Improving Daily Functioning with Cognitive Training in Stroke Patients and the Role of the Therapist: A Systematic Literature Review

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Abstract

Cognitive rehabilitation for stroke patients should facilitate the generalization of cognitive improvements to real world functioning. It is not yet clear to what extent cognitive improvements achieved with cognitive training may transfer to daily functioning and what the role of the therapist is in this process. The aim of this systematic review was to explore the current state of knowledge in the literature regarding these two questions. Studies that (a) investigated the population of stroke patients; (b) administered cognitive training as an intervention; and (c) measured cognitive outcomes with optional inclusion of functional outcome measures, were eligible for inclusion. We searched in PubMed, PsycINFO, and the Cochrane Library. The methodological quality of the systematically reviewed studies was judged with the Cochrane risk-of-bias tool for randomized trials. Data was extracted in Excel and reviewed in a narrative synthesis alongside a summary table. Fifteen randomized controlled trials were included. Nine of those studies measured functional outcomes. Whereas two of these nine observed significant improvement, the majority of seven studies found no significant improvement as a result of the cognitive training. Since only one of the studies that measured functional outcomes also included a therapist in the cognitive training, we could not gather sufficient information to explore the role of the therapist. Future research should compensate for previous shortcomings by assessing functional outcomes and the role of the therapist in order to be able to answer the question whether cognitive improvements can generalize to improved daily functioning and if a trained therapist can facilitate this process.

Keywords: cognitive rehabilitation, stroke patients, daily functioning

Improving Daily Functioning with Cognitive Training in Stroke Patients and the Role of the Therapist: A Systematic Literature Review

Stroke is considered to be a leading cause of mortality and disability, being the second leading cause of death worldwide and the third leading global cause of disability (World Health Organization, 2019). Disabilities following stroke can pertain to a wide range of domains. For example, limitations in cognition (Stolwyk et al., 2021), difficulties with completing activities of daily living and mobility (Smith, 2015), depression (Sivolap and Damulin, 2020; Smith, 2015), or aphasia (Flowers et al., 2016) are common consequences. We live in an ageing population where the incidence of stroke is increasing (Douiri et al., 2013; Duncan, 1994). Therefore, stroke and its entailed limitations can be considered an increasing problem. In order to reduce limitations in stroke patients, post-stroke health care needs to address these limitations effectively. Cognitive rehabilitation is a treatment approach developed to treat cognitive deficits and is becoming a standard treatment in neurological rehabilitation (De Luca et al., 2018). Cognitive impairment is notably common in stroke patients (Lo Coco et al., 2016; Stolwyk et al., 2021; Wesselhoff et al., 2018), and may be persistent for several years (Patel et al., 2003). The prevalence of cognitive impairment in stroke is high, but the literature reports widely ranging numbers of how many patients are affected. Directly after stroke, the number of stroke patients experiencing limitations in cognitive functioning ranges from 78% (Leśniak et al., 2008) to 39% (Patel et al., 2003) and 24% (Douiri et al., 2013), and remaining as high as 21% even 14 years after the stroke occurred (Douiri et al., 2013).

How can stroke affect cognition and daily life activities?

Cognitive processes are required to complete everyday tasks (Stolwyk et al., 2021). Therefore, if cognitive functioning is impaired, this may in turn lead to impaired daily functioning (Wentink et al., 2016; Leśniak et al., 2008). Indeed, it has been found that cognitive impairment contributes to a stroke patients’ inability to complete both basic and complex daily activities (Stolwyk et al., 2021). Stolwyk et al. (2021) define daily functioning as the ability to complete both basic and more complex tasks in everyday life. Activities of daily living (ADL) include basic tasks such as eating, bathing, dressing, toileting, transferring, and continence. Instrumental activities of daily living (IADL) are more complex tasks. Those include housekeeping, living independently in the community, preparing meals, handling medication and finances, mobility within the community, and making phone calls (Stolwyk et al., 2021). In line with that, other research showed that impairments in cognition may be manifested in dependence and decreased quality of life (De Luca et al., 2018), diminished participation in social and leisure activities (Stolwyk et al., 2021), or in not being able to return to work (van der Kemp et al., 2019; Wentink et al., 2016).

Different cognitive abilities might be impaired after stroke, frequently involving attention, language, short-term memory, long-term memory, or executive functions (Leśniak et al., 2008). Taking a closer look at what cognitive domains are especially associated with poor functional outcomes, executive functioning seems to be an important predictor (Leśniak et al., 2008). Executive functioning includes processes such as initiation, planning, solving novel problems, mental flexibility, emotion regulation, and self-awareness. These abilities are necessary in order to perform goal-directed actions (Sira and Mateer, 2014). Poor executive functioning can lead to limitations in completing both ADLs and IADLs (Cornelis et al., 2019). For example, executive dysfunction decreases the probability of independently completing ADLs such as getting dressed (Chung et al., 2013). The reason behind this is that executive dysfunction might occur alongside physical limitations such as motor impairments of the limbs. In this case, patients have to relearn to complete the process of getting dressed because of the limb impairment. Both relearning and figuring out alternative ways to get dressed require intact executive functioning, specifically involving the ability of solving novel problems. Executive dysfunction might therefore hinder the completion of basic ADLs such as getting dressed after experiencing a stroke (Chung et al., 2013). Furthermore, working memory can be impaired following a stroke (Westerberg et al., 2007). Working memory is the ability to hold and simultaneously process incoming information in order to adjust one's response based on this process (Borella et al., 2019; Westerberg et al., 2007). Impaired working memory can lead to functional limitations in stroke patients (Westerberg et al., 2007). Furthermore, working memory is crucial for accomplishing daily tasks, vocational performance, and social functioning (Westerberg et al., 2007), or driving a car (de Waard, 1996).

Cognitive rehabilitation

Cognitive rehabilitation is designed to improve cognitive functioning (De Luca et al., 2018), such as attention, memory or executive functions (Chung et al., 2013), and functional outcomes (Cicerone et al., 2005). The restorative approach, which relies on directly targeting specific cognitive domains with cognitive training, might foster neuroplasticity (Gates and Valenzuela, 2010), and cognitive training has been associated with functional and anatomical neural changes (Biel et al., 2020). Computerized cognitive training, a tool that can be used for restorative training purposes (Lynch, 2002), is increasingly administered in cognitive rehabilitation because of its convenient, low cost and individualized implementation (Sigmundsdottir et al., 2016; Ye et al., 2020). Indeed, computerized cognitive training might be a promising treatment approach for improving cognition (De Luca et al., 2018). Their study found that global cognitive improvement can be achieved with computerized cognitive training. In agreement with that, other research concluded that cognitive functions that might be impaired after stroke, such as learning (Yoo et al., 2015) and working memory (Lundqvist et al., 2010), can be improved with computerized cognitive training. These studies on computerized cognitive training suggest that cognitive interventions can be effective in improving cognitive functioning in stroke patients. Cognitive rehabilitation based on virtual reality can also improve global cognitive functioning, allowing for improvements in attention, executive functioning or visuo-spatial abilities (Faria et al., 2016). Rogers et al. (2018)

recently reviewed the effectivity of cognitive interventions and also concluded that cognitive training can improve cognitive functioning in stroke patients. However, other reviews detected no long-term maintenance of gains in attention (Loetscher et al., 2019) or memory (das Nair et al., 2016).

Generalization of cognitive improvement to improved daily functioning - A challenge?

De Luca et al. (2018) described the need for treatment that allows for the transfer of the cognitive improvements that were achieved with cognitive training to improvements on the functional level. Recent research revealed contradicting evidence on the effect of cognitive rehabilitation on daily functioning in stroke patients, which highlights that the transfer of improvements to non-trained areas remains a key problem in the field (Lynch, 2002). On the one hand, Yoo et al. (2015) concluded that the cognitive improvements on the impairment level did not generalize to improvements in functional outcomes. This is in line with the findings of Wentink et al. (2016), who found no far transfer to functional outcomes, such as improvement of self-perceived cognitive problems, self-efficacy or quality of life. However, their sample also showed no improvements on cognitive functioning measured on the impairment level, except for small improvements in working memory and speed. This lack of improvement on the impairment level might be the reason that no generalization was observed in their study. On the other hand, the results of Westerberg et al. (2007) suggested that generalization of cognitive training can be achieved. Their training of working memory led to both improved performance on non-trained tasks and to improved functional outcomes, namely less self-perceived cognitive problems. This has also been observed with acquired brain injury in general. Lundqvist et al. (2016) provided computerized working memory training to patients who experienced cognitive deficits as a result of brain injury, where the majority of the sample were stroke patients. Here, patients experienced increases in daily functioning and reported better occupational performance and increased satisfaction with problem solving abilities in the occupational context. Recent reviews observed only short-term cognitive improvements and no functional improvements as a result of cognitive training. Loetscher et al. (2019) reviewed the effect of cognitive rehabilitation on attention deficits in stroke patients and found no improvements in daily functioning as a result of cognitive rehabilitation. In line with that, das Nair et al. (2016) found that neither functional abilities, quality of life nor mood were significantly improved with memory rehabilitation. However, both reviews did only find short-term improvement on the impairment level (i.e., no long-term improvement of attention; Loetscher et al., 2019; no long-term improvement of memory; das Nair et al., 2016) which might be the reason for the lack of generalization.

Although there are some studies investigating generalization, research has primarily been evaluating the effect of cognitive training on cognitive outcomes (Sigmundsdottir et al., 2016), but it should to the same degree focus on reducing disability and on improving functioning in contexts that are relevant for the patient (Cicerone et al., 2005). The majority of studies measure improvements only at the impairment level (i.e., cognitive functioning) and neglect the effect on functional outcomes (Sigmundsdottir et al., 2016), which is in contradiction to the ultimate goal of improving functioning in activities (Cicerone et al., 2005). Given the incomplete assessment of relevant outcomes in the majority of studies it is in those cases not possible to judge the effect of cognitive training on daily functioning. Thus, research is needed to evaluate if and how cognitive improvements achieved with cognitive training can generalize to daily functioning (Cicerone et al., 2005). The present review will comply with this need and search for the literature that is presently available on the topic in order to explore whether the benefits of cognitive training for stroke patients involve improved daily functioning. In fact, exploring how to optimize functional outcomes for stroke patients is essential, because functional limitations in stroke patients can lead to decreased life satisfaction (Smith, 2015). Especially cognitive limitations and limitations in daily activities are associated with low life satisfaction in stroke patients (Smith, 2015). The author stresses the importance of improving these limitations in rehabilitation in order to improve the quality of life of stroke patients.

Which factors can facilitate generalization?

Looking at the conflicting results regarding generalization indicates that cognitive training alone might not be sufficient to improve daily functioning. As long as cognitive rehabilitation might not sufficiently satisfy the goal of improved daily functioning, research should work on how to improve or complement current treatments for patients with cognitive impairments. Cicerone et al. (2005) described the need for further research on which factors are essential for providing efficient cognitive rehabilitation many years ago. This is underlined by Rogers et al. (2018) who point out that research should go well beyond the question whether cognitive training is effective, but should explore which factors regarding design and application are crucial for the training to be effective. According to the authors, this has not yet been examined for stroke patients. From other fields we can learn which factors might contribute to increased generalizability of cognitive training. Research in schizophrenia is a field that is already notably advanced. Here, Bowie et al. (2019) published an outline of the core elements that are essential for providing effective treatment for cognitive deficits in patients with schizophrenia. One of the core features described by the authors is the presence of an active and trained therapist who should have well-grounded knowledge about cognitive processes and their relation to everyday functioning. A recent meta-analysis confirmed that the involvement of a trained therapist led to greater improvements in both cognition and functional outcomes than with no therapist present (Vita et al., 2021). According to Bowie et al. (2020), developing problem-solving strategies and procedures to link cognitive and real-world functioning are next to cognitive exercise also core elements. The importance and effectivity of these elements on both cognitive and functional outcomes have also been confirmed by recent meta-analytic research on schizophrenia (Vita et al., 2021). Those additional elements also necessitate the involvement of the therapist. The therapist can help to identify strategies that proved to be helpful during cognitive training and should educate the patient about the link between cognitive skills and daily functioning, for example by setting cognitive training goals that are relevant for the patients' real-world functioning (Bowie et al., 2020). It is possible that complementing cognitive training with additional strategies might likewise be beneficial for stroke patients who experience difficulties with cognitive functioning. Furthermore, cognitive training for patients with multiple sclerosis or brain tumors also relies on therapist-assisted training of cognitive functions and the application of strategies that help patients to cope with everyday life (Sigmundsdottir, et al., 2016). Hence, research from other fields describes the positive influence of a trained therapist complementing the cognitive training on patients who experience cognitive deficits. One can assume that stroke patients might likewise benefit from the described elements. Looking at the findings from other fields, it may therefore be possible that the assistance of a trained therapist is a therapy factor in cognitive training for stroke patients that improves functional outcomes by facilitating the transfer of cognitive improvements to daily functioning.

The basis of the questions this review addresses is the well-established relationship between cognitive functions and daily functioning (Cornelis et al., 2019). As outlined above, there is still some uncertainty about whether improved cognition can as a consequence lead to improved daily functioning also. In cognitive rehabilitation for stroke patients, to our knowledge, the generalization of cognitive improvements remains an unresolved question (Das Nair et al., 2016, Loetscher et al., 2019, Poulin et al., 2012) and the role of the therapist has not yet sufficiently been addressed in this context by previous research. Therefore, this systematic literature review will explore the existing literature on the following topics:

1. Can cognitive training improve daily functioning in stroke patients by improving cognitive functions?

2. Is a trained therapist a therapy factor that can facilitate the transfer of cognitive improvements to daily functioning?

Method

This review was conducted and written in line with the PRISMA guidelines (Liberati et al., 2009). We developed a protocol according to the PROSPERO database instructions prior to beginning the search. In this international database, researchers can register their systematic reviews prospectively in order to reduce duplication (PRISMA, 2021), but for this master's thesis we did not register the review on PROSPERO.

Inclusion criteria

The type of studies included were randomized controlled trials or clinical trials that were published in English, Dutch, or German. Based on the PICO criteria for systematic reviews (Methley et al., 2014), we formulated the inclusion criteria. The PICO criteria serve as a guide for the development of a comprehensive research question by providing a framework that captures the main concepts of the question that the review addresses (Methley et al., 2014). This framework allows for the identification and organization of relevant information on the population, the intervention, the comparison, and the outcome (Methley et al., 2014).

Population

The population investigated in this review were patients who experienced a stroke. The review looked at the general stroke population, regardless of the specific type of stroke. Studies with mixed samples that consisted of patients with acquired brain injury in general or traumatic brain injury patients together with stroke patients were excluded.

Intervention

The intervention investigated was cognitive training. An intervention was considered cognitive training if it was designed with the goal of improving cognitive impairments, if it targeted specific cognitive domains, and if it was administered more than once (Gates and

Valenzuela, 2010). In line with this definition, interventions that did not include cognitive exercise (e.g., strategy training) were excluded. Furthermore, interventions that were cognitive in nature but whose main purpose was the treatment of a particular disorder, such as neglect or aphasia, were excluded as well. The reason for that was that these interventions' goal, the reduction of the symptoms of a specific disorder, is in contrast to the main goal of cognitive training, which is the improvement of cognitive functioning (De Luca et al., 2018). We also excluded combinations of cognitive training with other treatments (e.g., physical exercise or transcranial direct current stimulation).

Comparison

Regarding the comparison, this review included studies with active and passive control groups that administered interventions that were not cognitive training according to the definition above. Interventions of control conditions that specifically formulated the improvement of cognition as their main goal (e.g., strategy training), and might therefore be associated with cognitive improvements in stroke patients (Ahn et al., 2017), were viewed to considerably, but not entirely, overlap with our definition of cognitive training. Consequently, those were excluded in order to prevent ambiguous classification of interventions and indistinct differentiation between the conditions. Furthermore, if there was more than one control condition (i.e., active and passive), the intervention was compared against the active control condition.

Outcome

Outcome measures must include measures of cognitive functioning according to the categorization of neurocognitive domains in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM–5; American Psychiatric Association, 2013). The six domains of cognitive functioning described there include executive function, perceptual-motor function, language, social cognition, learning and memory, and complex attention (Sachdev et al., 2014). Outcome measures could additionally include functional outcome measures. There is no consensus on a standard set of outcome measures in neuropsychological rehabilitation (van Heugten et al., 2020), and no generally used definition for daily life activities in patients with cognitive impairment (Cornelis et al., 2019). For this reason, this review used no specific containments regarding functional outcomes but included a broad variety of measures regarding participation and daily life impairment or functioning, such as quality of life measures, cognitive functioning at participation level (Rogers et al., 2018), or activities of daily living measures (Yoo et al., 2015). Measurements of motor impairments that were a direct result of the stroke and not a result of the cognitive impairment following the stroke were not considered functional outcomes related to the topic of this review.

Search strategy

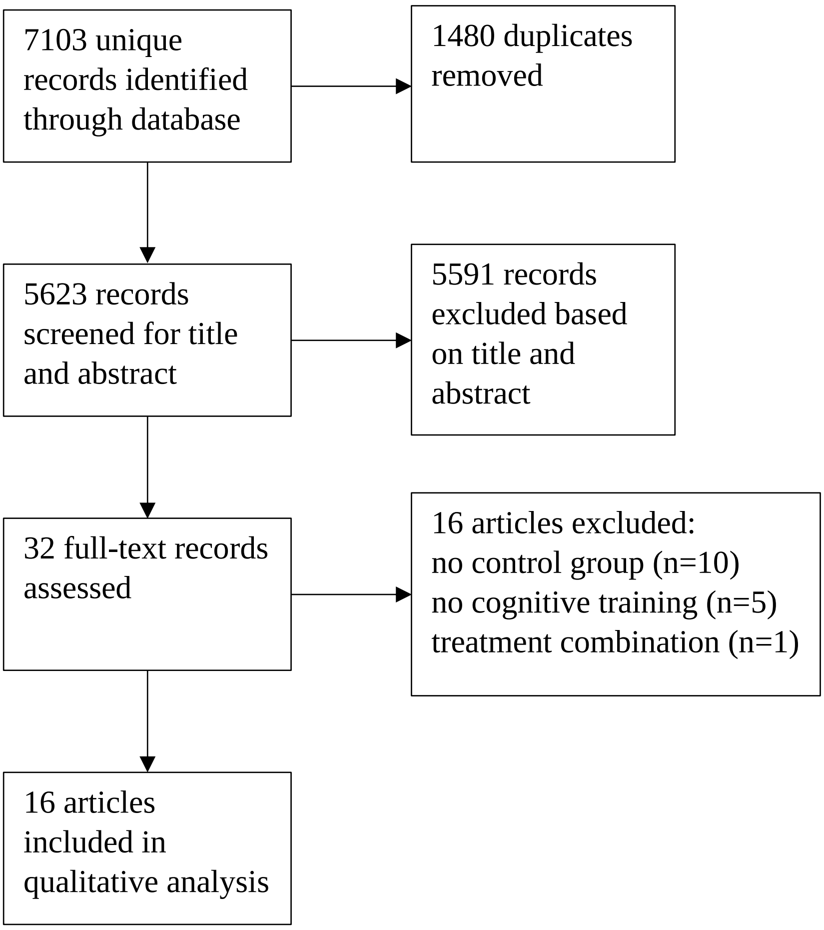
The Cochrane Library, PubMed and PsycINFO were systematically searched in May 2021. The last search included a combination of three search terms, each representing one of our key concepts and their corresponding synonyms: (a) Cognitive training; (b) stroke patients; and (c) randomized controlled trials. Since the focus of this review lay on reviewing how to improve daily functioning in stroke patients, we originally ran a prior search that included a fourth search term that represented the concept of functional outcomes. However, that search yielded only a small number of studies. Based on the literature stating that functional outcomes are not often measured (Sigmundsdottir et al., 2016), we hypothesized that the literature is limited regarding this topic or that our search term might not have captured all relevant studies. In order to remove possible limitations of the search, we ran the last search without the term for functional outcomes as described in this section. The full search strategies for PubMed, PsycINFO, and The Cochrane Library can be found in Appendix B.

Study Selection and Data Extraction

The studies obtained from the search were imported to Zotero for duplicate deletion. The remaining studies were imported in Rayyan for a title and abstract screening. The studies included in the previous step were read in full. A visualization of the screening process can be found below (Figure 1). In the next step, the data of the remaining studies included based on the full-text screening was collected in an Excel spreadsheet. Here, information on sample characteristics (i.e., stroke type, size, age, sex), trial characteristics (i.e., aim of intervention, intervention type, intervention setting, length of intervention, time between stroke and intervention, control condition intervention, trained cognitive domains, therapist role), outcome measures (i.e., outcome domain, measurement instrument, significance of the result, effect size), study results, and review conclusions was extracted. One reviewer (M.S.) performed all the steps of the study selection and data extraction.

Figure 1

Screening flow diagram



Risk of Bias

The methodological quality of the included studies was assessed with the Cochrane risk of bias tool for randomized trials. We used the tool to judge risk of bias for the five different domains (i.e., randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, selection of reported results) that can be addressed with the tool (Sterne et al., 2019). For each of the domains, all studies were either judged to be at high risk of bias, some risk of bias or low risk of bias. Based on this assessment, one reviewer (M.S) made an overall judgement of risk of bias for each study accordingly.

Method of Analysis

The results of the literature review are presented in a narrative synthesis alongside a summary table showing the main characteristics and results of the included studies with an evaluation of how their results are relevant for the topic of this review. The reviewed studies were grouped and analyzed according to the outcome measures they used. Regarding cognitive outcomes, we grouped and analyzed the studies according to the cognitive subdomain that they assessed in order to evaluate whether and which cognitive domain could be improved with cognitive training. Likewise, the studies that assessed functional outcomes were grouped with regard to the domain of functioning that they measured so that functional domains that may be improved with cognitive training would become apparent. Those studies were also grouped based on whether they included a therapist or not in order to determine whether the presence of the therapist facilitated improvements on functional outcomes measures.

Results

Study characteristics

As visualized in the flowchart above (Figure 1), sixteen of the 7103 identified articles met the inclusion criteria and were included in the qualitative analysis. Two of the identified articles were based on the same study and published by the same authors (van de Ven et al.,

2017) and were therefore treated and referred to as one study in the current review. Of the fifteen included studies in the current review, thirteen were published in 2013 or later, leaving one study from 2007 and the least recent one from 1983. The characteristics of the reviewed studies (i.e., methodology, intervention, results) can be found in Appendix A (Table S1). The studies all aimed at evaluating the effect of the intervention on cognition. In addition to that, five of the studies mentioned the aim to examine the effect of the intervention on functional outcomes (Cho et al., 2016; van de Ven et al., 2017; Wentink et al., 2016; Westerberg et al., 2007; Withiel et al., 2019). Eleven studies aimed at assessing the effect of computerized cognitive training on rehabilitation (Cho et al., 2015; Cho et al., 2016; Gamito et al., 2017; Jung et al., 2020; Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; van de Ven et al., 2017; Wentink et al., 2017; Westerberg et al., 2007; Zucchella et al., 2014).

Participants

The studies included a total of 740 stroke patients with 337 patients being in the experimental conditions and 403 patients being analyzed in the control conditions. The samples were characterized by heterogeneity regarding the type of stroke. In six of the studies, the type of stroke was not reported (Carter et al., 1983; Cho et al., 2015; Cho et al., 2016; Gamito et al., 2017; Prokopenko et al., 2013; van de Ven et al., 2017). Three studies investigated samples consisting of only ischemic stroke patients (Hasanzadeh Pashang et al., 2020; Prokopenko et al., 2018; Prokopenko et al., 2019). Six studies (Chen et al., 2015; Jung et al., 2020; Wentink et al., 2016; Westerberg et al., 2007; Withiel et al., 2019; Zucchella et al., 2014) investigated samples consisting predominantly of ischemic stroke patients (55.56 - 82.76%), followed by hemorrhagic stroke patients (17.24 - 44.45%). The mean age of the participants ranged from 53.6 years to 73.4 years.

Intervention characteristics

The duration of interventions ranged from eight to 58 sessions occurring over two to 12 weeks. Two of the studies used paper-pencil methods for cognitive training. Carter et al.

(1983) used a thinking skills workbook and Hasanzadeh Pashang et al. (2020) used the workbook of Powell for cognitive training purposes. The remaining 13 studies all based their intervention on computerized interventions but the used programs varied per study and are listed in Supplementary Table 1 (Appendix A).

The intervention setting varied per study and could be grouped into the hospital setting, the rehabilitation clinic setting and the at home setting. Most interventions took place in rehabilitation clinics (Chen et al., 2015; Gamito et al., 2017; Hasanzadeh Pashang et al., 2020; Jung et al., 2020; Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; Zucchella et al., 2014). Three of the interventions were administered in a hospital (Carter et al., 1983; Cho et al., 2015; Cho et al., 2016). Besides, four of the interventions were self-administered at home (van de Ven et al., 2017; Wentink et al., 2016; Westerberg et al., 2007; Withiel et al., 2019).

The reviewed studies trained a variety of cognitive domains. An overview of the trained domains can be found in the table below (Table 1). The most targeted domain was attention, which was trained by 11 studies. This is closely followed by memory, which was trained by nine studies. Furthermore, seven studies targeted visual-spatial skills and five studies targeted executive functions. Working memory was trained by three studies and concentration (Cho et al., 2015; Cho et al., 2016) and calculation (Gamito et al., 2017) were targeted by a small minority of studies.

Table 1

Trained cognitive domains

Study	Att.	Mem.	VS	EF	WM
Carter et al. (1983)			×		
Chen et al. (2015)	×	×	×	×	
Cho et al. (2015)	×				
Cho et al. (2016)	×	×			

Study	Att.	Mem.	VS	EF	WM
Gamito et al. (2017)	×		×	×	×
Hasanzadeh et al. (2020)	×	×			
Jung et al. (2020)	×	×			
Prokopenko et al. (2013)	×		×		
Prokopenko et al. (2018)		×	×		
Prokopenko et al. (2019)	×	×	×		
van de Ven et al. (2017)	×			×	×
Wentink et al. (2016)	×	×		×	
Westerberg et al. (2007)					×
Withiel et al. (2019)		×			
Zucchella et al. (2014)	×	×	×	×	

Note. Att. = Attention, Mem. = Memory, VS = Visual-spatial skills, EF = Executive functioning, WM = Working memory, × = the domain was trained by the study

Outcome measures

Cognitive outcome measures. All studies assessed cognition with cognitive outcome measures. As an exception, Cho et al. (2016) assessed cognitive functioning with a submeasure of the Functional Independence measure (FIM) that measures cognitive functioning. The most frequently used outcome measures for cognition were the Mini-Mental State Examination (MMSE; Jung et al., 2020; Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; Zucchella et al., 2014) and the Montreal Cognitive Assessment (MoCA; Chen et al., 2015; Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019) which were used to measure overall cognitive functioning. A complete list of the cognitive measures used by each study can be found in Supplementary Table 1 (Appendix A).

Daily functioning measures. Activities of daily living were assessed by six studies. Independent daily functioning was on the one hand assessed with the Functional Independence Measure (FIM) by Cho et al. (2016) and Zucchella et al. (2014) and on the other hand with measures for independent activities for daily living (IADL) by Prokopenko et al. (2013), Prokopenko et al. (2018), Prokopenko et al. (2019), and van de Ven et al. (2017).

Perceived functioning in daily life. Subjective cognitive functioning was assessed by four studies. Three of the studies used the Cognitive Failure Questionnaire (CFQ) which measures subjective cognitive failures (van de Ven et al., 2017; Wentink et al., 2016; Westerberg et al., 2007). Other measures that assessed subjective cognitive functioning were the Dysexecutive Functioning Questionnaire (DEX; van de Ven et al., 2017), the Everyday Memory Questionnaire-Revised (EMQ-R; Withiel et al., 2019), and the Comprehensive Assessment of Prospective Memory (CAPM; Withiel et al., 2019). Estimates by proxy were also assessed by two studies that administered the CFQ and the DEX (van de Ven et al., 2017) and the CAPM (Withiel et al., 2019) to a significant other. Quality of life was measured by two studies (Prokopenko et al., 2013; Wentink et al., 2016) with the Stroke-Specific Quality of Life Scale (SSQoL).

Risk of Bias

The majority of studies was judged to be at high risk of bias (Chen et al., 2015; Cho et al., 2015; Cho et al., 2016; Gamito et al., 2017; Hasanzadeh Pashang et al., 2020; Jung et al., 2020; Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; Westerberg et al., 2007). Furthermore, four studies were judged to be at some risk of bias (Carter et al., 1983, van de Ven et al., 2017; Wentink et al., 2016; Zucchella et al., 2014). The only study that demonstrated good reporting of methodological quality (Withiel et al., 2019) was judged to be at low risk of bias.

Across all assessed domains, we often observed poor standard or lack of reporting methodological quality which resulted in a judgement of high risk of bias for those studies according to the tool. This was especially the case for risk of bias due to missing outcome data. The process of randomization and the measurement of the outcome did not raise concerns or raised only some concerns in the majority of studies. The selection of reported results was judged to be at some risk of bias in almost all studies. Bias due to deviations from the interventions were very variable, ranging from being at low risk of bias to high risk of bias.

Effect of the intervention on cognition

Overall cognition

An overview of all results can be found below in Table 2. Results regarding improvement of overall cognition assessed with the MoCA or MMSE were mixed. On the one hand, three studies found significant improvements of the experimental groups in comparison to the control condition (Chen et al., 2015; Jung et al., 2020; Zucchella et al., 2014). On the other hand, four studies did not find significant improvement (Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; van de Ven et al., 2017).

Attention

In the domain of attention, the included studies showed contradicting evidence. Cho et al. (2015) and Gamito et al. (2017) found limited evidence for improved attention. This is further underlined by the findings from Prokopenko et al. (2019) and Wentink et al. (2016) who did not find improvements in attention skills. In contrast, the findings from Hasanzadeh Pashang et al. (2020), Prokopenko et al. (2013), and Zucchella et al. (2014) suggested that attention can be improved with cognitive training.

Memory

For memory, Chen et al. (2015), Cho et al. (2015), and Zucchella et al. (2014) reported significant differences between experimental and control conditions in favor of the experimental group. Despite, Zucchella et al. (2014) also found non-significant differences in verbal memory submeasures. In line with that, Gamito et al. (2017) found no differences between groups post-intervention for visual memory. The results by Withiel et al. (2019) for visual and verbal memory did also not provide evidence that cognitive training can improve memory functioning.

Executive functioning

Evidence that cognitive training can be effective at improving executive functioning came from Chen et al. (2015) and Prokopenko et al. (2013). However, the majority of studies which measured executive functioning suggested otherwise (Prokopenko et al., 2018; Prokopenko et al., 2019; van de Ven et al., 2017; Wentink et al., 2016; Westerberg et al., 2007). Zucchella et al. (2014) reported diverging results depending on the measurement.

Visual-spatial skills

Visual-spatial skills have been assessed by six of the studies. Carter et al. (1983) found that visual scanning and visual-spatial skills significantly improved in the experimental group in comparison with the control group. Prokopenko et al. (2013) and Westerberg et al. (2007) also found improvement of the experimental group compared to the control condition. Yet, the results of Prokopenko et al. (2018), Prokopenko et al. (2019), and Zucchella et al. (2014) showed no effect of cognitive training on this domain.

Working memory

Similar to the abovementioned cognitive domains, results on the improvement of working memory were also heterogeneous. According to the results of Gamito et al. (2017), Jung et al. (2020), and Westerberg et al. (2007) working memory improved significantly more in the experimental group. This is not supported by the findings of Wentink et al. (2016) and Withiel et al. (2019) who found no differences between groups on measures of visual and verbal working memory.

Effect of the intervention on functional outcomes

Daily functioning

In contrast to the mixed results regarding cognitive outcomes, results of daily functioning measures among different studies were in conformity with each other. All those studies found no significant differences between groups post-intervention.

The most often assessed outcome among the reviewed studies was the ability of completing independent activities of daily living. Prokopenko et al. (2013), Prokopenko et al. (2018), Prokopenko et al. (2019), and van de Ven et al. (2017) did not detect significant improvements in any of the groups on this measure. Neither the computerized cognitive training nor the control conditions that received at least standard rehabilitation with in some cases additional mock interventions resulted in improvements on this measure.

Cho et al. (2016) and Zucchella et al. (2014) measured the performance on basic activities of daily living and did not find significant differences between groups after the intervention either, but observed significant within-group improvements in all groups. Thus, their computerized training in the experimental conditions and standard rehabilitation in the control conditions resulted in significant improvements in all groups. However, this was not the case for Prokopenko et al. (2013), Prokopenko et al. (2018), Prokopenko et al. (2019), and van de Ven et al. (2017) with similar experimental and control conditions.

Perceived functioning in daily life

Perceived cognitive functioning in daily life as measured by the CFQ revealed mixed results. Van de Ven et al. (2017) and Wentink et al. (2016) did not find significant differences between groups after the intervention. This was also the case for perceived executive functioning on the DEX (van de Ven et al., 2017). Interestingly, van de Ven et al. (2017) found significant within-group improvements in all groups on the CFQ and DEX. Contradictory, Westerberg et al. (2007) did find significant improvement on the CFQ in the experimental group compared with the control condition. In line with that, subjective everyday memory functioning and prospective memory improved significantly in comparison with the control condition (Withiel et al., 2019). The authors observed significant differences between groups in favor of the cognitive training group in prospective memory evaluated by a close other which did however not last to follow-up measurement (Withiel et al., 2019). Furthermore, no significant differences between groups post-intervention were detected in quality-of-life measures (Prokopenko et al., 2013; Wentink et al., 2016).

Role of the therapist

Among the nine studies that measured functional outcomes, seven did not include a therapist (Prokopenko et al., 2013; Prokopenko et al., 2018; Prokopenko et al., 2019; van de Ven et al., 2017; Wentink et al., 2016; Westerberg et al., 2006; Withiel et al., 2019). Except for some short-term improvement in subjective memory functioning that was not maintained at follow-up (Withiel et al., 2019) and improvement of subjective cognitive functioning in one of the studies (Westerberg et al., 2007), no improvement in functional outcomes was observed in the absence of a therapist by the rest of those studies. For Cho et al. (2016) it was difficult to interpret whether a therapist was present during the training. They mention the presence of a therapist during the traditional rehabilitation but do not elaborate on the presence during the cognitive training or on qualification or tasks of the therapist in any detail. Here, the experimental group did not improve significantly more than the control conditions in activities of daily living.

The one study that mentioned the presence of a therapist and measured functional outcomes did not find evidence for significant differences between groups regarding improved functional outcomes as a result of the intervention (Zucchella et al., 2014). Aside from those findings, significant within-group improvements were observed in both conditions where the control condition had sessions with a psychologist about general topics on the same schedule as the experimental group that was guided by a neuropsychologist during the cognitive training (Zucchella et al., 2014).

Table 2

Overview results

Study	Mem.	Att.	WM	EF	VS	GC	FO	Therapist presence
Carter et al. (1983)					++		n.m.	unclear, probably yes
Chen et al. (2015)	+	+		+	+	+	n.m.	no
Cho et al. (2015)	++++	oo ++					n.m	no
Cho et al. (2016)						o	o	unclear, probably no
Gamito et al. (2017)	o	o +	+				n.m.	no
Hasanzadeh et al. (2020)		++					n.m.	unclear, probably yes
Jung et al. (2020)			++			+	n.m.	no
Prokopenko et al. (2013)		+		+	+	oo	oo	no
Prokopenko et al. (2018)				o	o	oo	o	no
Prokopenko et al. (2019)		o		o	o	oo	o	no
van de Ven et al. (2017)				oo		o	oooooo	no
Wentink et al. (2016)		o	ooo +	oo			oo	no
Westerberg et al. (2007)			++++	oo	+		+	no
Withiel et al. (2019)	ooooo		oo				oooo ++	no
Zucchella et al. (2014)	ooo +++	+++		oo	o	o	o	yes

Note. + = Significant improvement of the experimental condition in comparison with the controls, o = No significant improvement of the experimental condition in comparison with the controls, n.m.= Not measured, Mem. = Memory, Att. = Attention, WM = Working memory, EF = Executive functioning, VS = Visual-spatial skills, GC = Global Cognition, FO = Functional outcomes

Discussion

The aim of this systematic review was to explore the current state of knowledge in the literature regarding the question whether cognitive training could improve cognition and whether those could in turn generalize to improved functioning in daily life. The role of the therapist in this process was also investigated. Regarding functional outcomes, no improvements were observed in the ability to complete activities of daily living or in quality of life. Results regarding subjective cognitive functioning in daily life were divergent, but the majority of measures revealed no improvements. However, there was mostly no basis for generalization to functional outcomes due to lack of cognitive improvement. The role of the therapist remains unclear, yet the single study that measured both functional outcomes and involved a therapist in the intervention observed no significant functional improvements. Based on the fifteen studies we reviewed both questions could not be addressed at full length because little evidence is presently available on the topic of the current review and reporting of methodological quality in the reviewed studies was mostly poor.

Transfer of cognitive improvements to improved daily functioning

The present review found no improvements in the ability to complete activities of daily life. Van de Ven et al. (2016) reviewed the effect of computerized cognitive training on executive functioning among stroke patients and found mixed results on measures of activities of daily life. They observed some improvement on the one hand, as well as lack of improvement in a study that was also included in the present review on the other hand. Since executive functioning is especially influential on the completion of daily life activities (Leśniak et al., 2008), it might be that van de Ven et. al (2016) observed improved daily functioning because they examined the effect of interventions that targeted executive functioning in particular whereas the present review looked at cognitive interventions regardless of the targeted cognitive domain.

Regarding perceived functioning in daily life, the present review revealed mixed results. Two studies detected significant improvements of subjective cognitive functioning in daily life, whereas the majority of measures did not detect significant improvement in the rest of the studies. The review of van de Ven et al. (2016) found only within-group improvements, but no significant between-group differences in subjective cognitive functioning were observed by the authors which is in line with the predominantly not significant between-group results detected by the present review. Poulin et al. (2012) however, found unanimously improved self-perceived daily functioning in their review. Of the ten studies they reviewed, three studies were in line with our reviews' definition of cognitive training and measured functional outcomes. These three studies, amongst them also a study reviewed in the present systematic review (Westerberg et al., 2007), all observed improvements in subjective cognitive functioning post-intervention. Like van de Ven et al. (2016), they reviewed the effect of interventions specifically targeting executive functioning on both cognitive and functional outcomes among stroke patients, which might again explain the different results between their review and the present paper. However, their review also included studies that were not randomized controlled trials which might also explain the differences of the results. Besides, the present review did not observe significant improvements in quality of life as a result of the intervention. This is not in line with the results of van de Ven et al. (2016), who found significantly increased quality of life in their review. It might be that training executive functioning is more influential on quality of life than other cognitive domains. All in all, results regarding the improvement of functional outcomes with cognitive training varied per study and did not allow for firm conclusions.

Those mixed results, where the majority of studies did not find improved functional outcomes, can raise the question of why this variability occurred. Inherent to the idea of improving daily functioning with cognitive training via cognitive improvement is the actual observation of cognitive improvement. In line with this idea are the observations by the review by Poulin et al. (2012), where cognitive improvements formed the basis of all reported improved functional outcomes. Looking at the reviewed studies in the present paper, cognitive improvement could not always be observed in the first place which means that there is no basis for the generalization of improved daily functioning. This was the case for six of the nine studies that assessed functional outcomes. Note that this explanation cannot be transferred to all reviewed studies, as there are also two studies that observed cognitive improvement but no functional improvement and one study observed both cognitive and functional improvements. Similar variability was reported by van de Ven et al. (2016) which underlines our findings that it is still unclear whether and under which conditions improved functional outcomes can be the result of improved cognition.

Can the therapist facilitate generalization?

The only study reviewed here, that both involved a therapist and measured functional outcomes, found no significant results (Zucchella et al., 2014). They administered cognitive training in conjunction with the support of a therapist who provided strategy training in order to foster generalization. A single study is clearly not enough to be able to judge the effectiveness of this approach or to compare against the eight studies who did not involve a therapist. According to the results of a focus-group study, computerized cognitive training and therapist-provided strategy training are complementary components of cognitive rehabilitation for patients with acquired brain damage (Eriksson and Dahlin-Ivanoff, 2002) and for patients with schizophrenia (Bowie et al., 2020). Based on the clinicians' and patients' evaluations of the therapist-guided computerized cognitive training, Eriksson and Dahlin-Ivanoff (2002) concluded that computerized training can be effective at improving daily life functioning in patients with acquired brain damage, but only with the guidance of a therapist. Looking at our results, three of the reviewed studies administered cognitive exercise with the guidance of a therapist. Only Zucchella et al. (2014) assessed functional outcomes, where within-group improvements of the completion of activities of daily living could be observed but the experimental group did not improve significantly more than the controls on functional outcomes. The other two studies only assessed cognition (Carter et al., 1983; Hasanzadeh Pashang et al., 2020), where the experimental groups improved significantly in comparison to the control conditions. Due to the lack of functional outcome measures, there was no information available whether those two studies could have provided supporting evidence for administering cognitive exercise with the guidance of a therapist. This is especially detrimental to advancing the knowledge regarding the research question because in those studies cognitive improvements were observed that might have generalized to improved daily functioning but no measures were included to capture a possible transfer.

In line with Eriksson and Dahlin-Ivanoff (2002), Wentink et al. (2018) also highlight the importance of the involvement of a therapist. Supervision provided by a therapist can be beneficial by increasing the adherence to a self-administered restitution-based intervention. Twelve out of 14 of the reviewed studies administered this type of intervention but little information was provided about the adherence to the training. Wentink et al. (2018) found that the supervision of the therapist led to a 36 % adherence rate of the experimental group in comparison to a 10 % adherence rate in the control group. Withiel et al. (2019), a study included in the present review, addressed this topic and found only minimal differences in completion of the training between the groups where one intervention was characterized by close assistance of a therapist and the other was self-administered. In order to be able to make conclusions about this topic, more than one study needs to be consulted. Based on the findings of Wentink et al. (2018), it may still be that this type of intervention that does not provide therapist support can be difficult to adhere to as intended by up to 90% of the patients. Therefore, we have to ask if the trend towards self-administered computerized cognitive training is observed because of the therapeutic value of the treatment or if practical factors, such as easy administration and saving costs, predominate the popularity of this type of intervention. Unfortunately, even the most effective intervention might lose all its worth when the administration mode is inapplicable in practice.

Exploring reasons for the lack of evidence

Our literature search revealed that including a search term for functional outcomes reduced the number of results from 7103 results to 1049 results. This observation that functional outcomes are not commonly assessed in cognitive rehabilitation for stroke patients is not a new discovery. In order to show that cognitive rehabilitation can be effective at improving functional outcomes, cognitive and functional outcome measures need to be assessed likewise, and this need has long been pointed out (Cappa et al., 2005). Interestingly, Carter et al. (1983) recognized that the cognitive skills that they trained in their study are highly relevant for functioning in daily life. Despite this recognition, the paper of Carter et al. (1983) which was included in the present review, did not include measures capturing daily functioning. One can criticize this approach and question why the importance of the trained cognitive skills for daily functioning was described by the authors, yet no functional measurements were included. Researchers being aware of the functional aspect of cognition in daily life but not adapting their research accordingly leads to impactful deficiencies in knowledge that would be necessary for providing effective interventions and training to patients affected by cognitive and functional impairments.

Van Heugten et al. (2012) recognized the need to determine the effective elements of cognitive rehabilitation for patients with acquired brain injury and took initiative on developing an international checklist to promote the standardization of cognitive rehabilitation. Other fields of research like schizophrenia are also aware of this necessity and have established expert working groups to identify the components of effective treatment (Bowie et al., 2020). In that context, the trained therapist has been identified as a crucial component of rehabilitation (Bowie et al., 2020). In the present review, a trained therapist did rarely play a relevant role in the reviewed studies. This appears to be in line with the current state of knowledge in the stroke literature where only little effort has been made to identify the therapist as a crucial component in facilitating the transfer of cognitive improvements to daily functioning. In line with that, van Heugten et al. (2012) reviewed the content of cognitive rehabilitation in acquired brain injury and made a similar observation. The authors found that none of the 95 papers described the role or the competencies of the involved staff in detail and that 23% of the studies provided no information on the clinicians at all. Given that similar observations have been made now and approximately ten years ago, we can conclude that this problem has not been tackled sufficiently in the meantime.

Self-administered cognitive training and the therapist – are they mutually exclusive?

The present review found that research practice might even tend to lean towards the opposite approach of specifically excluding a therapist by focusing on the evaluation of the efficacy of self-administered computerized cognitive training. From clinical experience, we know that computerized cognitive training is a frequently used intervention in clinical practice. The literature agrees that this approach, which emerged in the years around the last turning of the century (Spreij et al., 2014), is a frequently administered and increasingly popular intervention (Sigmundsdottir et al., 2016). In clinical practice, the opportunities for providing individually tailored strategies or support by a therapist during the cognitive training might be limited due to lack of time and trained personnel. It appears that researchers are well aware of those practical limitations in the rehabilitation setting and therefore aim at developing interventions that take into account those limitations. Jung et al. (2020) aimed at delivering a self-administered training that is effective specifically without the involvement of a therapist. Likewise, the research group of Prokopenko and colleagues noted that there is a need for approaches where the patient can train independently because the availability of one-to-one interventions with a therapist is limited, even though they described the one-to-one training as the gold standard of clinical practice. Furthermore, they promoted computerized cognitive training as a promising intervention because of its convenience in implementation due to the possibility of training independently. Since their studies were part of the group of six out of eight studies that administered the intervention without a therapist and found no improvements in functional outcomes at all, one can conclude that there is room for improving these interventions. In order for patients to understand how cognitive impairments can affect daily life functioning and to learn about strategies regarding memory difficulties or emotion regulation and how to transfer them to daily life, a therapist is necessary (Eriksson and Dahlin-Ivanoff, 2002). Learning and applying those strategies are seen as skills that cannot be derived by the patients from the computer program alone (Eriksson and Dahlin-

Ivanoff, 2002). Poulin et al. (2017) investigated the effect of cognitive interventions that were therapist-guided and found improvements in both functional and cognitive outcomes. Further support comes from the findings of Withiel et al. (2019). The authors found that a therapist-guided intervention targeting memory skills led to improved everyday memory functioning. Since relying on the active involvement of a therapist has shown its effectiveness (Eriksson and Dahlin-Ivanoff, 2002; Poulin et al., 2017; Withiel et al., 2019), we should critically ask whether the current trend of focusing primarily on self-administered interventions due to practical obstacles is acceptable.

Recommendations for Future Research

Future randomized controlled trials should compare the effect of cognitive training with and without the guidance of a therapist on both cognitive and functional outcomes in stroke patients. Furthermore, the heterogeneity of cognitive impairments may affect the type and extent of limitations in daily functioning. Therefore, future research should investigate the effect of cognitive training on daily functioning per cognitive subdomain before determining its effectiveness in general.

Poor methodological quality appears to be an ongoing problem in this field of research (Cappa et al., 2005; Loetscher et al., 2019), which can lead to mixed findings and inconsistent conclusions about generalization. For example, das Nair et al. (2016) reported in their review that they could not draw clear conclusions about the effectiveness of cognitive rehabilitation on functional outcomes because the available evidence mostly suffered from poor methodological quality. Fulfilling the need of methodologically qualitative studies with inclusion of measurement on the cognitive and functional level (Cappa et al., 2005) might sort out the mixed findings of past research and this review.

Strengths and limitations

A strength of this systematic review is that it is to our knowledge the first review that focused specifically on the role of the therapist in cognitive rehabilitation for stroke patients with regard to functional outcomes. The need for including functional outcomes and exploring effective components of cognitive rehabilitation has long been recognized by Cappa et al. (2005) and van Heugten et al. (2012). Our findings summarize the current deficient state of knowledge which calls for advancing the exploration of effective components of cognitive rehabilitation in stroke patients once more.

This review also has its limitations. Due to the exploratory nature of the research question, we were aware in advance of the literature search that it might reveal a limited number of studies that would contribute to answering the questions. As discussed elaborately above, the research questions could not fully be answered. It might be a possibility that there simply were not enough studies to detect or that our search did not capture all relevant studies. Despite careful considerations regarding the search terms, not all studies that were found beforehand with manual searching in the context of exploring the literature, were also captured in the actual literature search. Furthermore, due to the limited time capacities of this research project in the context of a master's thesis, the abstract and full-text screening and risk of bias assessment were not completed by multiple researchers. Also, most studies included were judged to be at risk of bias and their results should therefore be interpreted with caution.

Conclusion

Cognitive impairment is a frequent consequence after stroke. However, how to effectively treat cognitive impairment and the resulting functional limitations of stroke patients remains subject to review. Although functional improvement is considered to be the ultimate goal of rehabilitation and the lack of inclusion of functional outcomes has been criticized for many years, it does not currently appear to be standard practice to measure real-world functioning. The literature search therefore revealed only a limited amount of evidence, which made it difficult to draw solid conclusions on whether cognitive training can improve daily functioning and whether a trained therapist can facilitate this process. Future research should focus on assessing functional outcomes and including a therapist in order to understand which components of treatment interventions are effective in improving both cognition and daily functioning while taking into account the heterogeneity of impairments in the stroke population.

References

Ahn, S., Yoo, E., Jung, M., Park, H., Lee, J., & Choi, Y. (2017). Comparison of cognitive orientation to daily occupational performance and conventional occupational therapy on occupational performance in individuals with stroke: A randomized controlled trial. *NeuroRehabilitation, 40*(3), 285–292. https://doi-org.proxy-ub.rug.nl/10.3233/NRE-161416

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Biel, D., Steiger, T. K., Volkmann, T., Jochems, N., & Bunzeck, N. (2020). The gains of a 4-week cognitive training are not modulated by novelty. Human Brain Mapping, 41(10), 2596–2610. https://doi-org.proxy-ub.rug.nl/10.1002/hbm.24965

Borella, E., Cantarella, A., Carretti, B., De Lucia, A., & De Beni, R. (2019). Improving everyday functioning in the old-old with working memory training. *The American Journal of Geriatric Psychiatry, 27(9),* 975–983. https://doi-org.proxy-ub.rug.nl/10.1016/j.jagp.2019.01.210

Bowie, C. R., Bell, M. D., Fiszdon, J. M., Johannesen, J. K., Lindenmayer, J.-P., McGurk, S. R., Medalia, A.A., Penadés, R., Saperstein, A.M., Twamley, E.W., Ueland, T., & Wykes, T. (2020). Cognitive remediation for schizophrenia: an expert working group white paper on core techniques. *Schizophrenia Research, 215,* 49–53. https://doi.org/10.1016/j.schres.2019.10.047

Cappa, S. F., Benke, T., Clarke, S., Rossi, B., Stemmer, B., & van Heugten, C. M. (2005). EFNS guidelines on cognitive rehabilitation: Report of an EFNS task force. *European Journal of Neurology*, *12*(9), 665–680. https://doi.org/10.1111/j.1468-1331.2005.01330.x

Carter, L. T., Howard, B. E., & O'Neil, W. A. (1983). Effectiveness of cognitive skill remediation in acute stroke patients. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 37(5),* 320–6.

Chen, C., Mao, R., Li, S., Zhao, Y., & Zhang, M. (2015). Effect of visual training on cognitive function in stroke patients. *International Journal of Nursing Sciences*, *2*(4), 329–333. https://doi.org/10.1016/j.ijnss.2015.11.002

Cho, H. Y., Kim, K. T., & Jung, J. H. (2015). Effects of computer assisted cognitive rehabilitation on brain wave, memory and attention of stroke patients: A randomized control trial. *Journal of Physical Therapy Science*, *27*(4), 1029–32. https://doi-org.proxy-ub.rug.nl/10.1589/jpts.27.1029

Cho, H. Y., Kim, K. T., & Jung, J. H. (2016). Effects of neurofeedback and computer-assisted cognitive rehabilitation on relative brain wave ratios and activities of daily living of stroke patients: A randomized control trial. *Journal of Physical Therapy Science*, *28*(7), 2154–8. https://doi-org.proxy-ub.rug.nl/10.1589/jpts.28.2154

Chung, C.S.Y., Pollock, A., Campbell T., Durward B.R., & Hagen, S. (2013). Cognitive Rehabilitation for executive dysfunction in adults with stroke or other non-progressive acquired brain damage. *Cochrane Database of Systematic Reviews, Issue 4,* Art. No.: CD008391. doi:10.1002/14651858.CD008391.pub2.

Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., Kneipp, S., Ellmo, W., Kalmar, K., Giacino, J.T., Harley, J.P., Laatsch, L., Morse, P.A., & Catanese, J. (2005). Evidence-based cognitive rehabilitation: updated review of the literature from 1998 through 2002. *Archives of Physical Medicine and Rehabilitation, 86(8),* 1681–1692. https://doi.org/10.1016/j.apmr.2005.03.024

Cornelis, E., Gorus, E., Van Schelvergem, N., & De Vriendt, P. (2019). The relationship between basic, instrumental, and advanced activities of daily living and executive functioning in geriatric patients with neurocognitive disorders. *International Journal of Geriatric Psychiatry, 34(6),* 889–899. https://doi-org.proxy-ub.rug.nl/10.1002/gps.5087

Das Nair, R., Cogger, H., Worthington, E., & Lincoln, N. B. (2016). Cognitive rehabilitation for memory deficits after stroke. *The Cochrane Database of Systematic Reviews, 9,* 002293. https://doi.org/10.1002/14651858.CD002293.pub3

De Luca, R., Leonardi, S., Spadaro, L., Russo, M., Aragona, B., Torrisi, M., Maggio, M.G., Bramanti, A., Naro, A., De Cola, M.C., & Calabrò Rocco, S. (2018). Improving cognitive function in patients with stroke: can computerized training be the future? *Journal of Stroke and Cerebrovascular Diseases, 27(4),* 1055–1060. https://doi.org/10.1016/j.jstrokecerebrovasdis.2017.11.008

De Waard, D. (1996). *The Measurement of Drivers' Mental Workload* (Doctoral thesis) University of Groningen, Groningen

Douiri, A., Rudd, A. G., & Wolfe, C. D. (2013). Prevalence of poststroke cognitive impairment: South London stroke register 1995-2010. *Stroke, 44(1),* 138–45. https://doi.org/10.1161/STROKEAHA.112.670844

Duncan, P. W. (1994). Stroke disability. *Physical Therapy, 74(5),* 399–407.

Eriksson, M., & Dahlin-Ivanoff, S. (2002). How adults with acquired brain damage perceive computer training as a rehabilitation tool: A focus-group study. *Scandinavian Journal of Occupational Therapy, 9*(3), 119–129. https://doi-org.proxy-ub.rug.nl/10.1080/11038120260246950

Faria, A. L., Andrade, A., Soares, L., & I Badia, S. B. (2016). Benefits of virtual reality based cognitive rehabilitation through simulated activities of daily living: A randomized controlled trial with stroke patients. *Journal of Neuroengineering and Rehabilitation, 13(1),* 96. https://doi-org.proxy-ub.rug.nl/10.1186/s12984-016-0204-z

Flowers, H.L., Skoretz S.A., Silver, F.L., Rochon, E., Fang, J., Flamand-Roze, C., & Martino, R. (2016). Poststroke aphasia frequency, recovery, and outcomes: A systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation, 97*, 2188-2201.

Gamito, P., Oliveira, J., Coelho, C., Morais, D., Lopes, P., Pacheco, J., Brito, R., Soares, F., Santos, N., & Barata, A. F. (2017). Cognitive training on stroke patients via virtual reality-based serious games. *Disability and Rehabilitation*, *39*(4), 385–388. https://doi.org/10.3109/09638288.2014.934925

Gates, N., & Valenzuela, M. (2010). Cognitive exercise and its role in cognitive function in older adults. *Current Psychiatry Reports*, *12*(1), 20–27. https://doi.org/10.1007/s11920-009-0085-y

Hasanzadeh Pashang, S., Zare, H., Alipour, A., & Sharif-Alhoseini, M. (2020). The effectiveness of cognitive rehabilitation in improving visual and auditory attention in ischemic stroke patients. *Acta Neurologica Belgica*. https://doi.org/10.1007/s13760-020-01288-4

Jung, H.-T., Daneault, J.-F., Nanglo, T., Lee, H., Kim, B., Kim, Y., & Lee, S. I. (2020). Effectiveness of a serious game for cognitive training in chronic stroke survivors with mild-to-moderate cognitive impairment: A pilot randomized controlled trial. *Applied Sciences*, *10*(19), 6703–6703. https://doi.org/10.3390/app10196703

Leśniak M., Bak, T., Czepiel, W., Seniów Joanna, & Członkowska, A. (2008). Frequency and prognostic value of cognitive disorders in stroke patients. *Dementia and Geriatric Cognitive Disorders, 26(4),* 356–363. https://doi.org/10.1159/000162262

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., Clarke, Clarke, M., Devereaux, P.J., Kleijnen, J., Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Medicine*, *6*(7), e1000100.

Lo, C. D., Lopez, G., & Corrao, S. (2016). Cognitive impairment and stroke in elderly patients. *Vascular Health and Risk Management, 12,* 105–16. https://doi.org/10.2147/VHRM.S75306

Loetscher, T., Potter, K.J., Wong, D., & das Nair, R. (2019). Cognitive rehabilitation for attention deficits following stroke. *Cochrane Database of Systematic Reviews, Issue 11,* Art. No.: CD002842. doi:10.1002/14651858.CD002842.pub3.

Lundqvist, A., Grundström, K., Samuelsson, K., & Rönnberg, J. (2010). Computerized training of working memory in a group of patients suffering from acquired brain injury. *Brain Injury, 24(10),* 1173–1183. https://doi-org.proxy-ub.rug.nl/10.3109/02699052.2010.498007

Lynch, B. (2002). Historical review of computer-assisted cognitive retraining. *The Journal of Head Trauma Rehabilitation*, *17*(5), 446–57.

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). Pico, picos and spider: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *Bmc Health Services Research*, *14*(1). https://doi.org/10.1186/s12913-014-0579-0

Patel, M., Coshall, C., Rudd, A. G., & Wolfe, C. D. (2003). Natural history of cognitive impairment after stroke and factors associated with its recovery. *Clinical Rehabilitation, 17(2),* 158–66.

Poulin, V., Korner-Bitensky, N., Bherer, L., Lussier, M., & Dawson, D. R. (2017). Comparison of two cognitive interventions for adults experiencing executive dysfunction post-stroke: A pilot study. *Disability and Rehabilitation*, *39*(1), 1–13. https://doi.org/10.3109/09638288.2015.1123303

Poulin, V., Korner-Bitensky, N., Dawson, D. R., & Bherer, L. (2012). Efficacy of executive function interventions after stroke: A systematic review. *Topics in Stroke Rehabilitation*, *19*(2), 158–171. https://doi-org.proxy-ub.rug.nl/10.1310/tsr1902-158

Prokopenko, S. V., Mozheyko, E. Y., Petrova, M. M., Koryagina, T. D., Kaskaeva, D. S., Chernykh, T. V., Shvetzova, I. N., & Bezdenezhnih, A. F. (2013). Correction of post-stroke cognitive impairments using computer programs. *Journal of the Neurological Sciences*, *325*(1-2), 148–153. https://doi-org.proxy-ub.rug.nl/10.1016/j.jns.2012.12.024

Prokopenko, S. V., Bezdenezhnykh, A. F., Mozheyko, E. U., & Petrova, M. M. (2018). A comparative clinical study of the effectiveness of computer cognitive training in patients with post-stroke cognitive impairments without dementia. *Psychology in Russia: State of the Art*, *11*(2), 55–67. https://doi-org.proxy-ub.rug.nl/10.11621/pir.2018.0205

Prokopenko, S. V., Bezdenezhnykh, A. F., Mozheyko, E. Y., & Zubrickaya, E. M. (2019). Effectiveness of computerized cognitive training in patients with poststroke cognitive impairments. *Neuroscience and Behavioral Physiology*, *49*(5), 539–543. https://doi-org.proxy-ub.rug.nl/10.1007/s11055-019-00767-3

Rogers, J. M., Foord, R., Stolwyk, R. J., Wong, D., & Wilson, P. H. (2018). General and domain-specific effectiveness of cognitive remediation after stroke: Systematic literature review and meta-analysis. *Neuropsychology Review, 28(3),* 285–309. https://doi-org.proxy-ub.rug.nl/10.1007/s11065-018-9378-4

Registration. PRISMA - Transparent reporting of systematic reviews and meta-analyses. Retrieved June, 30 2021 from http://www.prisma-statement.org/Protocols/Registration

Sachdev, P. S., Blacker, D., Blazer, D. G., Ganguli, M., Jeste, D. V., Paulsen, J. S., & Petersen, R. C. (2014). Classifying neurocognitive disorders: The DSM-5 approach. *Nature Reviews Neurology, (2014 09 30).* https://doi.org/10.1038/nrneurol.2014.181

Sigmundsdottir, L., Longley, W. A., & Tate, R. L. (2016). Computerised cognitive training in acquired brain injury: A systematic review of outcomes using the International Classification of Functioning (ICF). *Neuropsychological Rehabilitation, 26(5–6),* 673–741. https://doi-org.proxy-ub.rug.nl/10.1080/09602011.2016.1140657

Sira, C.S., & Mateer, C.A. (2014). Executive Function. *Encyclopedia of the Neurological Sciences (Second Edition),* 239-242. https://doi.org/10.1016/B978-0-12-385157-4.01147-7

Sivolap, Y. P., & Damulin, I. V. (2020). Stroke and depression. *Neuroscience and Behavioral Physiology, 50(6),* 683–686. https://doi-org.proxy-ub.rug.nl/10.1007/s11055-020-00955-6

Smith, D. L. (2015). Does type of disability and participation in rehabilitation affect satisfaction of stroke survivors? Results from the 2013 Behavioral Risk Surveillance

System (BRFSS). *Disability and Health Journal, 8(4),* 557–563. https://doi-org.proxy-ub.rug.nl/10.1016/j.dhjo.2015.05.001

Spreij, L. A., Visser-Meily, J. M. A., van Heugten, C. M., & Nijboer, T. C. W. (2014). Novel insights into the rehabilitation of memory post acquired brain injury: A systematic review. *Frontiers in Human Neuroscience, 8*. https://doi.org/10.3389/fnhum.2014.00993

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H. Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … , & Higgins, J. P. T. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. *The BMJ, 366,* (l4898). https://doi.org/10.1136/bmj.l4898

Stolwyk, R. J., Mihaljcic, T., Wong, D. K., Chapman, J. E., & Rogers, J. M. (2021). Poststroke cognitive impairment negatively impacts activity and participation outcomes: A systematic review and meta-analysis. *Stroke, 52(2),* 748–760. https://doi.org/10.1161/STROKEAHA.120.032215

van de Ven, R. M., Buitenweg, J. I. V., Schmand, B., Veltman, D. J., Aaronson, J. A., Nijboer, T. C. W., Kruiper-Doesborgh, S. J. C., van Bennekom, C. A. M., Rasquin, S. M. C., Ridderinkhof, K. R., & Murre, J. M. J. (2017). Brain training improves recovery after stroke but waiting list improves equally: A multicenter randomized controlled trial of a computer-based cognitive flexibility training. *Plos One*, *12*(3), 0172993. https://doi.org/10.1371/journal.pone.0172993

van de Ven, R. M., Murre, J. M. J., Buitenweg, J. I. V., Veltman, D. J., Aaronson, J. A., Nijboer, T. C. W., Kruiper-Doesborgh, S. J. C., van Bennekom, C. A. M., Ridderinkhof, K. R., & Schmand, B. (2017). The influence of computer-based cognitive flexibility training on subjective cognitive well-being after stroke: A multi-center randomized controlled trial. *Plos One*, *12*(11), 0187582. https://doi.org/10.1371/journal.pone.0187582

van de Ven, R. M., Murre, J. M. J., Veltman, D. J., & Schmand, B. A. (2016). Computer-based cognitive training for executive functions after stroke: A systematic review. *Frontiers in Human Neuroscience*, *10*. doi: 10.3389/fnhum.2016.00150

van der Kemp, J., Kruithof, W. J., Nijboer, T. C. W., van Bennekom, C. A. M., van Heugten, C., & Visser-Meily, J. M. A. (2019). Return to work after mild-to-moderate stroke: Work satisfaction and predictive factors. *Neuropsychological Rehabilitation, 29(4),* 638–653.

van Heugten, C., Caldenhove, S., Crutsen, J., & Winkens, I. (2020). An overview of outcome measures used in neuropsychological rehabilitation research on adults with acquired brain injury. *Neuropsychological Rehabilitation*, *30*(8), 1598–1623. https://doi.org/10.1080/09602011.2019.1589533

van Heugten, C. M., Wolters Gregório, G., & Wade, D. (2012): Evidence-based cognitive rehabilitation after acquired brain injury: A systematic review of content of treatment *Neuropsychological Rehabilitation*, *22*(5), 653-673. http://dx.doi.org/10.1080/09602011.2012.680891

Vita, A., Barlati, S., Ceraso, A., Nibbio, G., Ariu, C., Deste, G., & Wykes, T. (2021). Effectiveness, core elements, and moderators of response of cognitive remediation for schizophrenia: A systematic review and meta-analysis of randomized clinical trials. *Jama Psychiatry*, *78*(8), 848–858. https://doi.org/10.1001/jamapsychiatry.2021.0620

Wentink, M. M., Berger, M. A. M., de Kloet, A. J., Meesters, J., Band, G. P. H., Wolterbeek, R., Goossens, P.H., & Vliet Vlieland, T. P. M. (2016). The effects of an 8-week computer-based brain training programme on cognitive functioning, QoL and self-efficacy after stroke. *Neuropsychological Rehabilitation, 26(5-6),* 847–865. https://doi.org/10.1080/09602011.2016.1162175

Wentink, M. M., Meesters, J., Berger, M. A. M., de Kloet, A. J., Stevens, E., Band, G. P. H, Kromme, C.H., Wolterbeek, R., Goossens P. H., & Vliet Vlieland, T. P. M. (2018): Adherence of stroke patients with an online brain training program: The role of health professionals' support. *Topics in Stroke Rehabilitation.* https://doi.org/10.1080/10749357.2018.1459362

Wesselhoff, S., Hank, T.A., & Evans, C.C. (2018). Community mobility after stroke: A systematic review. *Topics in Stroke Rehabilitation.* doi: 10.1080/10749357.2017.1419617

Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Östensson, M.-L., Bartfai, A., & Klingberg, T. (2007). Computerized working memory training after stroke - A pilot study. *Brain Injury, 21(1),* 21–29. https://doi-org.proxy-ub.rug.nl/10.1080/02699050601148726

Withiel, T. D., Wong, D., Ponsford, J. L., Cadilhac, D. A., New, P., Mihaljcic, T., & Stolwyk, R. J. (2019). Comparing memory group training and computerized cognitive training for improving memory function following stroke: A phase II randomized controlled trial. *Journal of Rehabilitation Medicine, 51*(5), 343–351. https://doi.org/10.2340/16501977-2540

World Health Organization. (n.d.) *Global Health Estimates: Life expectancy and leading causes of death and disability.* https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates

Ye, M., Zhao, B., Liu, Z., Weng, Y., & Zhou, L. (2020). Effectiveness of computer-based training on post-stroke cognitive rehabilitation: A systematic review and meta-analysis. *Neuropsychological Rehabilitation*, *1-17*, 1–17. https://doi.org/10.1080/09602011.2020.1831555

Yoo, C., Yong, M. H., Chung, J., & Yang, Y. (2015). Effect of computerized cognitive rehabilitation program on cognitive function and activities of living in stroke patients. *Journal of Physical Therapy Science, 27(8)*, 2487–9. https://doi.org/10.1589/jpts.27.2487

Zakariás L., Kelly, H., Salis, C., & Code, C. (2019). The methodological quality of short-term/working memory treatments in poststroke aphasia: A systematic review. *Journal of Speech, Language, and Hearing Research, 62(6),* 1979–2001.

Zucchella, C., Capone, A., Codella, V., Vecchione, C., Buccino, G., Sandrini, G., Pierelli, F., & Bartolo, M. (2014). Assessing and restoring cognitive functions early after stroke. *Functional Neurology*, *29*(4), 255–262.

Appendix A

Table S1

Study characteristics

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
Carter et al., 1983	RCT	33 (16:17) stroke patients	Cognitive skills remediation (Thinking skills workbook), 3 sessions per week over 3 to 4 weeks, hospital stroke programme	None, TAU	Visual scanning, visual-spatial skills, time-judgement	Visual scanning, visual-spatial matching, time estimation	Cognition: Experimental group showed significant improvement in visual scanning, visual-spatial orientation and time-judgement skills in comparison with control group
Chen et al., 2015	RCT	80 (40:40) ischemic and hemorrhagic stroke patients	Visual training (BrainHQ) 5 sessions per week over 5 weeks	None, TAU	Visual-spatial skills, EF, attention, memory	MoCA	Cognition: Experimental group showed significant improvement on all measured domains in comparison with control group
Cho et al., 2015	RCT	25 (12:13) stroke patients	Computer-assisted cognitive rehabilitation (RehaCom), semi-weekly sessions over 6 weeks	None, TAU	Attention, concentration	DST, VST, VCPT, ACCPT	Cognition: significant improvement in memory and partly visual attention, but not on auditory attention in comparison with the control group

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
Cho et al., 2016	RCT	44 (14:14:16) stroke patients	Computer-assisted cognitive rehabilitation (RehaCom), 2 sessions per week over 6 weeks	None, TAU	Attention, concentration, memory	FIM	Cognition: no significant improvement of the experimental group in comparison to the control group Functional outcome: no significant differences between groups
Gamito et al., 2017	RCT	20 (10:10) stroke patients	Cognitive training with virtual-reality based serious games (CopeLabs), 2 to 3 sessions per week over 4 to 6 weeks	None, waiting list	WM, visual-spatial skills, attention, memory	WMS, TPT, ROCF	Cognition: Significant improvements in the experimental group on working memory measures in comparison with the control group, this was the case only for a submeasure of sustained attention and not the case for visual memory outcomes
Hasanzadeh et al., 2020	RCT	20 (10:10), ischemic stroke patients	Cognitive Rehabilitation with Workbook of Powell, 1 session per week over 8 weeks	None, TAU	Memory, attention	IVA+Plus	Cognition: Experimental group improved significantly on visual and auditory attention in comparison with the control group

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
Jung et al., 2020	RCT	29 (14:15), ischemic and hemorrhagic stroke patients	Cognitive training with self-administered serious games (NeuroWorld), twice a week over 12 weeks	None, standard medical care	Memory, attention	MMSE, DBS, DFS, GDS	Cognition: Significant difference between groups on working memory measures and overall cognition in favor of the experimental group
Prokopenko et al., 2013	RCT	43 (24:19), stroke patients	Neuropsychological computer training (Shulte's table and figure background test), 7 days a week over 2 weeks	None, TAU	Attention, visual-spatial skills	MMSE, MoCA, CDT, FAB, Shulte's Table, IADL, SS-QoL- 2	Cognition: experimental group improved significantly on EF, visual-spatial and attention measures compared with the control group, but not on overall cognition Functional outcomes: no significant differences between groups in measures of quality of life and independent functioning in daily life

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
Prokopenko et al., 2018	RCT	26 (10:6:9), ischemic stroke patients	Neuropsychological computer games (KrasSMU based on Luria), 7 days a week for 10 days	Active: entertaining computer programs with TAU Passive: none, waiting list	Visual-spatial skills, visual and spatial memory	MMSE, MoCA, CDT, FAB, IADL	Cognition: no significant improvement of the experimental group in comparison with the active control group on visual-spatial skills, overall cognition and EF Functional outcomes: no significant differences between groups for IADL
Prokopenko et al., 2019	RCT	68 (23:19:26), ischemic stroke patients	Neuropsychological computer programs (Shulte's table, figure background test, clock hands position test), 7 days a week over 10 days	Active: distracting computer games with TAU Passive: none with TAU	Spatial skills, attention, visual memory	MMSE, MoCA, CDT, FAB, Shulte's Table,	Cognition: no significant improvement of the experimental group in comparison with the active control group on visual-spatial skills, attention, overall cognition and EF Functional outcomes: no significant improvements of the experimental group in comparison with the control groups for functional state (IADL measure)

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
van de Ven et al., 2017	RCT	97 (38:35:24) stroke patients	Computer-based cognitive flexibility training (Braingymmer), 5 sessions per week over 12 weeks	Active: mock training Passive: none, waiting list	EF, attention, reasoning, WM	EF and overall functioning measures, CFQ, DEX, IADL, HADS D	Cognition: no significant improvement of the experimental group in EF, cognitive flexibility or overall cognition Functional outcome: no significant differences between groups in subjective cognitive and executive functioning
Wentink et al., 2016	RCT	110 (53:57), ischemic and hemorrhagic stroke patients	Computer-based brain training (Lumosity), 5 sessions per week over 8 weeks	Education about stroke	Attention, memory, speed, flexibility, problem-solving	TMT, Raven SPM, Flanker Task, BST, DST, CFQ, SS-QoL	Cognition: no significant improvement in the experimental group compared to the controls in attention, flexibility and fluid intelligence measures, significant improvement in minor submeasures of WM and speed Functional outcomes: No significant differences between groups in subjective cognitive failure, quality of life

Authors	Methodology		Intervention				Results
	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	
Westerberg et al., 2007	RCT	18 (9:9), ischemic and hemorrhagic stroke patients	Computerized WM training (RoboMemo, CogMed), 5 sessions per week over 5 weeks	None, passive	WM	Span Board, Digit Span Test, Stroop Test, Raven, PASAT, Ruff, Word List Learning, CFQ	Cognition: Experimental group showed significant improvement in comparison with the control group on most WM measures but not on EF measures Functional outcomes: Significant difference between groups in favor of the control group in subjective cognitive failure
Withiel et al., 2019	RCT	41 (22:19) Mostly ischemic stroke patients	Computerized cognitive training (Lumosity), 5 sessions per week over 6 weeks	None, waiting list	Memory	RAVLT, BVMT-R, WAIS-IV, WMS-IV, RPAPProMem, CAPM, EMQ-R	Cognition: No significant differences between groups on all cognitive measures Functional outcome: Significant improvement of the experimental group in comparison with the control group on prospective memory judged by proxy and on goal attainment, both were not maintained at follow up. No significant differences between groups on everyday memory, self-perceived prospective memory and strategy use

	Methodology		Intervention				
Authors	Study design	Participants	Intervention therapy	Control therapy	Cognitive domain trained	Outcome measures	Results
Zucchella et al., 2014	RCT	87 (42:45), ischemic and hemorrhagic stroke patients	Computerized cognitive rehabilitation (Una palestra per la mente, Training di riabilitazione cognitive), 4 sessions per week over 4 weeks	Sessions with psychologist about general topics and TAU	EF, spatial and time orientation, visual attention, memory	MMSE, Digit Span, Corsi's Test, RAVLT, PM 47, TMT, FAB, Semantic and Phonological Fluency, Logical Memory and Attention Measures, Rey-Osterrieth Figure, FIM	Cognition: Significant improvement of experimental group in attentional measures and overall cognition and mixed results for memory measures. No significant differences between groups in language and visuo-constructive skills. Functional outcome: No significant differences between groups on functional independence

Note. MoCA = Montreal Cognitive Assessment, DST: Digit Span Test; VST: Visual Span Test; VCPT: Visual Continuous Performance Test; ACCPT: Auditory Controlled Continuous Performance Test , FIM = Functional Independence Measure, WMS=Wechsler Memory Scale, TPT = Toulouse–Piéron Test, ROCF = Rey Complex Figure, IVA+Plus = Integrated Visual and Auditory Continuous Performance test, DBS = Digit Backward Span (DBS) of the Wechsler Adult Intelligence Scale-IV, DFS = Digit Forward Span of the Wechsler Adult Intelligence Scale-IV, MMSE = Mini Mental State Examination, CDT=Clock Drawing Test, FAB=Frontal Assessment Battery, Shulte's Table, IADL=Instrumental Activities of Daily Living, SS-QoL- 2 = Stroke-Specific Quality of Life scale, CFQ = Cognitive Failure Questionnaire; DEX = Dysexecutive Functioning Questionnaire, TMT = Trail Making Test, Raven SPM = Raven Standard Progressive Matrices, Flanker task = Eriksen Flanker Task, BST = Block Span Task from Corsi, DST=Digit Span Task from Wechsler, Span board= Span Board from the Wechsler Adult Intelligence Scale-Revised NI (WAIS R-NI), Digit Span Test= Digit span from WAIS R, Stroop Test, Raven= Raven's Progressive Matrices, PASAT = Paced Auditory Serial Addition Test, Ruff = 2 and 7 Selective Attention Test, Word List Learning = Claeson-Dahl, RAVLT = Rey Auditory Verbal Learning Task, BVMT-R = Brief Visuospatial Memory Test-Revised, WAIS-IV = Wechsler Adult Intelligence Scale-IV, WMS-IV = Wechsler Memory Scale–IV, RPAPProMem = Royal Prince Alfred Prospective Memory Test, (EMQ-R = Everyday Memory Questionnaire-Revised, CAPM = Comprehensive Assessment of Prospective Memory), PM 47 = Progressive Matrices 47

Appendix B

Search term

PubMed
(
(“Cognitive”[tiab] OR “Cognition”[tiab] OR “Neurocognitive”[tiab] OR “Memory”[tiab] OR “Attention”[tiab] OR “Verbal Learning”[tiab] OR “Visual Learning”[tiab] OR “Vigilance”[tiab] OR “Reasoning”[tiab] OR “Problem Solving”[tiab] OR “Speed of Processing”[tiab] OR “Brain”[tiab] OR “Executive Function”[tiab] OR “Executive Functioning”[tiab])
AND
(“Training”[tiab] OR “Intervention”[tiab] OR “Remediation”[tiab] OR “Rehabilitation”[tiab] OR “Enhancement”[tiab] OR “Retraining”[tiab])
)

AND

("stroke"[tiab] OR "non-progressive acquired brain injury"[tiab] OR "CVA"[tiab] OR "cerebrovascular accident"[tiab] OR "brain ischemia"[tiab] OR "cerebral ischemia"[tiab] OR "hemorrhagic stroke"[tiab] OR "non-traumatic brain injury"[tiab] OR "NTBI"[tiab])

AND

(“randomly” OR “randomized” OR “randomised” OR “RCT” OR “Clinical Trial”)

PsycINFO
(
(“Cognitive” OR “Cognition” OR “Neurocognitive” OR “Memory” OR “Attention” OR “Verbal Learning” OR “Visual Learning” OR “Vigilance” OR “Reasoning” OR “Problem Solving” OR “Speed of Processing” OR “Brain” OR “Executive Function” OR “Executive Functioning”)
AND
(“Training” OR “Intervention” OR “Remediation” OR “Rehabilitation” OR “Enhancement” OR “Retraining”)
)

AND
("stroke" OR "non-progressive acquired brain injury" OR "CVA" OR "cerebrovascular accident" OR "brain ischemia" OR "cerebral ischemia" OR "hemorrhagic stroke" OR "non-traumatic brain injury" OR "NTBI")

AND
(“randomly” OR “randomized” OR “randomised” OR “RCT” OR “Clinical Trial”)

Cochrane

ID	Search
#1	("cognitive"):ti,ab,kw
#2	("cognition"):ti,ab,kw
#3	("neurocognitive"):ti,ab,kw
#4	("memory"):ti,ab,kw
#5	("attention"):ti,ab,kw

#6 ("verbal learning"):ti,ab,kw
#7 ("visual learning"):ti,ab,kw
#8 ("vigilance"):ti,ab,kw
#9 ("reasoning"):ti,ab,kw
#10 ("problem solving"):ti,ab,kw
#11 ("speed of processing"):ti,ab,kw
#12 ("brain"):ti,ab,kw
#13 ("executive functioning"):ti,ab,kw
#14 ("executive function"):ti,ab,kw
#15 {OR #1-#14}
#16 ("training"):ti,ab,kw
#17 ("intervention"):ti,ab,kw
#18 ("rehabilitation"):ti,ab,kw
#19 ("remediation"):ti,ab,kw
#20 ("enhancement"):ti,ab,kw
#21 ("retraining"):ti,ab,kw
#22 {OR #16-#21}
#23 #15 and #22
#24 "randomised"
#25 "randomized"
#26 "randomly"
#27 "clinical trial"
#28 "RTC"
#29 {OR #24-#28}
#30 #23 and #29
#31 ("stroke"):ti,ab,kw
#32 ("non-progressive acquired brain injury"):ti,ab,kw
#33 ("CVA"):ti,ab,kw
#34 ("cerebrovascular accident"):ti,ab,kw
#35 ("brain ischemia"):ti,ab,kw
#36 ("cerebral ischemia"):ti,ab,kw
#37 ("hemorrhagic stroke"):ti,ab,kw
#38 ("non-traumatic brain injury"):ti,ab,kw
#39 ("NTBI"):ti,ab,kw
#40 {OR #31-#39}
#41 #23 and #29 and #40