Review

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Cognitive Training and Rehabilitation in Aging

Yaşlanmada Bilişsel Egzersiz ve Rehabilitasyon

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ABSTRACT

Aging is a life stage in which progressive deterioration occurs in biological, psychological, and socio-cultural processes. Therefore, along with all the other changes observed in aging, cognitive change is inevitable. In older adulthood, the speed of processing information, the ability to remember contextual information such as where and when events occur, and executive function performance are impaired. Moreover, this change in cognitive processes causes the deterioration of functionality in daily life. Although it is well known that physical activity, nutrition, and social support play a key role in preventing the adverse effects of aging, the impact of cognitive training and rehabilitation have been relatively less studied. This review aims to examine cognitive training and rehabilitation practices applied to different cognitive processes (episodic memory, working memory, executive functions, attention and processing speed) to help compensate for or regain cognitive functions that are impaired in older adults. In this context, the effectiveness of the practices, the transfer of gains to different cognitive areas, and whether they are preserved for long periods were examined. The contribution of conscious and systematic practices, such as cognitive training and rehabilitation, in reducing the adverse effects of aging has been discussed.
Keywords: Aging, cognitive aging, cognitive training, cognitive rehabilitation

ÖZ

Yaşlılık; biyolojik, psikolojik ve sosyo-kültürel süreçlerde ortaya çıkan ve giderek artan bozulmaların görüldüğü bir yaşam evresidir. Bu nedenle yaşlanmada gözlenen diğer tüm değişimlerle birlikte bilişsel değişim de kaçınılmazdır. İleri yetişkinlikte bilgileri işleme hızı, olayların nerede ve ne zaman gerçekleştiği gibi bağlamsal bilgileri hatırlama becerisi ve yönetici işlev performansı zayıflamaktadır. Üstelik bilişsel süreçlerdeki bu değişim, gündelik yaşamdaki işlevselliğin bozulmasına neden olmaktadır. Yaşlanmanın olumsuz etkilerinden korunmada fiziksel aktivite, beslenme ve sosyal desteğin anahtar rol oynadığı iyi bilinmekle birlikte bilişsel egzersiz ve rehabilitasyonların etkisi görece daha az araştırılmıştır. Bu derlemenin amacı, ileri yetişkinlerde bozulan bilişsel işlevlerin telafi edilmesine ya da belirli ölçülerde yeniden kazanılmasına yardımcı olmak için farklı bilişsel süreçlere (epizodik bellek, çalışma belleği, yönetici işlevler, dikkat, işleme hızı) yönelik uygulanan bilişsel egzersiz ve rehabilitasyon uygulamalarını incelemektir. Bu kapsamda uygulamaların etkinliği, kazanımların farklı bilişsel alanlara aktarımı ve uzun süreler korunup korunmadığı incelenmiş; bilişsel egzersiz ve rehabilitasyon gibi bilinçli ve sistematik uygulamaların yaşlanmanın olumsuz etkilerini azaltmadaki katkısı tartışılmıştır.
Anahtar sözcükler: Yaşlanma, bilişsel yaşlanma, bilişsel egzersiz, bilişsel rehabilitasyon

Introduction

The life expectancy of people has increased significantly due to positive developments in public health (United Nations 2022). The period of advanced adulthood constitutes a longer part of human life compared to the past. For this reason, the common goal of research on aging has been to ensure that older adults can remain as healthy, productive, and happy as possible by reducing or preventing the negative consequences of the process (Cosco et al. 2014). It has long been known that physical activity, nutrition, and social support play a key role in healthy aging (Forbes et al. 2008, Krivanek et al. 2021); however, although each of them is an important factor in overcoming the difficulties of the aging process, they are not sufficient alone. In recent years, cognitive training and rehabilitation interventions have become increasingly popular as low-cost (Knapp et al. 2006) and low-risk (Spector et al. 2003) solutions that may not only help to regain or compensate for impaired cognitive functions resulting from conditions affecting the brain (such as stroke, head injuries, epilepsy, and neurodegenerative diseases) but also be effective in reducing the negative effects of aging.

Aging is defined as a gradually increasing deterioration observed in multiple systems (biological, psychological, and socio-cultural) of individuals in the last stages of life (Whitbourne et al. 2015, Cavanaugh and Banchard-Fields 2019). The decline in cognitive processes starts much earlier than the period accepted as old age (mid-20s); however, this change reaches a level that can negatively affect the quality of life from the mid-60s (Park

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and Reuter-Lorenz 2009, Salthouse 2010). On the other hand, the findings of studies examining the effect of leading a cognitively active life on human life are promising. In a longitudinal study with a forty-four-year follow-up period, it was shown that there was a negative relationship between the cognitive activity level of individuals in middle age and the risk of dementia; the risk of dementia due to different causes decreased by 34%, and the risk of Alzheimer-type dementia (ATD) decreased by 46% in individuals with high cognitive activity level (Najar et al. 2019). In addition, a meta-analysis of 19 studies (Yates et al. 2016) showed that participation in cognitive leisure activities (such as puzzles, card games, computer use, and crafts) in older adulthood reduced the risk of cognitive impairment by 31% and the risk of dementia by 42%. Cognitive leisure time activities help to maintain memory, processing speed, and executive function performance at a healthy level (Yates et al. 2016). The results of these studies, which show the benefits of staying cognitively active without conscious effort, indicate that conscious and systematic practices, such as cognitive training and rehabilitation, may have important contributions in reducing the negative effects of aging. In this context, the main purpose of the present review is to examine whether it is possible to prevent the negative effects of aging on cognitive functions. In order to achieve this aim, the effectiveness of cognitive training and rehabilitation applied to regain or compensate different cognitive functions (episodic memory, working memory, executive functions, attention, processing speed) in older adulthood, the transfer of gains to other cognitive areas and whether they are maintained for long periods of time are discussed.

Effect of Aging on Cognitive Functions

Cognitive change is observed in all older adults as an inevitable consequence of aging. One of the most prevalent symptoms associated with cognitive aging is the occurrence of complaints related to episodic memory (Ponds et al. 1997, Iliffe and Pealing 2010). Within the cognitive system, encoding, storage, and retrieval of memories based on place and time are realized through episodic memory (Anderson 2020). In addition to subjective complaints, the results obtained from neuropsychological tests also show that episodic memory impairment is an important cognitive dysfunction observed in older adults (Small et al. 2003, Small et al. 2012). Episodic memory losses are closely related to age-related structural and functional changes in brain regions such as the prefrontal cortex, medial temporal lobe, parietal lobe, cingulate gyrus, and cerebellum (Tromp et al. 2015). Additionally, it is known that working memory functions also significantly decline with age (Park et al. 2002, Borella et al. 2008, Hale et al. 2011). The cognitive system of working memory permits the storage and active processing of a specific amount of information (Baddeley et al. 2020). Working memory deficits in older adults; negatively affect other complex cognitive processes such as long-term memory, language, problem-solving, and reasoning (Conway et al. 2002).

The general slowing in processing speed starts in the 30s and lasts throughout life (Salthouse et al. 1995, McDowd and Shaw 2000, Salthouse 2010). According to Salthouse (1996), this general slowing in processing speed explains most of the cognitive changes observed in older adults. This is because higher-level cognitive functions corresponding to more complex processes are negatively affected by the slowing in basic cognitive processes (Salthouse 1995, Salthouse 1996, Salthouse 2010). Nevertheless, to what extent the general slowing in processing speed can explain all the cognitive changes observed in older adults or what other factors contribute to this process remains a matter of debate (see Park et al. 1996, Park and Reuter-Lorenz 2009).

Executive functions are an area of cognitive functioning that enables clear identification, realization, modification, and evaluation of goals using cognitive components such as working memory and attention capacity (Burgess and Simons 2005). As suggested in the Frontal Aging Hypothesis (Dempster 1992), executive functions, which are closely linked to other cognitive processes, are closely related to frontal brain areas that are particularly sensitive to aging (Salthouse et al. 2003). Indeed, Fjell et al. (2017) supported with a longitudinal study that executive function performance weakens due to structural and functional changes observed in the frontal lobes during aging. Cognitive explanations for the loss of executive function due to aging focus on decreased inhibitory control in older adults. When working memory capacities are analyzed, it is thought that the lack of control in inhibition functions is due to a general attention disorder in response suppression, task switching, and response competition (Hasher et al. 2007).

As a result, although there are individual differences, all older adults are affected by the cognitive changes in the aging process. Moreover, this process, which starts with subjective memory complaints, may evolve into Mild Cognitive Impairment (MCI) and then dementia. MCI is a transitional process between healthy aging and dementing processes and represents a clinical process often thought to evolve into dementia (Smith and Butts 2018). When individuals with MCI are evaluated with neuropsychological tests, it is seen that their test scores are 1-2 standard deviations below the norm values (Saykin and Rabin 2014). Dementia is a neurodegenerative disease that mostly starts with structural impairment in hippocampal functions, leading to progressive losses (Smith and Butts 2018). Although pharmacotherapy has an important place in the treatment of MCI and dementia, the importance of cognitive exercise and rehabilitation practices -as in healthy aging- has been increasing in recent years.

Cognitive Training and Rehabilitation

Cognitive training paradigms consist of standardized exercise sequences that are applied repeatedly and standardized as much as possible to regain a certain cognitive function by focusing directly on the function in which the deficit is observed (Clare and Woods 2004, Rabipour and Raz 2012). It is assumed that cognitive exercises based on continuity have the potential to improve performance in the relevant functional area and that this effect can be generalized beyond the gains achieved (Bahar-Fuchs et al. 2013). On the other hand, cognitive rehabilitation is based on the preservation of existing functions and compensation of deficiency with intact existing functions rather than direct improvements in cognitive skills (Clare et al. 2003, Wilson 2002, Bahar-Fuchs et al. 2013). In this context, cognitive rehabilitation paradigms aim to maximize the individual's participation in daily activities in biological, psychological, and psychosocial terms. Such an approach requires an interdisciplinary team in which the patient, caregiver, and neuropsychologist contribute to the treatment process and other specialists (behavioral neurologist, clinical psychologist, psychiatrist, nurse, etc.) cooperate (Wilson 2002). In cognitive rehabilitation practices, behavioral disorders that reflect an inadequacy in cognitive functions in daily life are determined, and exercises covering multiple cognitive function areas are planned individually to support impaired cognitive function areas (Wilson 2002, Clare et al. 2003).

Cognitive training and rehabilitation paradigms include two main theoretical approaches: restorative and compensatory (Ylvisaker et al. 2002, Sitzer et al. 2006, Sharma et al. 2016). Restorative approaches, also defined as traditional, are based on repetitive exercises to restore impaired functions related to specific cognitive domains. On the other hand, context-based compensatory approaches involve learning different strategies that can be used instead of neurocognitive functions that negatively affect the individual's daily life and are no longer functional. Thus, it is aimed to compensate for inadequacies and support everyday functionality. In this context, it is possible to say that cognitive training is mainly based on applications based on the restorative approach, while cognitive rehabilitation consists of applications that include both restorative and compensatory approaches together (see Buschert et al. 2010).

Compensatory strategies used in cognitive rehabilitation include cognitive compensation, enhanced learning, external aids, and environmental adaptation (Wilson et al. 2009). Cognitive compensation refers to the process in which the cognitive functions of the participant's deficit are compensated with preserved cognitive skills. For example, visual images can compensate for the verbal learning difficulties of an individual with poor verbal learning but preserved visual memory. Enhanced learning includes methods such as effortful processing, dual cognitive support, and errorless learning, enabling new knowledge and skills to be learned more effectively (Kelly and O'Sullivan 2015). The effortful processing method suggests that the more effort the participant spends to produce correct responses, the greater the benefit. During a cued recall task in patients with early dementia, it was shown that the facilitative effect of new associations was greater in high-effort conditions (fewer cues) compared to low-effort conditions (many cues) (Dunn and Clare 2007). Dual cognitive support refers to using skills that can facilitate both the encoding and retrieval performance of participants (Mimura and Komatsu 2007). For example, in Alzheimer's patients, the realization of encoding in multisensory modality (more than one sensory field) during learning facilitates the recall of information in the subsequent process (Rusted et al. 1997). Errorless learning is especially useful in terms of facilitating learning or retrieval of information by minimizing the number of incorrect responses from the participant (Haslam and Kessels 2018, Wilson and Fish 2018). To ensure errorless learning, the participant is regularly reminded to say "I am not sure" or not to answer at all if he/she is not sure about an answer during the application; when he/she gives such a response, a clue or command is given immediately to help the participant remember the correct answer (Wilson et al. 1994).

Commonly used retrieval strategies include mnemonics, cueing, method of loci (mind palace), chunking, and spaced retrieval (Buschert et al. 2010, Kelly and O'Sullivan 2015, Wilson and Fish 2018). Mnemonics are learning techniques that help to retain information. Making connections between visual images, stories, poems, or abbreviations and the information to be remembered is among the helpful mnemonic strategies. Often mnemonics are combined with other methods, such as spaced retrieval/repeated presentations. Providing relevant cues helps retrieval of information during recall and is particularly useful for learning and remembering information involving faces or numbers (Clare 2008). Chunking is a retrieval strategy that facilitates recall by linking some of the items retained in memory to form a meaningful whole (Thalmann et al. 2019, Norris et al.

2020). Memorizing telephone numbers as three- or two-digit numbers is one of the most commonly used examples of chunking. In the method of loci, information is organized by matching it with parts of a well known place, which facilitates later recall (Yates 1966, Bower 1970). Finally, the spaced retrieval method involves initially retaining information for shorter intervals and then gradually increasing the interval for retention as success is achieved (Brush and Camp 1998a, Brush and Camp 1998b).

External aids are various tools and materials used for the successful completion of cognitive tasks (Wilson et al. 2009). A diary to compensate for memory problems, an electronic alarm to remind medication times, or using reminder notes when making an important speech are examples of compensatory external aids. External aids have successfully overcome cognitive problems in various areas, such as attention, organization and planning, calculation, retrieval from memory, emotion regulation, and self-awareness (Gillespie et al. 2012). Finally, environmental adaptation involves organizing relevant environments to reduce cognitive demands, such as working in a quiet and distraction-free room to help focus, or having an important conversation when not tired (Wilson et al. 2009).

According to Anderson and Winocur (2020), efficacy, transfer, and maintenance are the main criteria that come to mind when discussing successful cognitive training or rehabilitation. Firstly, cognitive training/rehabilitation is successful if it is effective, that is if it leads to an increase in performance in the areas targeted by the intervention. Secondly, the gains obtained as a result of a successful intervention should go beyond the intervention; they should be transferred to other tasks that are similar to the task used in the intervention at near, intermediate, and far levels. Near transfer refers to performance improvements in tasks that are similar to the task applied during cognitive training/rehabilitation but have not been worked on before. The intermediate transfer represents improvements transferred to other functional areas within the cognitive domain being worked on (e.g., from spatial to episodic memory). The far transfer includes reflections on other untrained cognitive domains or other aspects of daily life. Finally, successful training/rehabilitation should lead to improvements that are maintained (i.e., sustained) after the completion of the intervention. In this context, developing a training/rehabilitation intervention that is effective, well-transferred, and has long-term benefits in older adults is the main goal of researchers and clinicians working on cognitive aging (Anderson and Winocur 2020).

Cognitive Training and Rehabilitation Practices for Different Cognitive Processes

Episodic Memory

Memory is one of the most common cognitive complaints for older adults, which is probably why most research on cognitive rehabilitation in aging has focussed on improving memory function. A meta-analysis of thirty-five studies (Gross et al. 2012) showed that cognitive training alone led to small effect sizes in enhancing memory performance in older adults. However, multi-strategy training, which involves combining different strategies such as the method of loci, association, categorization, and visual imagery, has been reported to lead to greater improvements (Gross et al. 2012). For example, a recent study found that drawing pictures of words presented during the encoding phase improved both the free recall and recognition performance of older adults more than young adults (Meade et al. 2018).

In a randomized controlled study (Zimmermann et al. 2016) examining near, intermediate, and far transfers in episodic memory training in healthy older adults, participants were assessed at the beginning, middle, end, and four months after a 30-session associative memory (object-position) training given for six weeks. It was found that object-position associative memory training caused a significant increase in performance in near and far-related tasks, and the gains were preserved for four months after the training. The researchers evaluated near transfer effects with visual-spatial memory tasks, intermediate transfer effects with verbal memory tasks, and far transfer effects with visual-spatial reasoning tasks. In contrast to object-location associative memory training, the reason why performance did not differ in intermediate transfer tasks is that these tasks require the learning of verbal relations (Zimmermann et al. 2016). In other words, it seems to be an important condition for successful transfer as a result of associative memory training that the target tasks in question contain the same cognitive representations or processes as the training given.

The severity of the cognitive decline in aging is not the same for all memory processes. The ability to recall contextual information about when and where an event occurred, which is a slow and controlled process (recollection), declines with age. On the other hand, familiarity, a fast and automatic process, is relatively preserved in older adults, even if the details cannot be remembered (without contextual information) (Koen and

Yonelinas 2014). Therefore, the main goal of cognitive exercises to improve episodic memory is to strengthen memory traces of contextual information about the time and place of events.

Jennings and Jacoby (2003) aimed to improve recall performance in episodic memory in healthy older adults with repetition lag training. A standard repetition lag paradigm begins with a study phase requiring memorization of a list of words. In the recognition test that follows, participants are expected to distinguish the old words learnt during the study phase from the new ones when presented with a list of old words learnt during the study phase and new words not learnt during the study phase. However, the main difference distinguishing the repeated delay paradigm from a standard recognition test is that each new word is presented twice in the recognition phase, but not consecutively. Thus, when the new word is presented for the first time, it causes familiarisation; when the same word is presented for the second time, the participants are more likely to respond incorrectly to the new word. For participants to produce correct responses, contextual information about whether a word presented in the recognition phase was encountered in the study phase or the second time in the recognition phase must be successfully recalled. In a study with healthy older adults, Jennings and Jacoby (2003) performed a repetition delay training task in which the number of words between two presentations of novel words gradually increased in the treatment group. In contrast, the control group performed a repetition delay task in which the number of words did not gradually increase (randomized). Results showed that the number of correctly recalled words and the length of the delay interval between two correctly recalled novel words were much higher in healthy older adults who were given repeated delay training compared to the control group. As a result, despite a greater number of intervening words, participants who underwent repeated delay training had an increased ability to recall contextual information about whether a presented word was encountered during the study or recognition phases. The effectiveness of repeated delay training in enhancing episodic memory in older adults has been confirmed in many other studies (Jennings et al. 2005, Lustig and Flegal 2008, Bailey et al. 2011, Stamenova et al. 2014). It has been shown that gains can be maintained even three months after the training (Anderson et al. 2018).

Assessment of cognitive changes in aging is important, because cognitive aging may start with subjective memory complaints and progress to mild cognitive impairment and dementia. Subjective memory complaints, usually not reflected in neuropsychological test scores, should not be perceived as insignificant because they only include self-reported complaints. Subjective memory complaints are closely associated with cognitive impairment and dementia risk that may occur in the process as well as causing a decrease in daily functioning (Balash et al. 2013, Jessen et al. 2014, Mendonça et al. 2016). A study showed that seniors who reported subjective memory complaints exhibited enhancements in both their objective memory performance and subjective memory complaints, six months following seven memory strategy training sessions (Frankenmolen et al. 2018). In addition, a 10-week cognitive rehabilitation program aiming to improve daily functions with the use of compensatory strategies applied to individuals with subjective memory complaints was found to increase the use of compensatory strategies, improve daily functioning and improve the interaction of individuals with brain health-related activities for six months after training (Denny et al. 2023). In a meta-analysis of fourteen studies, different memory intervention methods applied to older adults with subjective memory complaints were compared; as a result, multiple training models (including psychoeducation, cognitive restructuring, and memory strategies training) were found to be the most effective method in improving the subjective memory functions of older adults (Metternich et al. 2010).

It has been reported that mental imagery exercises applied in patients with mild memory impairment lead to better recall of appointments as well as improvement in neuropsychological test performances, including immediate and delayed story recall used in the evaluation of episodic memory (Kaschel et al. 2002). Studies conducted on patients with MCI show that different intervention methods such as episodic memory strategies training (Belleville et al. 2006), computerized cognitive training (Rozzini et al. 2007), prospective memory training (Kinsella et al. 2009), mnemonic skills and compensatory strategies training (Kim et al. 2022) and virtual reality-based cognitive-motor rehabilitation (Park et al. 2020) have the potential to improve cognitive skills. A recent meta-analysis reports that computerized cognitive training has positive effects on improving memory performance as well as general cognitive function, working memory, and executive functions in older adults with MCI (Zhang et al. 2019). However, it is not known how long the gains can be maintained and whether they reduce the risk of future dementia. Evidence on the effectiveness of episodic memory training in adults with mild to moderate dementia is relatively weak. Meta-analyses, including randomized controlled trials, show that cognitive training and rehabilitation do not significantly improve the memory performance of patients with mild to moderate dementia (Clare and Woods 2004, Bahar-Fuchs et al. 2013, Bahar-Fuchs et al. 2019). Therefore, starting cognitive training and rehabilitation before the onset of dementia seems to be an important condition for older adults to improve cognitive performance and progress toward recovery.

Working Memory

Working memory is one of the cognitive areas with the highest deterioration in the aging process (Park et al. 2002, Borella et al. 2008, Hale et al. 2011). Standard working memory tasks such as verbal or non-verbal spatial tests or N-back tasks are mostly used in training to improve working memory. These tasks used to improve working memory consist of adaptive stages whose difficulty level can be adjusted according to the participant's performance. The advantage of adaptive training is that it allows the participant to experiment with different difficulty levels, progressing from easy to difficult (Lövdén et al. 2010). For this reason, it is thought that the gains obtained due to adaptive training are higher than nonadaptive training (Zelinski 2009, Brehmer et al. 2012). On the other hand, a meta-analysis study conducted on executive control and working memory training in healthy older adults shows no difference between the gains obtained from adaptive and non-adaptive training (Karbach and Verhaeghen 2014).

In one of the early examples of adaptive working memory training, Dahlin et al. (2008) reached promising results on the effectiveness of working memory training in older adults. The researchers compared the working memory performance of older adults who received 5 week working memory training on five different tasks and a control group before and after the training. In four tasks, participants were presented with stimuli (letters, numbers, colors, or spatial locations) of different spans. The span of the items presented in the list gradually increased as the correct response condition was met. After the presentation, the participant was asked to report the last four stimuli. In the fifth task, participants were asked to indicate to which of a series of categories each of the 15 words presented consecutively belonged and were instructed to recall the last word in each category at the end of the trial. In addition to the training tasks, the N-back task was used as an evaluation criterion to observe transfer effects. The findings show that the working memory training group had higher performance gains on the tasks used in training than the control group; however, there was no difference between the groups regarding N-back performance. Despite the small sample size, the findings obtained from the first studies indicate that working memory training is effective in healthy older adults; however, the transfer does not occur. Apart from one (McAvinue et al. 2013), the results of many other studies conducted on older adults (Brehmer et al. 2012, Borella et al. 2014, Heinzel et al. 2014, Wayne et al. 2016, Payne and Stine Morrow 2017) similarly show that working memory training leads to strong improvements in performance on the tasks used in training.

Another important example of adaptive working memory training is the CogMed computer program developed by Klingberg et al. (2002) and initially designed for children with Attention Deficit Hyperactivity Disorder (ADHD). The CogMed application aims to increase working memory capacity with training applied five days a week for five weeks (Shinaver et al. 2014). In a study conducted on older adults, it was shown that small improvements were achieved as a result of 5-week CogMed working memory training; however, these gains were not transferred to other cognitive areas (Vermeij et al. 2015). Similar results were obtained after working memory training using computerized N-back tasks; task-specific training effects in working memory were reported to be small, and far transfer effects were negligible (Li et al. 2008, Salminen et al. 2015).

The majority of studies investigating whether improvements are maintained after working memory training (for an exception, see Buschkuehl et al. 2008) show that performance on the working memory task used in training is still high compared to baseline when re-measured after varying time intervals (3-18 months) (Dahlin et al. 2008, Brehmer et al. 2012, Borella et al. 2014, Zinke et al. 2014). On the other hand, the maintenance of transfer effects is shorter than training effects (Borella et al. 2010, Borella et al. 2014, Borella et al. 2017). Results regarding transfer effects are contradictory; findings from some studies (Von Bastian et al. 2012, Zinke et al. 2012, Wayne et al. 2016, Goghari and Lawlor Savage 2017) indicate that transfer is not possible, while others (Buschkuehl et al. 2008, Richmond et al. 2011, Brehmer et al. 2012, Borella et al. 2014, Heinzel et al. 2014, Zinke et al. 2014, Payne and Stine-Morrow 2017) reported performance improvements indicating near and far transfer of working memory training.

Executive Functions and Attention

Rehabilitation programs to improve executive functions, which include cognitive components such as inhibition, planning, set-shifting, goal-directed behavior, reasoning, and problem-solving, generally consist of multimodal cognitive interventions (Spikman 2017). The Cognitive Orientation to Daily Occupational Performance (CO-OP: Cognitive Orientation to Daily Occupational Performance; Polatajko and Mandich 2004) approach is a good example of multimodal cognitive intervention. In the CO-OP approach, in which specific steps are followed in problem-solving and goal achievement, participants use this strategy training, which consists of goal-plan-do-check steps, in real-life daily activities. When the effectiveness of the CO-OP approach on older adults was examined, it was reported that participants showed significant improvement in achieving real-life goals compared to controls; however, no difference was found between groups in terms of neuropsychological test performances evaluating executive functions (Dawson et al. 2014).

Another intervention method to improve executive functions is Goal Management Training (GMT: Goal Management Training; Levine et al. 2000), which involves self-regulation in goal-directed behaviors. Improvements in task performance and self-report assessments of executive functioning have been reported in older adults after GMT (Levine et al. 2007). The GMT technique involves a process of stop-wait-check, where an individual regularly compares their current actions with their goals to prevent any task-irrelevant behaviors. GMT involves dividing a larger goal (e.g., planning a holiday) into a series of prioritized smaller sub-goals and performing the tasks necessary to achieve these sub-goals. In this process, the participant learns to regularly stop the ongoing activity and assess whether this activity is getting closer to achieving the current sub-goal. The GMT also includes relaxation/awareness training to support staying in the moment and homework assignments that require goal management practices in daily life (Levine et al. 2000). It was found that subjective executive function complaints of older adults decreased long-term when they were assessed immediately after a 12-session GMT training lasting six weeks and then again seven weeks later (Van Hooren et al. 2007). However, this effect was not reflected in objective measures. In addition, follow-up evaluations determined that the anxiety levels of the participants who received training decreased significantly compared to the pre-training period (Van Hooren et al. 2007).

Inductive reasoning training is one of the methods frequently applied to improve executive functions. Inductive reasoning refers to the capability of creating a generalized model from numerous observations. The ACTIVE (Advanced Cognitive Training for Independent and Vital Elderly) study, in which strategies for identifying a pattern in a sequence of letters or words and predicting the next item in the sequence are taught, also includes reasoning training (Ball et al. 2002). The training program comprises of ten sessions that last between sixty-five to seventy minutes, and focuses on practical situations like identifying patterns in bus timetables. It was reported that the executive function performance of healthy older adults who received training for ten years after the training was higher than those who did not (Willis et al. 2006, Rebok et al. 2014). A similar structured training for executive functions was developed by Anand et al. (2011) (Strategic Memory Advanced Reasoning Training [SMART: Strategic Memory Advanced Reasoning Training]). SMART focuses on reasoning based on simplifying much complex information starting from the most important one. During the training, participants learn to arrange intricate data, give it priority, remove any irrelevant information, and eventually deduce abstract significance. Studies conducted on healthy older adults report that SMART practices improve executive function performances such as abstract reasoning, cognitive shifting, and verbal fluency (Anand et al. 2011, Chapman et al. 2017).

There is evidence that rehabilitation of executive functions can improve cognitive performance in older adults with pathological conditions. In a quasi-randomized controlled study (Cisneros et al. 2021), the effect of the Cognitive Enrichment Program on older adults with traumatic brain injury was examined. The Cognitive Enrichment Programme included 24 sessions of executive function training over 12 weeks. This training consists of planning, problem-solving, and goal management training, as well as strategies focusing on self-awareness. The findings of the study showed that the executive function performance of older adults with traumatic brain injury improved when trained with the Cognitive Enhancement Programme. In addition, the evaluation conducted six months after the training found that the patients' participation in daily activities improved (Cisneros et al. 2021).

Other exercises related to executive function and attention include methods to improve multitasking performance. These exercises are implemented through different dual-task paradigms, namely fixed-priority, and variable-priority. Fixed-priority exercises require both tasks to be performed simultaneously. Therefore, the participant's attention is divided equally between the two tasks in such training. Variable-priority training, on the other hand, involves alternating the performance of both tasks by directing attention (Kramer et al. 1995). Studies conducted on older adults have reported improvements in divided attention tests and N-back task performance in relation to near transfer after both fixed- and variable-priority training (Bherer et al. 2008, Bier et al. 2014). In addition, it was found that performance gains were higher in participants given variable-priority training than those given fixed-priority training (Belleville et al. 2014, Bier et al. 2014, Lussier et al. 2017).

Processing Speed

Training programs focusing on information processing speed usually consist of computer-based exercises involving detection, identification, discrimination, and localization of target stimuli (Ball et al. 2007). To increase the processing speed during the training programs, the display time of the target stimuli is gradually decreased, and the difficulty level is increased. In Useful Field of View (UFOV; Ball et al. 1988) training, which involves discriminating targets among stimuli with progressively faster presentation times, stimuli are initially presented only in central locations, but as the participant's success rate increases, they appear in a mixed manner in both central and peripheral locations. It has been reported that UFOV training increases the processing speed, and gains are maintained for a long time in healthy older adults (Ball et al. 2002, Willis et al. 2006). It has also been reported that the increase in processing speed reduces the risk of dementia (Edwards et al. 2017) and causes improvements in daily activities such as driving performance (Roenker et al. 2003). Studies on the transfer of information processing speed training report that although near transfer effects are observed as a result of the training, far transfer to other cognitive areas, such as executive functions or working memory, does not occur (Ball et al. 2007, Takeuchi and Kawashima 2012, Lampit et al. 2014, Edwards et al. 2018).

Changes in Brain Structures Caused by Cognitive Training and Rehabilitation

Behavioral research on improving cognitive functions is supported by findings from neuroimaging studies that examine structural changes in the brain. In a randomized controlled study (Engvig et al. 2010), which examined the relationship between an 8-week loci training aimed at improving verbal source memory and macrostructural changes in the brain, it was found that this training significantly improved source memory performance. In addition, magnetic resonance imaging (MRI) results showed regional increases in cortical thickness measurements of memory training participants. It was reported that the increase in cortical thickness in the right fusiform and lateral orbitofrontal areas after training was positively correlated with source memory performance. In a functional magnetic resonance imaging (fMRI) study examining the relationship between memory training and brain activations, Kirchhoff et al. (2012) reported that cognitive training caused increased activation in the medial superior frontal gyrus, right precentral gyrus, and left caudate during encoding. In addition, increased activation in brain regions such as prefrontal and left lateral temporal areas mediating semantic processing was significantly associated with recognition memory performance (Kirchhoff et al. 2012).

Memory training causes not only macrostructural changes and increased cortical activation detected in imaging studies but also microstructural changes shown by white matter integrity. When the effectiveness of memory training applied in young and older adults and the contribution of this training to white matter integrity were examined with diffusion tensor imaging (DTI: Diffusion Tensor Imaging), it was observed that memory performance improved in both young and older adults; compared to the control group, the age-related decline in the white matter microstructure of older adults participating in memory training was less (De Lange et al. 2017).

When investigating the brain activity of older adults before and after working memory training, studies typically indicate a reduction in frontoparietal activation post-training (Erickson et al. 2007, Brehmer et al. 2011, Heinzel et al. 2017). For example, Vermeij et al. (2016) reported that prefrontal activation during the 3-back task decreased in older adults after five weeks of CogMed training. This result supports the findings of increased neural efficiency in healthy older adults as a result of working memory training. On the other hand, behavioral improvements were observed only in the 1-backward task, but no difference was found in prefrontal activation (Vermeij et al. 2016). In a study in which event-related potentials (ERP: Event-Related Potential) were evaluated simultaneously with working memory performance in CogMed-trained older adults, although there was no difference in behavioral performance between the training group and the control group, differences in neural activity manifested by an increase in P3 amplitude in the training group were reported (Tusch et al. 2016). Regarding this matter, research exploring cortical alterations noticed following working memory training reveals a decrease in prefrontal activity, suggesting an overall enhancement in neural efficiency (Buschkuehl et al. 2012). Similar results are also evident in applications structured to improve executive functions. According to Motes et al. (2018), SMART training resulted in a decline in the activation of the left prefrontal cortex in older adults, indicating an improvement in neural efficiency. When the neural connections of SMART applied in older adults were examined comprehensively, it was reported to cause an increase in both regional and whole brain blood flows, synaptic connections in the central executive network, and white matter integrity (Chapman et al. 2015). In summary, the findings of various studies show that cognitive training and rehabilitation practices may cause changes at different levels in the brain structures of older adults.

Conclusion

There is strong evidence for the efficacy of cognitive training and rehabilitation in healthy adults, individuals with subjective memory complaints, and individuals with MCI. Episodic memory training, which involves teaching different mnemonic strategies, appears beneficial for older adults, but transfer to other cognitive domains appears to be poor. Programs targeting working memory are mostly repetitive cognitive training, and far transfer effects are rarely seen. Improvements in processing speed reduce the risk of dementia as well as its long-term preservation. Multimodal training programs targeting executive functions and attention have a stronger transfer to different cognitive domains compared to others. As a matter of fact, the benefits of multimodal training, especially for daily functioning, have been strongly emphasized in the literature.

The results obtained from research on the effectiveness of cognitive training and rehabilitation in aging and the changes it causes in brain structures are promising; however, various methodological problems constitute important limitations of the relevant literature and shed light on future research areas. When the studies in the literature are reviewed, it is seen that most of the studies on cognitive training and rehabilitation in older adults do not have sufficient sample sizes. Inadequate sample sizes increase the likelihood that the non-existent activities of these cognitive training and rehabilitations are accepted as existing; in other words, the possibility of Type 1 error increases. Another limitation is that most research reports contain limited information about the method used in cognitive exercise or rehabilitation. In most of the studies, information such as the duration, intensity, and endpoints of the interventions needed to be clearly reported.

In the evaluation of the effectiveness of cognitive training and rehabilitation, it is very important to determine how long the improvements are maintained; however, it is noteworthy that in the majority of studies, long-term follow-up results are not available. Another significant limitation is the possibility of practice-related effects when the same tasks or tests are used repeatedly during follow-up (e.g., Zinke et al. 2014, Zimmermann et al. 2016, Borella et al. 2017, Anderson et al. 2018, Frankenmolen et al. 2018). It is thought that the effects of repetitive practice can be eliminated by using alternative forms during follow-up. Similarly, it is important to form appropriate control groups to evaluate the effectiveness of cognitive training and rehabilitation accurately. Studies using passive control groups increase the probability of Type 1 error. Establishing active control groups by giving placebo tasks similar to the experimental group's practices will increase the results' internal validity. Finally, many studies need more information on how the benefits gained after the training is reflected in real life. In this context, future research will make important contributions to show the reflections of the improvements obtained as a result of cognitive training and rehabilitation in daily life.

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