training group completed the regular, adaptive Cogmed training whilst the control group completed a non-adaptive version. Participants in the training group showed significantly greater gains in working memory scores (on the Automated Working Memory Assessment, Alloway, 2007) and their scores were maintained after six months. Studies such as this suggest that the adaptive nature of Cogmed, a core feature of the programme, is a major advantage.

What does the research say?

According to the website, 'no other cognitive training program has the level of research support that backs Cogmed Working Memory Training,' (http://www.cogmed.com/cogmed-cognitive-training-programs). Many studies have investigated the effectiveness of the programme, with researchers over the last five years completing reviews and meta-analyses of the abundant research, (e.g. Apter, 2012, Shipstead, Redick and Engle, 2010 and Melby-Lurvag and Hulme, 2013). A number of studies have found improved scores following Cogmed training on working memory tasks that are highly similar to the training activities (e.g. Gropper, Gotlieb, Kronitz and Tannock, 2014; Dahlin, 2013). There is some level of consensus that Cogmed can produce short term, specific improvements on similar working memory tasks. However, two main questions emerged within the Cogmed research and are the continued focus of studies: are the effects maintained over time and can they be generalised onto other tasks and cognitive skills? Roche and Johnson (2014) concluded that although Cogmed is 'one of the better working memory training programmes currently available….how enduring and generalisable the treatment effects from Cogmed training are remains to be demonstrated (p381).' This is partly due to inconsistent findings and methodological flaws within a number of studies.

Generalisability of effects

In the 'User Stories' section of the Cogmed website, benefits of the programme mentioned include improved self-confidence, academic performance, initiative, socialising, focus, control of emotions, organisational and planning skills and reduced attention deficit hyperactivity disorder symptoms. Klingberg (2010, p319), the programme creator, explains that the 'overlap between the neural mechanisms underlying the control of attention and those responsible for working memory,' means that by training on working memory tasks, we are also training attentional control. Working memory and attention could underpin all of the other improvements mentioned above, such as improved socialisation (due to the ability to pay attention as a listener and to control impulses for interrupting) and academic performance (the ability to concentrate in class and process the teacher's explanations and instructions).

Shipstead et al (2010) provide a description of the concepts of near and far-transfer. Near-transfer describes increased performance measured on tasks that are 'highly similar to those being trained,' (p250) whilst far-transfer refers to improved 'post-training performance on tasks which are not of the same nature or appearance as those trained,' (p250). Near-transfer might occur between two different tasks that measure working memory whilst far-transfer takes place between a working memory training task and a task used to measure a separate construct such as attention, reading comprehension or reasoning. For Cogmed's value as a cognitive intervention to be appreciated, research needs to provide evidence of not just near but more importantly far-transfer.

Gropper et al (2014) conducted a study with sixty-two children with ADHD and/or 'learning difficulties'. The experimental group undertook five weeks of Cogmed training and the control group were placed on a waiting list. They found evidence for far-transfer, when experimental participants showed lower rates of ADHD symptoms and cognitive failures following training, compared with controls. Dahlin (2010, 2013) found that children taking part in Cogmed training demonstrated more significant gains on reading comprehension and maths tests than control participants.

However, Chacko, Bedard, Marks, Feirsen, Uderman, Chimiklis et al (2013) conducted a randomised control trial, with eighty-five children, aged seven to eleven, with diagnoses of ADHD. Their approach involved a Cogmed working memory training active group and a Cogmed working memory training placebo group. It was found that although the active group demonstrated greater improvements on working memory tasks than controls (near-transfer) there were no differences in parental and teacher ratings of attention, impulsivity and academic achievement. Furthermore, Holmes, Gathercole and Dunning (2009) found that there were no measurable differences post-training between adaptive training participants and non-adaptive training participants, on tests of reading comprehension and maths skills.

The former group of studies can be criticised in terms of their approach to control groups. Gropper et al used waiting list controls, meaning that they would not have received any attention from the researchers and would not be expecting to see any improvements in their own learning or behaviour. The Hawthorne effect could have been an issue, referring to the tendency of participants to work harder and perform better when they are participants in an experiment. The results therefore might need to be interpreted with caution, as the changes in ADHD behaviours could have been due to Cogmed training *or* the attention that they had received. Dahlin's (2013) study did not use random assignment of participants to control groups, meaning that there could have been unknown or unacknowledged differences between experimental and control groups that influenced the outcomes.

Moreover, in their meta-analysis of the research, Melby-Lurvag and Hulme (2013) found evidence for significant near-transfer of working memory abilities to other similar tasks but concluded that there was no evidence that 'training produces generalised gains to the other skills that have been investigated (verbal ability, word decoding, or arithmetic),' (p281). For further clarification of this, they noted that when they only included those studies with satisfactory control group procedures (ie. randomised and active) within their meta-analysis, the effect sizes for far-transfer measures dropped to close to zero. Therefore, the current literature is not supportive of the generalisability of Cogmed's impacts.

Maintenance of effects

For Cogmed to be a successful working memory intervention, the effects must endure over time. The website suggests that Cogmed is a 'computer-based *solution* for attention problems caused by poor working memory' (http://www.cogmed.com/program) and talks about the sustained effects associated with the programme. A consideration of the research can assist in drawing conclusions about whether or not this might be the case.

Holmes et al (2009) found that for children with low working memory capacities, Cogmed training led to working memory improvements which were stable after six months. However, this study did not follow the control group at the six months stage, meaning that although the training group participants' scores were still higher than their original pre-training ones, it is not certain that they would still be outperforming the control group and whether the training was likely to be the variable contributing to maintained scores. Dahlin, Nyberg, Backman and Neely (2008) did also conclude that the effects of Cogmed training on working memory were maintained six months later, whilst Hovik, Saunes, Aarlien and Egeland (2013) found higher scores eight months later. However, these studies focused only on near-transfer gains, as the post-training tests were very similar to those trained.

There is a shortage of research claiming to have shown the longer-term maintenance of any *far*-transfer improvements. Gropper et al (2014) did find that participants (with ADHD or learning difficulties) demonstrated continued declines in cognitive failures at a two month follow-up, but this is a rather short gap compared to the majority of studies and furthermore, the researchers used a waiting list control group who received no researcher attention. Klingberg et al (2005) found that children who received Cogmed training demonstrated higher working memory scores, non-verbal reasoning and response inhibition scores and lower parental ratings of inattentive and hyperactive-impulsive symptoms, as measured post-training and at a three month follow-up. This was compared to a control group who experienced low level working memory training tasks. However, whether a study conducted by the creator of Cogmed and his colleagues would have been entirely objective is open for debate.

The review conducted by Melby-Lurvag and Hulme (2013) suggests a less optimistic view, concerning both near and far transfer in the long term. On the whole, trained participants showed significantly greater gains in verbal working memory compared to controls, but after nine months (on average) these differences between training and control groups were non- significant. The reviewed studies generally showed that trained participants also demonstrated significant improvements on visuospatial tasks, with the mean effect being significant and moderate at both immediate testing and five months follow-up. This seems to suggest that some near-transfer gains can be maintained over time. However, the immediate effects in a number of the studies analysed were very small and one study found negative immediate impacts of training on scores. Therefore, the follow-up tests in this selection of studies were likely to show improvements in scores, as they were often being compared to low first measurements. In terms of far transfer, the review concluded that participants’ scores on all of these sorts of measures, including attentional control, arithmetic, and word decoding tests, were not significantly improved compared to the control groups after a delay. In contrast to the work of Klingberg and colleagues mentioned above, this review does not provide evidence for long term maintenance of the effects of Cogmed.

It might be the case that Cogmed has the potential to provide long term benefits, but that the programme has not yet been implemented in the most effective way. Klingberg (2010) believes that there are ‘many questions yet to be answered regarding working memory training such as the optimal duration and spacing of training to achieve … durable improvements (p322).’ Cogmed is thought to rely on a ‘physical-energetic model’ (Melby-Lurvag and Hulme, 2013, p282) of brain neuroplasticity, whereby repeated challenging tasks lead to the building of working memory capacity, akin to exercising and building a muscle. If this is indeed an accurate model, then it seems questionable that a one-off five week training programme would lead to long-lasting effects; muscles need consistent and intense training to maintain or increase in size and/or strength.

Conclusion and Implications for Educational Psychologists

It can be seen that Cogmed working memory training rests on a number of major psychological theories; the multi-component model of working memory (Baddeley and Hitch, 1974), the relationship between working memory and learning/educational outcomes (e.g. Alloway, 2009) and the neuroplasticity of the corresponding brain structures (e.g. Soderqvist, Nutley, Ottersen, Grill, and Klingberg, 2012). Whilst the first two theories are widely-accepted within the field, there remains some disagreement over the static versus dynamic nature of working memory capacity.

Following a review of the research surrounding Cogmed, it can be suggested that it is an effective short-term and specific intervention for working memory. However, this has very limited utility, because the research is not currently supportive of its power to bring about longer term and wider benefits. Although the programme claims to impact upon many other cognitive and behavioural functions, this process of far-transfer lacks empirical support. Similarly, the programme was developed as a ‘solution’ to working memory problems, yet the research tends to find that improvements are not maintained over time, apart from some studies using highly similar tasks to those trained.

EPs might be rather cautious in recommending Cogmed working memory training as an intervention. They will need to carefully consider their own beliefs about whether working memory capacities can be increased or are fixed. In consultations with school staff and parents, EPs should promote a critical stance regarding computerised working memory training programmes and might tend to favour environmental and coping skills development strategies over training programmes.

In terms of future research, EPs might investigate the impact of altering the logistics of Cogmed training, for example, allowing children to experience ongoing but less frequent sessions. It is possible that there is more value within such programmes, but the practical application has not yet been optimised.

In conclusion, the Cogmed working memory training programme is not likely to provide the majority of benefits that it claims to. EPs and other educational professionals must consider it with caution and strive to support children and young people with working memory and attentional difficulties in other ways.

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