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Reply

Working memory training remains a work in progress

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In recent years, understandable enthusiasm (e.g., Sternberg, 2008) regarding landmark publications such as Klingberg, Forssberg, and Westerberg (2002) and Jaeggi, Buschkuehl, Jonidas, and Perrig, (2008) has been met with reasonable skepticism (Melby-Lervåg & Hulme, 2012; Moody, 2009; Shipstead, Redick, & Engle, 2012). We do not view this skepticism as an attempted rebuttal of the hope that psychologists will develop methods for reliably training working memory (WM) and associated abilities. Rather, it is a simple acknowledgment that not everybody finds the available data to be persuasive.

In general, research is progressing as it should. Experimental methods are improving (Gathercole, Dunning, & Holmes, 2012) and researchers are developing training techniques that recognize the complexity of WM (Gibson, Gondoli, Johnson, Steeger, & Morrissey, 2012) and the complexity of humans that are engaged in training (Shah, Buschkuehl, Jaeggi, & Jonides, 2012). Yet, while most of the commentators provide valid reasons for believing that WM training will one day become a reliable method of cognitive remediation, few argue that current WM training techniques represent a finished project.

And this is the thrust of our concern. The most accurate description of the state of WM training is that the fundamental techniques remain a work in progress. From a scientific perspective, this is completely normal. However, outside of academia it is clearly problematic. Cogmed sells their product to school systems and to unhealthy individuals under the guise of scientific validation (Cogmed, 2012). Lumosity has begun to advertise their products on television and claim to have 20 million users (Lumostiy, 2012).

The claims that these and other companies make have no bearing on whether or not WM training works; only continued research can provide that answer. However, it does increase the importance of arriving at supportable conclusions. While the statements made by commercial providers have no bearing on the science of WM training (Jaeggi, Buschkuehl, Jonides, & Shah, 2012), the converse is not true. Interesting findings are rapidly turned into advertisements. Moreover, providers of commercial products are not subject to peer review and can thus present results selectively, advertise through insinuation (e.g., Cogmed, 2011a, 2011b), or make unsubstantiated claims (e.g., Jungle Memory, 2011; Lumosity, 2011).

From this perspective, skeptics can be forgiven if their reaction seems overly conservative. WM training is an area of cognitive psychology in which the general public has clear interest. Thus the role of the skeptic is not simply to provide peer review, but also a mechanism through which the public can receive the other side of the story.

1. Near transfer, generally speaking

The most fundamental question regarding Cogmed is whether or not it actually leads to increases in WM capacity. We can bog the discussion down by examining the cases where simple span tasks do and do not provide adequate measurement of WM capacity (e.g., Jaeggi et al., 2012), or whether or not visuo-spatial simple spans have a special relationship to fluid intelligence or ADHD

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(e.g., Klingberg, 2012).[1] However, the true question is simple: does Cogmed increase WM capacity, or does it simply turn trainees into expert span task performers?

In order to demonstrate that Cogmed training increases WM capacity, it is critical to demonstrate near transfer to tasks that minimize potential practice effects. In particular, Cogmed training provides a month of practice on serial-order memory tasks, yet most studies test near transfer using serial-order memory tasks. How does one differentiate increased WM capacity from task-relevant practice?

In order to deal with this question, one must recognize that no one task or procedure has a monopoly as a test of WM capacity. Although a great deal of WM capacity research has been conducted using simple and complex span tasks, there are many other WM capacity tasks that tap this construct, but through different demands (e.g., visual arrays, keeping track). If Cogmed training increases WM capacity, then this change should be apparent across such tasks.

2. Does WM need to change?

On a related point, Jaeggi et al. (2012) question whether WM needs to be the mechanism of near transfer. In other words, could training affect some other process? Part of this discussion depends on what you mean by "WM". If we define WM through complex span tasks (e.g., Fig. 1a from the target article), then for n-back training, it is almost certainly the case that something other than WM is changed by training. It is becoming clear that individual differences in complex span and n-back performance are, at best, weakly related (Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Kane, Conway, Miura, & Colflesh, 2007). Thus it would be unrealistic to expect n-back training to transfer to complex span performance. Nor would we expect complex span research to be very useful in generating predictions regarding the effects of n-back training.

When discussing training techniques such as Cogmed (which employ span tasks, rather than the n-back) the issue of transfer is one of coherence. A principled approach to training assumes that a WM training task will only train processes that are critical to performing that task. At the very least, the proposed mechanism of transfer should be related to the method of training. Thus, while it remains possible that training will only affect certain subcomponents of WM (e.g., Gibson et al., 2012; Logie, 2012), transfer results cannot be accepted willy-nilly. Transfer should fit within predictions that are generated from the greater literature. Otherwise, mundane explanations like posttest motivation and type I error provide parsimonious accounts of training effects.

3. Control groups: an important concern with no clear answer

Our discussion regarding non-adaptive control groups elicited diverging opinions. Morrison and Chein (2012) summarized our concern much better than we did when they stated that non-adaptive control conditions are problematic, due to their "repetitive and unchallenging nature". Jaeggi et al. (2012), on the other hand, remain unconvinced. For instance, they note that a recent study by Bergman Nutley et al. (2011) found no evidence of differential motivation between adaptive and non-adaptive groups. Although this is a valid point, we note that the transfer results found by Bergman Nutley et al. (2011) were limited to near transfer to tasks that resembled the training tasks. Our concern with control group-related motivation regards broad transfer effects (e.g., Klingberg et al., 2005, 2002).

Regardless, we acknowledge that our position on non-adaptive control groups is speculative. And in reality, this may not have been the best forum to express these concerns. After all, our argument is that, regardless of control group, the evidence that Cogmed training has any effect on cognition is unconvincing.

However, for the greater literature, it remains important that researchers attempt to equate training and control groups in terms of experiences. As Orne (1962) pointed out, the testing environment is a social situation. The people in that situation probably do not know much about psychologists, but they do have a notion that psychologists are qualified to make judgments about human mental competency. The pretest–posttest situation only makes such judgments more obvious. Therefore, in order to equate posttest motivation, researchers should ensure that the expectation of change has been communicated to both training and control groups. While it is true that giving feedback and rewards to a participant in a non-adaptive condition equates the groups in terms of explicit feedback (Jaeggi et al., 2012), the non-adaptive control condition does not equate implicit communication that arises from the difficulty of the training task.

4. The synergy of qualitative and quantitative approaches

In parallel to our own work, Hulme & Melby-Lervåg (2012; Melby-Lervåg & Hulme, 2012) find little reason to conclude that Cogmed training produces reliable improvements to WM or any other mental processes. Our own avoidance of using meta-analytic techniques stems from concern that, while effects may be present, the source of those effects needs to be understood as well. Nonetheless, we have arrived at remarkably similar conclusions.

Hulme and Melby-Lervåg (2012) conclude that there is no effect of Cogmed training on Stroop performance. This comports well with our argument that improved performance on the Stroop tasks that are included in Cogmed studies cannot be explained by WM training (i.e., WM has little relation to Stroop performance when congruent trials are excluded). Far transfer to these Stroop tasks appears to be type I error.

Moving forward, Cogmed studies should not give up on testing controlled attention. Our argument is that this potential effect has yet to be adequately explored. Although no effect has been produced in the extant literature, this does not mean that no effect can be produced. However, controlled attention tasks need to be selected with greater care. We do not recommend the continued use of the Stroop task, as it requires a large number of trials and the interaction with WM capacity can be quite small (Kane & Engle, 2003). Instead, we suggest that going forward the antisaccade task (cf. Kane, Bleckley, Conway, & Engle, 2001) and flanker task (cf. Redick & Engle, 2006; Shipstead, Harrison, & Engle, 2012) are more appropriate, as the relationship of these tasks to WM capacity is not as dependent upon overall task congruency (see target article).

5. A note on Green et al. (2012)

Since the acceptance of the target article, an interesting new study by Green et al. (2012) has been published. These researchers trained ADHD-diagnosed children on Cogmed and measured transfer through a battery of five relevant behaviors. Critically, the behaviors were scored by trained raters, who were blind to condition assignment. Relative to a non-adaptive control group, Cogmed training was associated with reductions in the number of times two of five behaviors were performed.

Whether transfer to these two behaviors is meaningful (or the luck of the draw) is a question that can only be addressed through

[1] For those who are interested in our opinion on the first two issues, see Shipstead, Redick, et al. (2012, pp. 634–635).

replication. However, this study does provide a valid model for future research on the effect of Cogmed training on ADHD-related symptoms. In particular, the use of objective measures of transfer, coupled with blind raters is more appropriate than asking parents or teachers for their subjective evaluations of behavioral changes. Indeed, although Green et al. (2012) found differential transfer to their objective measures, parents of both the adaptive and the non-adaptive groups reported equivalent improvement of symptoms.

6. Is working memory capacity fixed? Is this a meaningful question?

As Gibson et al. (2012) point out, existing theories of WM capacity are designed to explain individual differences, rather than change after training. Stability of WM capacity is not directly addressed, but this does not imply that the system is fixed. The mutability of WM capacity is, and always has been, an open question. Therefore, our position should not be misinterpreted as favoring a fixed-system WM. Our concern regards the quality of evidence that has been collected in support of specific training techniques.

Thus we turn to Klingberg (2012) who states that our target article distracts from the proper scientific question of whether or not WM capacity can be increased. This question is off-base. Even if every known WM training program were shown to be completely ineffective, this says nothing about future interventions. Thus, Klingberg's question cannot be answered in the negative. The only question that can be properly addressed is whether or not a given technique is adequate to increase WM capacity. In that respect, our target article is both properly focused and meaningful to researchers and to people who are considering paying for Cogmed training.

References

Bergman Nutley, S., Söderqvist, S., Bryde, S., Thorell, L. B., Humphreys, K., & Klingberg, T. (2011). Gains in fluid intelligence after training non-verbal reasoning in 4-year old children: A controlled, randomized study. *Developmental Science*, *14*, 591–601. http://dx.doi.org/10.1111/j. 1467-7687.2010.01022.x

Cogmed. (2011a). *Constrained by the brain*. Retrieved December 9, 2011 from: http://www.cogmed.com/constrained-by-the-brain (Archived by WebCite at: http://www.webcitation.org/63nx7Mq48)

Cogmed. (2011b). *Key populations*. Retrieved December 9, 2011 from: http://www.cogmed.com/category/color-bar/research/key-populations (Archived by WebCite at: http://www.webcitation.org/63nxZQ3pz)

Cogmed. (2012). *Introduction*. Retrieved July 23, 2012 from: http://www.cogmed.com/introductory-overview (Archived by WebCite at: http://www.webcitation.org/69N67kjf2)

Gathercole, S. E., Dunning, D. L., & Holmes, J. (2012). Cogmed training: Let's be realistic about intervention research. *Journal of Applied Research in Memory and Cognition*, *1*, 201–203. http://dx.doi.org/10.1016/j.jarmac.2012.07.007

Gibson, B. S., Gondoli, D. M., Johnson, A. C., Steeger, C. M., & Morrissey, R. A. (2012). The future promise of Cogmed working memory training. *Journal of Applied Research in Memory and Cognition*, *1*, 214–216.

Green, C. T., Long, D. L., Green, D., Iosif, A-M., Dixon, J. F., Miller, R. M., et al. (2012). Will working memory training generalize to improve off-task behavior in children with attention-deficit/hyperactivity disorder? *Neurotherapeutics*, http://dx.doi.org/10.1007/s13311-012-0124-y

Hulme, C., & Melby-Lervåg, M. (2012). Current Evidence Does not Support the Claims made for CogMed Working Memory Training. *Journal of Applied Research in Memory and Cognition*, *1*, 197–200.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Shah, P. (2012). Cogmed and working memory training – Current challenges and the search for underlying mechanisms. *Journal of Applied Research in Memory and Cognition*, *1*, 211–213. http://dx.doi.org/10.1016/j.jarmac.2012.07.002

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the N-back task as a working memory measure. *Memory*, *18*, 392–412. http://dx.doi.org/10.1080/09658211003702171

Jaeggi, S. M., Buschkuehl, M., Jonidas, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences of the USA*, *105*, 6829–6833. http://dx.doi.org/10.1073/pnas.0801268105

Jungle Memory. (2011). *How it works*. Retrieved September 30, 2011 from: http://junglememory.com/pages/how_it_works (Archived by WebCite at http://www.webcitation.org/625J2M76O)

Kane, M. J., Bleckley, K. M., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General*, *130*, 169–183. http://dx.doi.org/10.1037/0096-3445.130.2.169

Kane, M. J., Conway, A. R. A., Miura, T. K., & Colflesh, G. J. (2007). Working memory, attention control, and the N-back task: A question of construct validity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 615–622. http://dx.doi.org/10.1037/0278-7393.33.3.615

Kane, M. J., & Engle, R. W. (2003). Working memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General*, *132*, 47–70. http://dx.doi.org/10.1037/0096-3445.132.1.47

Klingberg, T. (2012). Is working memory capacity fixed? *Journal of Applied Research in Memory and Cognition*, *1*, 194–196. http://dx.doi.org/10.1016/j.jarmac.2012.07.004

Klingberg, T., Fernell, E., Olesen, P., Johnson, M., Gustafsson, P., Dahlström, K., et al. (2005). Computerized training of working memory in children with ADHD – A randomized, controlled, trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*, 177–186. http://dx.doi.org/10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24*, 781–791. http://dx.doi.org/10.1076/jcen.24.6.781.8395

Logie, R. H. (2012). Cognitive training: Strategies and the multicomponent cognitive system. *Journal of Applied Research in Memory and Cognition*, *1*, 206–207. http://dx.doi.org/10.1016/j.jarmac.2012.07.006

Lumosity. (2011). *Enhance creativity*. Retrieved December 9, 2011 from: http://www.lumosity.com/how-we-help/enhance-creativity (Archived by WebCite at: http://www.webcitation.org/63nvD8NzR)

Lumostiy. (2012). *Overview*. Retrieved July 23, 2012 from: http://www.lumosity.com/about (Archived by WebCite at: http://www.webcitation.org/69N6BJOEK)

Melby-Lervåg, M., & Hulme, C. (2012). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, http://dx.doi.org/10.1037/a0028228

Moody, D. E. (2009). Can intelligence be increased by training on a task of working memory? *Intelligence*, *37*, 327–328. http://dx.doi.org/10.1016/j.intell.2009.04.005

Morrison, A. B., & Chein, J. M. (2012). The controversy over Cogmed. *Journal of Applied Research in Memory and Cognition*, *1*, 208–210. http://dx.doi.org/10.1016/j.jarmac.2012.07.005

Orne, M. T. (1962). On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. *American Psychologist*, *17*, 776–783. http://dx.doi.org/10.1037/h0043424

Redick, T. S., & Engle, R. W. (2006). Working memory capacity and Attention Network Test performance. *Applied Cognitive Psychology*, *20*, 713–721.

Shah, P., Buschkuehl, M., Jaeggi, S., & Jonides, J. (2012). Cognitive training for ADHD: The importance of individual differences. *Journal of Applied Research in Memory and Cognition*, *1*, 204–205. http://dx.doi.org/10.1016/j.jarmac.2012.07.001

Shipstead, Z., Harrison, T. L., & Engle, R. W. (2012). Working memory capacity and visual attention: Top-down and bottom-up guidance. *The Quarterly Journal of Experimental Psychology*, *65*, 401–407.

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, http://dx.doi.org/10.1037/a0027473

Sternberg, R. J. (2008). Increasing fluid intelligence is possible after all. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 6791–6792. http://dx.doi.org/10.1073/pnas.0803396105