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EDITORIAL

Brain training: hype or hope?

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ABSTRACT

Brain training is topical yet controversial. Effects are often limited to trained tasks; and near and far effects to untrained tasks or everyday life measures are often small or lacking altogether. More recent approaches use evidence from cognitive neuroscience on neuroplasticity, resulting in novel cognitive interventions. This special issue encompasses the state of the art of these interventions. Two systematic reviews and nine experimental studies in a variety of patient groups or healthy participants are included, the results of which mostly confirm earlier findings: effects on trained tasks are consistently reported, but generalisation in terms of functional outcome is limited and little evidence is found of long-term effects. In general, the studies show promising, yet challenging training effects on cognition in healthy persons and patients with cognitive deficits. As such, they may be seen as positive “proof of principle” studies, highlighting that cognitive enhancement is possible. The field of brain training, however, is in urgent need of larger and more thoroughly designed studies. These future studies should also include outcome measures on daily functioning, self-efficacy and quality of life in addition to neuropsychological tests or tasks related to cognitive functioning.

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KEYWORDS Cognitive rehabilitation; working-memory training; outcome; brain injury; mild cognitive impairment

Brain training is “hot”. Both researchers and commercial parties have been developing computerised programmes and tools with the aim of ameliorating cognitive deficits through extensive practice and training. Such training may induce changes in the brain through neuroplasticity. Neuroplasticity is often defined as the neural functional and structural changes in response to experience and environmental stimulation (Shaw, Lanius, & Vandendoel, 1994). Cognitive domains that are typically targeted

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include (working) memory, attention, executive functions, reasoning skills, and speed of information processing. Brain training programmes are being used in school settings, in populations with developmental disorders, such as attention deficit hyperactivity disorder (ADHD) or learning disability (e.g., Melby-Lervåg & Hulme, 2013), in neuropsychiatric disorders, for instance schizophrenia (Lawlor-Savage & Goghari, 2014) , in patients with cerebral lesions after stroke or head injury (e.g., Spreij, Visser-Meily, Van Heugten, & Nijboer, 2014), and in older adults with subjective cognitive complaints or with mild or more severe cognitive impairments due to neurodegenerative diseases, such as mild cognitive impairments (MCI) or Alzheimer's disease (Reijnders, Van Heugten, & van Boxtel, 2013).

Brain training is also controversial. That is, users in this field "often rely on claims that are scientifically unsubstantiated" (Rabipour & Raz, 2012, p. 173). One commercial provider of brain games recently settled for $2 million with the US Federal Trade Comission for deceptive advertising, using unfounded claims (Federal Trade Commission v. Lumos Labs, Inc., 2016). Also, the scientific integrity of studies may be affected due to conflicts of interest, with training programme developers being eager to show that "their" tools work best and commercial providers funding research in this field, which may bias the (non-)publication of unsupportive results (Rabipour & Raz, 2012).

Brain training, however, is not new. As early as 1979, Abikoff reviewed the state of evidence with respect to cognitive training in children. He concluded that studies so far could often be criticised for methodological shortcomings, such as the lack of control groups or control interventions. Abikoff also made an important statement that is still valid today: "For a therapeutic intervention to be considered clinically meaningful, it is necessary that the skills and behaviours developed in treatment transfer to nontreatment tasks and settings that are sustained following treatment termination" (Abikoff, 1979, p. 74). In the 1970s and 1980s, brain training – at that time predominantly referred to as cognitive training – was used extensively in rehabilitation settings. However, the results of years of research on the effectiveness of cognitive training programmes were disappointing. That is, although patients who engaged in such training programmes improved on the trained tasks (referred to as criterion effects), the intervention effects neither generalised to untrained tasks in the same cognitive domain (near-transfer) nor to everyday life (far-transfer) (Wilson, 1997) Consequently, from the 1990s onwards, neuropsychological rehabilitation somewhat moved away from this strict impairment-focused, restorative approach of cognitive training, and started to focus on the training of compensatory strategy use, with more success (Wilson, 2002).

In the last two decades, new insights into neural plasticity have resulted in a revival of studies using cognitive training. Based on these insights, it has been hypothesised that both structural and functional brain changes may occur after intensive, repeated training (Park & Bischof, 2013). One of the first to show this was the group of Klingberg and others at the Karolinska Institute in Stockholm, Sweden. In a series of studies, they demonstrated that intensive and adaptive working memory training resulted in an increase in working memory capacity, transfer to untrained tasks, and an increased fronto-parietal activation level shown using functional magnetic resonance imaging (fMRI) that correlated with the increase in working memory capacity (see Klingberg, 2010, for an overview).

One crucial difference between the current brain training approaches and earlier cognitive training attempts lies in the adaptive nature of the training procedure: the difficulty level of the task can be adjusted on a trial-by-trial basis driven by the actual performance of the participant, thus continuously challenging the individual's performance and maximising cognitive effort. In addition, recent approaches are also more intensive and extensive than in the original cognitive training studies from the 1970s, nowadays often consisting of daily training sessions that can last up to 45 minutes, sustained over several weeks. Furthermore, recent advances in information and communication technology enable participants to perform brain training programmes on laptops, tablets or personal computers in their home environments, making them more user-friendly. Although studies on the effects of brain training were initially promising, later reviews have been more critical towards the effectiveness and efficacy of adaptive cognitive training, also highlighting methodological shortcomings (Makin, 2016).

Given the new insights into neuroplasticity and the developments in training programmes, new evidence is evolving. This could be interesting for the patient populations we encounter as neuropsychologists, both in clinical practice and in research. The purpose of this special issue was therefore to focus on the effectiveness of brain training in patients with cognitive impairments within a neurorehabilitation context. The list of topics covered includes (computerised) cognitive training, virtual reality training and serious gaming in clinical populations with cognitive impairments, such as acquired brain injury, MCI and dementia, schizophrenia, learning disabilities, and ADHD. In addition to the use of neuropsychological tests to assess training outcome, we were especially interested in studies on the efficacy of brain training using outcome measurements in the domains activities, participation, and quality of life.

In total we have included two systematic reviews and nine experimental studies in this special issue. Peijnenborgh, Hurks, Aldenkamp, Vles, and Hendriksen (2016) present a systematic meta-analytic review on working memory training programmes for children and adolescents with learning disabilities. They showed reliable short-term improvements in verbal and non-verbal working memory in 13 studies with a total sample size of over 300. Ninety-six studies were included in the systematic review of Sigmundsdottir, Longley, and Tate (2016) on computerised cognitive training in patients with acquired brain injury. Only 15% of these studies met the Level 1 criterion for high quality studies (randomised controlled trials). Some evidence for efficacy was found on speed and memory but whether this also improves functioning at the level of activities or participation remains unclear. Two studies by Sandberg and colleagues (Sandberg, Rönnlund, Derwinger-Hallberg, & Stigsdotter Neely, 2016; Sandberg, & Stigsdotter Neely, 2016) focused on cognitive training effects in healthy older adults. In their first study they investigated the predictors of training effects of a number-consonant mnemonic showing that different cognitive factors predict gain and maintenance of number recall, underlying individual differences in memory plasticity. In a second study, in which they also included young adults, they showed positive short-term effects of an executive process training on evaluation tasks that were most similar to the training tasks. These effects, however, disappeared at 18-month follow-up. Two studies focused on older adults with MCI. Vermeij, Claassen, Dautzenberg, and Kessels (2016) examined the effect of working memory training in healthy older adults and people with MCI. Both groups show training gains on trained and untrained WM tasks, but on an individual level only a minority of the participants showed a reliable training gain. Also, WM training effects did not generalise to other cognitive domains or to subjective cognitive complaints. Gooding et al. (2016) compared three different computerised cognitive training programmes in an MCI population. Their results suggest that cognitive training might be more beneficial when it is incorporated within a general cognitive enhancement approach. Four studies examined patients with mainly acquired brain injury. Claessen, van der Ham, Jagersma, and Visser-Meily (2016) showed promising results from a virtual reality navigation training in six stroke patients. Five of them successfully learned to apply an alternative navigation strategy, suggesting that navigation strategies may be less static than mostly assumed. Wentink et al. (2016) examined the effects of an 8-week computerised training in stroke patients in the chronic phase. Small training effects were found on neuropsychological tests that were closely related to the training tasks. No effects, however, were found on subjective cognitive functioning, self-efficacy or quality of life measures. In a single-case series of three traumatic brain injury patients, Dynowski, Ponsford, and Willmott (2016) investigated the effects of a computerised attention training followed by attention strategy training. Their mixed results underline the importance of an individualised attention training approach. Lindeløv et al. (2016) investigated the effects of an *N*-back task training in healthy people and patients with brain injury. Healthy people showed larger training effects on the trained task compared to brain-injured patients. Neither group improved on non-trained tasks. The authors conclude that both groups can learn specific cognitive skills, but brain-injury patients show far less improvement suggesting a specific impairment in the acquisition of these skills. Finally, Jonkman, Hurks, and Schleepen (2016) present a study in children with ADHD in which they showed placebo-controlled training effects of a metacognitive memory training and an attentional-perceptual-motor training on episodic memory. Interestingly, these effects were also reflected in memory-related evoked response potentials (ERPs), more specificly, the left parietal P600.

In all, taking together the findings of the papers in this special issue, and considering recent developments, some concluding remarks can be made and future directions can be formulated. One of the first issues that comes to mind is whether the method of brain training is nothing more than "old wine in new bottles". Why would new knowledge on neuroplasticity in humans lead to other training effects than those found before the 1990s; the brain itself has after all not changed? One could argue, however, that the more recent training methods have better potential due to their adaptive nature and because of advances in information and communication technology, both of which have also been applied in the studies in this special issue.

Summarising the results of these papers, divergent conclusions can be made: Peijnenborgh et al. (2016) concluded that the efficacy of working-memory training for the specific target group of children with learning disabilities is still inconclusive due to the small number of studies, Wentink et al. (2016) conclude that more research is needed in stroke patients, while Vermeij et al. (2016) suggest that more studies should be performed in MCI. The conclusion that the field of brain training needs larger and more thoroughly designed studies was also drawn in a recent paper on memory games (Makin, 2016), which stated that "even the meta-analyses do not agree" (p. S10). In all, most research so far should at best be considered as proof-of-principle studies, highlighting that cognitive enhancement is possible, but also addressing serious limitations.

However, the possibility that cognitive enhancement is indeed plausible is challenging. Furthermore, the small steps forward that are made inspire us clinicians and researchers to look further. In addition to the evident next step of more high-quality studies, other aspects should be considered as well. One recommendation would be the selection of outcome measures. If the optimal outcome of rehabilitation is better participation in society, future studies on brain training should also include functional outcome measures, and not only neuropsychological tests or tasks related to cognitive functioning. In addition, other outcomes could be considered as well. It has been shown, for example, that patient satisfaction and subjective well-being were equally improved after a multifaceted treatment programme for executive dysfunction and a computerised brain training programme (Spikman, Boelen, Lamberts, Brouwer, & Fasotti, 2010). Experiencing progression in task performance during game play could be the effective mechanism leading to higher levels of motivation and therefore well-being. This mechanism has also been suggested in a study by Akerlund, Esbjornsson, Sunnerhagen, and Bjorkdahl (2013) in which mood improvements were shown after computer training for patients with acquired brain injury who also had depressive complaints. Finally, from clinical practice it has been suggested that brain training could also be applied to increase awareness of deficits in patients: experiencing improvements in task-related performance in the absence of functional benefits may convince a patient to turn to the use of strategies and external aids instead of striving for restoration of function. Experiencing positive training effects may also increase the level of self-efficacy.

On a final note, these forms of rehabilitation are primarily focused on alleviating cognitive impairment. Neuropsychological rehabilitation is aimed at a broader spectrum of human functioning, also taking into account emotional, behavioural and social functioning with the ultimate goal to optimise the participation and quality of life of both patients and caregivers. Stand-alone brain training clearly does not have the potential to target all relevant rehabilitation goals. Although promising, these methods of rehabilitation should therefore always be offered only in combination with comprehensive neuropsychological rehabilitation programmes.

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