“Is there anything I can do to train my memory?” The rationale and evidence behind cognitive training as an intervention to promote healthy ageing.

**Dr Anna Crabtree, Lecturer & Clinical Psychologist, Doctorate in Clinical Psychology Programme, Royal Holloway University of London, Egham, Surrey TW20 0EX**

 *Abstract*

As clinical psychologists working with older adults, we are all likely familiar with the above question, both in memory services and those who do not have a diagnosed cognitive problem. In the context of an ageing population, much research has been focused on the development of cognitive training as an intervention to promote healthy ageing.  Defining what it means to age healthily, however, can be problematic, particularly given the heterogeneity evidenced in studies of normative cognitive functioning in older people.  Furthermore, although different cognitive training methods appear to have face value, the evidence base for the effectiveness of cognitive training is mixed, and has, to date, provided conflicting results. This article discusses the findings of major research studies in this area, and possible future directions of research are considered.

Key words: Cognitive training, healthy ageing

**Introduction**

As older adult clinicians, we all will have been familiar with questions from our clients about what they can do to “keep well” and to optimise their cognitive functioning. Cognitive decline is considered to be pervasive in ageing (Salthouse, 2010); it is a specific predictor of negative quality of life (QoL) in older people (Depp & Jeste, 2006), and is also known to negatively impact on self-esteem (Rosi et al., 2019), ability to engage with medication regimens (Maki et al., 2014) and social contact (Evans et al., 2019). The issue is a growing one too; we know that the world’s population is ageing, particularly in Western, developed countries. According to the Office for National Statistics, in 50 years’ time there is estimated to be over eight million additional people aged 65 and over in the UK. It is therefore of crucial interest, on personal *and* economic levels, to identify ways in which cognitive functioning can be maintained in older age (Sánchez-Izquierdo & Fernández-Ballesteros, 2021). Cognitive training (CT) is something that appears to have high face value to clients and also perhaps conveys a sense of agency and control in doing all that one can to maintain a good quality of life. CT can be defined as “specifically designed training programmes that provide guided practice on a standard set of cognitive tasks.” (Kelly et al., 2014).

**Defining healthy ageing**

The development of effective CT first relies on a clear understanding of its aims, and about what constitutes “healthy ageing”. Rowe and Kahn’s (1997) definition has been highly influential, positing that healthy ageing is being free of disease, having good physical and cognitive functioning, and being engaged socially. However, McLaughlin et al. (2012) argue that these criteria are unattainable for the majority of older people, and ignore the important influence of social inequalities on healthy ageing. Furthermore, normative cognitive change in ageing is heterogenous across different cognitive domains. Hartshorne and Germine (2015) examined the normative sample data of the Wechsler Adult Intelligence Scale and Wechsler Memory Scale, and found that working memory and processing speed showed decline from an *earlier point* than domains relying on learned/accumulated knowledge (e.g. vocabulary), but Packiam-Alloway and Alloway (2013) showed that older adults performed at comparable levels to teenagers in working memory tests. Many studies seeking to characterise normative cognitive change in aging are cross sectional and therefore run the risk of ignoring important cohort effects. Longitudinal studies can tend to show a more sustained maintenance of cognitive functions until later life, but may be susceptible to sample bias and skewed results, as healthier older adults are more likely to remain in follow up stages (Salthouse, 2010).

**The rationale for CT - neuroplasticity**

The rationale for CT is grounded in the concept of the ageing brain retaining a capacity for neuroplasticity (Zokaei et al., 2017). There have been numerous attempts to demonstrate neuroplasticity in the ageing brain via neuroimaging. Deng et al. (2019) studied healthy older adults who participated in CT for three months and compared resting state fMRI data at baseline and at one year follow up. The researchers utilised the concept of functional connectivity, the extent to which activity between a pair of brain regions covaries or correlates over time, to try to demonstrate neuroplasticity in ageing brains. They determined both that older adults had less local functional connectivity at baseline, but also that post cognitive training, more functional connectivity was observed. The researchers suggested that this could be seen as evidence of neuroplasticity in older people. McNab et al. (2009) demonstrated that improvements seen in working memory following CT were mirrored by a correspondent change in the density of dopamine receptors, leading to restoration of synaptic connectivity and thus, the researchers posited, providing evidence of neuroplasticity in later adulthood. However, this study (like many others in this research area), has a small sample size, thus limiting generalisability. Furthermore, there remains much debate in the literature about how to demonstrate neuroplasticity; as Fabiani (2012) has argued, different neuroimaging methods can give very different results, and the particular characteristics of each method may complicate the inferences and comparisons that can be made.

**The rationale for CT – Theoretical compensatory models**

Another facet of the rationale for CT is grounded in compensatory models, such as the Scaffolding Theory of Aging and Cognition (STAC) (Park & Reuter-Lorenz, 2009).  STAC suggests that the ageing brain can “shore up” declining brain function through engaging additional neural systems (“scaffolding”), and this process occurs as a response to the accumulated normative “neural insults” of ageing.  A number of studies have demonstrated that these “neural insults” can be present in cognitively stable older adults; for example, amyloid plaques and neurofibrillary tangles, as is found in Alzheimer’s disease (Kim & Kim, 2014), or increased rates of neurotransmitter dysregulation (Karrer et al., 2017). Researchers have suggested therefore that this may provide evidence of the “scaffolding” in the STAC model.

Further support for the STAC has come from neuroimaging studies, demonstrating a shift from activation of posterior brain regions to greater involvement of frontal brain regions, known as the Posterior to Anterior Shift in Ageing (PASA; Davis et al., 2008). fMRI research has demonstrated that not only does this shift occur in response to different tasks (e.g. working memory, Reuter-Lorenz et al. 2000), but that increased activation of frontal brain regions is associated with *better* task performance on particular cognitive domains (e.g. memory, Davis et al. 2008).

Furthermore, the Compensation Related Utilization of Neural Circuits Hypothesis (CRUNCH; Reuter-Lorenz & Cappell, 2008), posits that older adults engage additional brain regions as compared to younger adults when performing the same cognitive task, to compensate for declining brain structures and functions. In addition, the CRUNCH suggests that whilst this engagement of additional brain regions can meet lower levels of task demand, increasing task complexity will result in a poorer performance and a correspondent decrease in activation.  Iordan et al. (2020) found that CT shifted the peak in activation for older adults such that they were able to manage higher task demands. This too has been interpreted as evidence of the brain in older age compensating for decline by recruiting other brain regions, and as a rationale for developing CT that aims to enhance this “compensation”.

However, results from neuroimaging are only correlational and associative (Vaidya et al., 2019). Furthermore, it has been difficult for research to prove the compensation account; many of the studies that have identified “scaffolding” activation are cross sectional and therefore cannot demonstrate that the additional recruitment occurs as an age-related *response* to decline.  Nyberg et al. (2010) compared cross sectional and longitudinal analyses of their sample of 60 participants, who underwent fMRI scanning to measure brain activation in response to a semantic categorisation task.  The participants were also followed up six years later.  The researchers found that a cross sectional “reading” of the data revealed an “overrecruitment” of the dorsal frontal cortex in the older group, whereas the longitudinal analyses revealed an age-related reduction of activation in the same region.

**The evidence base for the effectiveness of CT**

The rationale for developing CT to promote healthy ageing, therefore, is the subject of much debate and it is perhaps therefore not surprising to find that there is little consensus in the evidence base as to the effectiveness of CT (Katz et al., 2018). In a comprehensive systematic and meta-analysis, Kelly et al. (2014) examined 31 RCTs and compared results across three groups: a “no intervention” control group, an active control group (e.g. diverse mental stimulation activities, which ranged from playing the piano to helping children with their reading skills), and a treatment group. They found that when compared with those in the control group, participants undertaking CT showed better results on measures of memory and subjective functioning; when compared with the active controls, CT was found to improve performance on measures of executive functioning and working memory. However, although the parameters of the meta-analysis were well described and were adherent to PRISMA guidelines, the authors themselves acknowledged a high level of heterogeneity in the types of CT being studied; furthermore, effect sizes were calculated for measures within the same cognitive domain, but domains were assessed using a wide variety of neuropsychological assessments (for example, older and newer tests, or a very wide range of different tests being analysed under the single umbrella of “executive functioning”).  Furthermore, Kelly et al (2014) acknowledged that the outcomes of their meta-analysis were measured solely by performance on neuropsychological assessment, with scant data about how any gains might be maintained or be translated into everyday functioning.

In another meta-analysis, Lampit et al. (2014) looked at the effects of computerised CT in healthy older adults and found only a small overall effect size of CT as opposed to the control group.  They found that the effect size varied according to the targeted cognitive domain, with small to moderate effect sizes found for visual, verbal and working memory, but no significant effects found for executive functioning and attention. Lampit et al. (2014), through moderator analyses, identified that the design of the CT was significant, with home based individual training being ineffective compared to group-based training. The authors also acknowledged that the parameters of their meta-analysis did not allow them to comment on the sustainability and durability of any gains made.

In an effort to examine the longer-term effects of CT, Rebok et al. (2014) followed up participants over a period of ten years, and in addition to examining the training’s effects on neuropsychological assessment performance, also included independent performance-based assessments of everyday functioning.  They showed that each CT intervention produced significant improvement in the targeted cognitive domains; this improvement was seen immediately after the intervention, and also remained for at least 5 years for memory training and for up to ten years for reasoning and speed of processing training. The authors reported that a “significant” percentage of participants in the CT groups continued to report less difficulty in activities of daily living (ADLs) than those participants in the control group; however, some 50 per cent of control group participants also reported no difficulties in ADLs. When ADL performance was measured utilising an independent assessment, there were only weak to absent effects of CT on ADL performance. The authors acknowledged the difficulty in quantifying and operationalising ADL performance, highlighting the poor ecological validity of the task utilised in their study (Rebok et al., 2014).

In a more recent and comprehensive systematic review, Gates et al. (2020) examined the effects of computerised CT on the cognitive function of healthy adults aged 65 and over. They found that generally the quality of the available evidence was poor, in that often studies offered insufficient detail about the exact nature and design of their interventions (which appears particularly important given the findings of Rebok et al., 2014), or often had small sample sizes, a lack of an active control comparison group, and limited assessment of “far” transfer (i.e. assessment of benefit outside of the specifically trained cognitive domains). The review had relatively stringent exclusion criteria, with the researchers examining the results of eight RCTs (from an initial count of over 300 studies). They found that CT as compared with active controls may result in slight improvements in global cognitive functioning, immediately after the completion of training, but not at a year follow up; they also found that CT had little or no impact on episodic or working memory, and were unable to draw any conclusions regarding the effects of cognitive training on executive functioning or speed of processing, due to the quality of evidence being very low.

**Conclusions and future directions**

In summary, the evidence for the effectiveness of CT is mixed, and there is a lack of consensus in the literature, alongside debate around the mechanisms underpinning the rationale for cognitive training. In terms of future directions for research, there is also little consensus.  Katz et al. (2018) highlight the importance of specifying a coherent theoretical framework to describe the mechanisms by which CT may work, whilst Gates et al. (2020) specify clear guidance for the improvement of research into CT, including ensuring that studies address the issue of skill transfer and that any training gains generalise to other tasks. Gobet and Sala (2022), however, argue that findings should only be limited to “near transfer” as the chances of finding a reliable measure of “far” transfer is low.

Nevertheless, it remains a compelling topic for researchers and older people alike, and undoubtedly the question of “is there anything I can do to train my memory” will continue to be asked. We need to offer an honest and ethical opinion to our clients about the lofty promises made by some cognitive training programmes, and perhaps speak in terms of “supporting” cognition rather than “training” cognition. As psychologists, we also know the value of formulation, and understanding the significance of that question for our particular client. For some of our clients, fear of dementia might be the main issue of concern. For others, they will be asking the question because they discern that things *are* starting to change with their cognition, and here returning to our neuropsychological formulation would be of the utmost value in responding to the question. It is interesting that many of the “active control” interventions in the evidence base are actually comparable to cognitive training in their effectiveness, and our clients can benefit from taking perhaps a wider viewpoint of what might be beneficial to their cognition.  For example, Bherer (2015) found that physical exercise improved not only physical capacity and overall quality of life, but also performance in some cognitive domains.  Ageing can be understood as a “whole body” phenomenon and researchers, clinicians and clients alike are likely to benefit from taking this more holistic viewpoint.

References

Bherer, L.  (2015). Cognitive plasticity in older adults: effects of cognitive training and physical exercise. *Annals of the New York Academy of Sciences,* 1337, 1-6.

Davis, S. W., Dennis, N. A., Daselaar, S. M., Fleck, M. S. & Cabeza R. (2008). Qué PASA? The posterior–anterior shift in aging. *Cerebral Cortex,* 18, *1201–1209.*

Deng, L., Cheng, Y., Wei, C., Hong, F., Lijuan, Z., Wenyuan, J., Shanbao, W., Junfeng, T. & Li, S. (2019) The effect of cognitive training on the brain's local connectivity organization in healthy older adults.  *Scientific reports,* 9.

Depp, C.A. & Jeste, D.V. (2006). Definitions and predictors of successful aging: a comprehensive review of larger quantitative studies. *The American Journal of Geriatric Psychiatry*, 14 (1), *6-20.*

Evans, I.E.M., Martyr, A., Collins, R., Brayne, C. & Clare, L. (2019). Social isolation and cognitive function in later life: A systematic review and meta-analysis. *Journal of Alzheimer’s Disease,* 70 (Suppl. 1), *S119-S144.*

Fabiani, M. (2012). It was the best of times, it was the worst of times: A psychophysiologist's view of cognitive aging. *Psychophysiology,* 49 (3), *283-304.*

Gates, N.J., Rutjes, A.W.S., Di Nisio, M., Karim, S., Chong, L.Y., March, E., Martínez, G. & Vernooij, R.W.M. (2020). Computerised cognitive training for 12 or more weeks for maintaining cognitive function in cognitively healthy people in late life*. Cochrane Database of Systematic Reviews*, Issue 2.

Gobet, F. & Sala, G. (2022). Cognitive training: a field in search of a phenomenon. *Perspectives on Psychological Science.*

Hartshorne, J.K. & Germine, L.T. (2015). When does cognitive functioning peak? The asynchronous rise and fall of different cognitive abilities across the life span. *Psychological Science*, 26 (4), *433-443.*

Iordan, A.D., Cooke, K.A., Moore, K.D., Katz, B., Buschkuel, M., Jaeggi, S.M., Polk, T.A., Peltier, S.J., Jonides, J. & Reuter-Lorenz, P.A. (2020). Neural correlates of working memory training: Evidence for plasticity in older adults. *NeuroImage,* 217, *116887.*

Karrer, T.M., Josef, A.K., Mata, R., Morris, E.D. & Samanez-Larkin, G. (2017). Reduced dopamine receptors and transporters but not synthesis capacity in normal aging adults: a meta-analysis.  *Neurobiology of Aging,*57, *36-46.*

Katz, B., Shah, P. & Meyer, D. (2018). How to play 20 questions with nature and lose: Reflections on 100 years of brain-training research. *Proceedings of the National Academy of Sciences of the United States of America,* 115, 9897-9904.

Kelly, M.E., Loughrey, D., Lawlor, B.A., Robertson, I.H., Walsh, C. & Brennan, S. (2014). The impact of cognitive training and mental stimulation on cognitive and everyday functioning of healthy older adults: A systematic review and meta-analysis. *Ageing Research Reviews,* 15, *28–43.*

Kim, E.Y. & Kim, K.W. (2014). A theoretical framework for cognitive and non-cognitive interventions for older adults: stimulation versus compensation. *Aging and Mental Health,* 18, *304-315.*

Lampit, A., Hallock, H. & Valenzuela, M. (2014). Computerized cognitive training in cognitively healthy older adults: A systematic review and meta-analysis of effect modifiers. *PLOS medicine,* 11.

Maki, Y., Yamaguchi, T., Yamagami, T., Murai, T., Hachisuka, K., Miyamae, F., Ito, K., Awata, S. Ura, C., Takahashi, R. and Yamaguchi, H. (2014). The impact of subjective memory complaints on quality of life in community-dwelling older adults. *Psychogeriatrics,* 14(3), 175-181.

McLaughlin, S.J., Jette, A.M. & Connell, C.M. (2012). An examination of healthy aging across a conceptual continuum: Prevalence estimates, demographic patterns and validity. *The Journals of Gerontology*, 67 (7), *783–789.*

McNab, F., Varronel, A., Farde, A., Jucaite, P., Bystritsky, H. Forssberg, T. & Klingberg, O. (2009). Changes in cortical dopamine D1 receptor binding associated with cognitive training. *Neuroimage,* 47, *Supplement 1:S77.*

Nyberg, L., Salami, A., Andersson, M., Eriksson, J., Kalpouzos, G., Kauppi, K., Lind, J., Pudas, S., Persson, J., & Nilsson, L.-G. (2010). Longitudinal evidence for diminished frontal cortex function in aging. *PNAS Proceedings of the National Academy of Sciences of the United States of America,* 107(52), 22682–22686.

Packiam-Alloway, T. & Alloway, R.G. (2013). Working memory across the lifespan: A cross-sectional approach. *Journal of Cognitive Psychology,* 25, *84-93.*

Park, D.C. & Reuter-Lorenz, P. (2009). The adaptive brain: aging and neurocognitive scaffolding. *Annual review of psychology,* 60, *173-96.*

Persson, L-G. & Nilsson, E. (2010). Longitudinal evidence for diminished frontal cortex function in aging. *Proceedings of the National Academy of Sciences of the United States of America*, 107, 22682-22686.

Rebok, G.W., Ball, K., Guey, L.T., Jones, R.N., Kim, H-Y., King, J.W., Marsiske, M., Morris, J.N., Tennstedt, S.L., Unverzagt, F.W. & Willis, S.L. (2014) Ten-year effects of the Advanced Cognitive Training for Independent and Vital Elderly cognitive training trial on cognition and everyday functioning in older adults. *Journal of the American Geriatric Society,* 62, *16-24.*

Reuter-Lorenz, P.A., Jonides, J., Smith, E., Hartley, A., Miller, A., Marshuetz, C. & Koeppe, R. (2000) Age differences in the frontal lateralization of verbal and spatial working memory revealed by PET. *Journal of Cognitive Neuroscience*. 12, *174–187.*

Reuter-Lorenz, P.A. & Cappell, K.A. (2008). Neurocognitive aging and the compensation hypothesis. *Current directives in Psychological Science,* 17, *177-182.*

Rosi, A., Cavallini, E. Gamboz, N., Vecchi, T., Tijmen Van Vugt, F., & Russo, R. (2019). The impact of failures and successes on affect and self-esteem in young and older adults. *Frontiers in Psychology*, 10.

Roski, C., Caspers, S., Lux, S., Hoffstaedter, F., Bergs, R., Amunts, K. & Eickhoff, S.B. (2014). Activation shift in elderly subjects across functional systems: an fMRI study. *Brain structure and function,* 219, *707-718.*

Rowe, J.W. & Kahn, R.L. Successful aging. *Gerontologist*, 37(4), *433-440.*

Sánchez-Izquierdo, M. & Fernández-Ballesteros, R. (2021). Cognition in healthy aging. *International journal of environmental research and public health,* 18(3), *962.*

Salthouse, T. (2010). *Major issues in cognitive aging.*Oxford; New York: Oxford University Press.

Vaidya, A.R., Pujara, M., Petrides, M., Murray, E.A. & Fellows, L.K. (2019). Lesion studies in contemporary neuroscience. *Trends in Cognitive Sciences*, 23, *655-673*.

Zokaei, N., MacKellar, C., Čepukaitytė, G., Patai, E.Z. & Nobre, A.C. (2017). Cognitive training in the elderly: bottlenecks and new avenues. *Journal of Cognitive Neuroscience,* 29, *1473-1482.*