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Effects of cognitive training interventions on the cognitive and everyday functioning of older adults – systematic overview of meta-analyses

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Abstract: As the population is aging, the prevalence of age-related cognitive decline is now the highest in history, with a long-term trend of increase. Many studies have examined whether cognitive training (CT) is an effective intervention for preventing and slowing down the neurodegenerative processes of aging so as to enable independent functioning and active living in older age. In order to summarize the available data, we conducted a systematic literature overview of meta-analyses investigating the efficacy of various CT interventions on cognitive and subjective/functional outcomes in healthy older adults, older adults with mild cognitive impairment, and older adults with subjective memory/cognitive complaints. We searched six databases (Web of Science, Scopus, PsycINFO, MEDLINE, CINAHL, and Cochrane Library) and identified eight eligible meta-analyses. The quality of the included meta-analyses was assessed using the AMSTAR-2 checklist. The confidence ratings were "moderate" for one meta-analysis, "low" for two meta-analyses, and "critically low" for five meta-analyses. Although there is a need for better methodological standards for meta-analyses, the available evidence suggests that CT is an effective intervention for improving both cognitive and subjective/functional outcomes in older adults. Future research should be more oriented toward measures that indicate the practical efficiency of CT and should be more specific regarding the type of CT intervention, so as to elucidate the potentially different underlying mechanisms of their functioning.

Keywords: cognitive training, older adults, overview, meta-analysis

Učinki kognitivnega treninga na kognitivno in vsakodnevno funkcioniranje starejših odraslih – sistematični pregled metaanaliz

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Izvleček: Ker se prebivalstvo stara, je razširjenost s starostjo povezanega kognitivnega upada najvišja v zgodovini ob dolgoročnem trendu naraščanja. Številne študije ugotavljajo, ali je kognitivni trening (KT) učinkovita intervencija za preprečevanje in/ali upočasnitev nevrodegenerativnih procesov staranja ter omogočanje neodvisnega delovanja in aktivnega življenja v pozni odraslosti. Da bi povzeli podatke, ki so na razpolago, smo izvedli sistematičen pregled metaanaliz, ki so preučevale učinkovitost različnih intervencij s pomočjo KT na kognitivne in subjektivne/funkcionalne rezultate pri zdravih starejših odraslih, starejših odraslih z blago kognitivno motnjo in starejših odraslih s subjektivno kognitivno pritožbo. Preiskali smo šest podatkovnih zbirk (Web of Science, Scopus, PsycINFO, MEDLINE, CINAHL in Cochrane Library) in identificirali osem primernih metaanaliz. Kakovost vključenih metaanaliz je bila ocenjena s kontrolnim seznamom AMSTAR-2. Ocene zaupanja so bile »zmerno« za eno metaanalizo, »nizko« za dve metaanalizi in »kritično nizko« za pet metaanaliz. Čeprav se kaže očitna potreba po boljših metodoloških standardih za metaanalize, dobljeni rezultati kažejo, da je KT učinkovita intervencija za izboljšanje kognitivnega in vsakodnevnega funkcioniranja pri starejših odraslih. Prihodnje raziskave bi morale biti bolj usmerjene k meram vsakodnevne funkcionalnosti, ki bi kazale na praktično učinkovitost KT in biti bolj specifične glede vrste KT, da bi razumeli potencialno različne mehanizme njihovega delovanja.

Ključne besede: kognitivni trening, starejši odrasli, sistematični pregled, metaanalize

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The prevalence of cognitive decline, as a result of an aging population, is now the highest in history, with a long-term trend of increase, predicting that by 2050 the older population will outnumber the young in many developed countries, and the prevalence of dementia will double (Eurostat, 2021; Scheltens et al., 2021; Statista, 2022). With aging, cognitive functions such as memory, processing speed, spatial ability, and abstract reasoning decline significantly (Murman, 2015; Salthouse, 2012; Tucker-Drob, 2019), and one is more susceptible to a variety of age-related neuropathologies that result in faster cognitive deterioration and dementia (Boyle, et al., 2021; Willik, 2021). Despite many efforts, there is no effective cure for Alzheimer's disease, the most common form of dementia; therefore, early intervention that targets the at-risk population is of great importance in preventing and slowing down these neurodegenerative processes (Scheltens et al., 2021), and possibly extending the independent everyday life of the elderly and improving their quality of living.

Neuroscientific research in the context of cognitive reserve and similar concepts (Stern et al., 2020) has shown a discrepancy between an individual's expected cognitive performance and their particular level of age- and pathology-related brain changes (Reed et al., 2010; Stern, 2009), which could be explained by better efficiency, capacity, or flexibility of cognitive neural networks, as a result of cognitively demanding life exposures (Stern, 2012; Stern et al., 2020).

Such cognitively demanding activity, or cognitive training (CT), presents itself as an intervention that could potentially maintain or improve cognitive functions and everyday living despite neurodegenerative processes. The assumption behind CT is that one can enhance cognitive abilities such as processing speed, working memory, perceptual abilities, attention, or general intelligence through dedicated behavioral training (Green et al., 2019). CT includes cognitive tasks focused on a certain cognitive ability, usually working memory, or other executive functions. A CT regime can either be single-domain, when training only one cognitive ability, or multi-domain, when targeting different abilities (e.g., working memory and processing speed or executive function; Binder et al., 2015). Furthermore, one possible approach is process-based training that aims to enhance processes of cognitive functions by repetitive tasks, usually with adaptive difficulty to adjust to the person's ability (Deveau et al., 2015; Morrisom & Chein, 2011; von Bastian & Oberauer, 2014), while strategy-based training is focused on enhancing the efficacy of function as a result of knowledge and skill acquisition, as in the use of a specific memory strategy, chunk learning, etc. (Morrisom & Chein, 2011; von Bastian & Oberauer, 2014).

Many studies have analyzed the effects of various CT regimes, and many meta-analytic studies have been conducted on this topic. While there is relatively consistent evidence of "*near-transfer*" effects in trained or similar cognitive abilities (e.g., Melby-Lervåg et al. 2016), "*far-transfer*" effects of different CT regimes on non-trained abilities or broader "real-world" measures, such as well-being and activities of daily living, are inconsistent and therefore highly debated (e.g. Gobet and Sala, 2023; Green et al., 2019).

In order to contribute to the debate and clarify the potential effects on age- and pathology- related cognitive declines, the aim of our research was to synthesize the results from systematic literature reviews with meta-analysis regarding the effects of various CT interventions on cognitive functions and everyday functioning for the elderly population with a mean age of 50 or above, as it is around this age that the first signs of age-related cognitive deterioration occur (Willik et al., 2021). We separately inspected populations with different risks for dementia, from low to high risk: healthy elderly, those with subjective memory/cognitive complaints (SM/CC), and mildly cognitively impaired elderly (MCI).

Methods

This review was carried out following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (Page et al., 2021).

Registration and protocol

The review protocol was registered with the International Register of Systematic Reviews PROSPERO (ID: CRD42022302151).

Eligibility criteria

Studies based on the following criteria were included:

1. Types of study design: Our focus were systematic literature reviews with meta-analysis. Only studies with the statistical, quantitative combination of results providing effect size estimates (standardized mean difference; Cohen's *d*, Hedges *g*, odds ratio or correlation coefficient) were included. Narrative reviews or clinical trials were excluded.
2. Types of Population: Included were studies on adults with a mean age of 50 or above and, based on the cognitive status, studies with one or more of the following categories of participants: a) healthy adults, b) adults with subjective cognitive/memory complaints, and/or c) adults with mild cognitive impairment. Studies with participants whose mean age was below 50 were excluded, as well as studies with participants with moderate or severe cognitive impairment, dementia, or other neurological or psychiatric conditions or diseases.
3. Type of intervention: Studies with various types of CT were included:
   - process-based or strategy-based
   - training of specific cognitive functions (memory, reasoning, executive functions…) or multi-domain-training type of CT (including video games).

   Cognitively stimulating activities (playing instruments, meditation, mindfulness...) and other types of cognitive intervention (exercise, pharmacological treatment, etc.) were excluded, as were combinations of CT with those or other interventions.
4. Type of control group: Randomized and non-randomized trials (quasi-experiment) were eligible for our study, with the active or passive control group. Although randomized controlled trials provide the highest quality of evidence, in order to make a more comprehensive review, we also

included non-randomized studies, as a significant number of systematic reviews include this type of study design (Shea et al., 2017). Studies with no control group, case studies, and other types of studies were excluded.

5. Type of outcome: All measures of cognitive functioning were eligible. Apart from cognitive measures, our systematic literature review had to include at least one measure indicating everyday functioning or measure of well-being, quality of life, mood, or subjective measures of cognitive functioning, as we wanted to inspect the extent of the effects and the impact on everyday living. If only a part of a study met our criteria and provided separate analysis for those data, we included said data in our review.

Search strategy

A systematic literature search of six databases (Web of Science, Scopus, PsycINFO, MEDLINE, CINAHL, and Cochrane Library) was conducted on 27 January 2022 using predefined keywords (keywords and syntax are provided in Supplemental materials (Table 1).

Considering that most of the crucial scientific articles are in English, only English-language papers were included due to insufficient resources for article translation. An additional, manual search of the references of relevant studies (those included based on title and abstract) was conducted.

Selection of studies

Two reviewers (the first and third authors) independently screened titles and abstracts of initial references. Articles deemed eligible based on our inclusion/exclusion criteria were then retrieved and the two reviewers then read the full-text articles to make the final selection of studies. Any potential selection inconsistencies between the two authors were resolved by discussion and consultation with the second author.

Risk of bias assessment

The first and third authors independently assessed the quality of studies using the AMSTAR-2 checklist (Shea et al., 2017; AMSTAR - A Measurement Tool to Assess systematic Reviews). Any potential inconsistencies of evaluations were resolved by discussion between the authors. The AMSTAR-2 is a 16-item instrument for critically appraising systematic reviews of randomized and non-randomized trials. The following seven items inspect domains that can critically affect the validity of the review:

– ITEM 2: written protocol
– ITEM 4: comprehensive literature search strategy
– ITEM 7: list of excluded studies with justification of exclusions
– ITEM 9: assessing the risk of bias (RoB)
– ITEM 11: appropriate methods for statistical combination of results
– ITEM 13: accounting for RoB when interpreting/discussing the results
– ITEM 15: publication bias inspection.

Rating the overall confidence in the results of the reviews is not based on the generation of an overall score; rather, the quality is categorized by an evaluation of the critical and non-critical weaknesses of a review based on the following criteria:

– high confidence: if the review has no or one non-critical weakness
– moderate confidence: more than one non-critical weakness
– low confidence: one critical flow with or without non-critical weaknesses
– critically low confidence: more than one critical flaw with or without non-critical weaknesses.

If we analyzed only one part of the data in an article (in accordance with our eligibility criteria), then the assessment of the quality of studies was made only for that part of the article.

Data collection and data synthesis

The first and second authors designed preset tables for the extraction of relevant data from eligible studies. Data extraction was made by the first author, while the third author extracted a sample of eligible studies, and the data extraction agreement between the authors was 100 percent.

Tables of extracted data include:

– general information about studies: author/s, name of the article, publishing year, number of studies included in the meta-analysis, number of participants included in the meta-analysis;
– PICO components: type of population, type of intervention, type of control group(s), type of outcomes, type of randomization;
– results of statistical analysis: type of effect size calculation, effect sizes, confidence intervals, and statistical significance for effects on different outcome measures, by population, intervention, control group, and randomization.

Outcome measures were divided into two broad categories: cognitive outcomes and functional/subjective outcomes. The taxonomy was made through consultation with A Compendium of Neuropsychological Tests (Strauss et al., 2006). Cognitive functions: general cognitive functioning, executive functions, attention, memory, visual perception, language, and semantic knowledge. Subjective and objective measures of functioning: adaptive functioning, activities of daily living, psychosocial functioning, quality of life, subjective well-being, subjective memory, subjective cognitive functioning, and mood (depression, anxiety…).

Data was collected in Microsoft Excel. Only a narrow synthesis of the results was performed due to heterogeneity and insufficiency of data for statistical analysis.

Table 1
PICO elements of studies included in our review

Article N of studies	Population cognitive status/age	Intervention	Randomization/control group	Outcomes
(Basak et al., 2020) $N = 215$	HEALTHY AND MCI; criteria mean age 60 or above, mean age was 70 or above	– single component (memory, executive functions, processing speed, reasoning, or language) or multi-component (trained two or more cognitive abilities sequentially or simultaneously, including video game training) – strategy- and process- based CT	RCT; passive or active	COGNITIVE: 1) episodic memory (e.g., subsequent memory or associative learning; 2) executive functions (e.g., shifting, working memory capacity, updating, or inhibition; 3) processing speed (perceptual discrimination, attention or visual perception 4) short-term memory; 5) reasoning and 6) language and semantic knowledge FUNCTIONAL/SUBJECTIVE: 7) everyday functioning, encompassing both subjective measures and objective tests
(Bhome et al., 2018) $N = 11$	participants with subjective cognitive complaints; no age restrictions, but available data indicates age was >55	– single component (mainly memory training) and multidomain CT; – strategy- and process-based	RCT; passive or active	COGNITIVE: objective cognitive performance. FUNCTIONAL/SUBJECTIVE: Meta-cognition, psychological well-being
(Hill et al., 2017) $N = 17$	MCI; The criteria was the mean age of 60 years old, the range was 67-81 years	– predominantly multidomain training, only a few studies included single component training; – no information if process-based CT only or strategy based CT too – At least 4 hours of drill and practice, with a clear cognitive rationale, video games, or virtual reality, had to be completed. Studies combining CCT with other interventions were eligible if the control group received the same adjacent intervention. 50% or more had to be CCT or not involving interaction with a computer (e.g., merely watching stimuli).	RCT; Passive (no-contact, wait-list), active (e.g., sham CCT, psychoeducation), or pencil-and-paper CT was required.	COGNITIVE: global cognition, verbal and nonverbal learning, verbal or nonverbal memory, working memory, processing speed, attention, language, visuospatial skills, and executive function, overall efficacy on cognitive outcomes FUNCTIONAL/SUBJECTIVE: instrumental activities of daily living; psychosocial functioning: neuropsychiatric symptoms, quality of life, and depression; activities of daily living (analysis not performed due to lack of data)
(Kelly et al., 2014) $N = 31$	healthy, age >50	– single and multidomain training, but most common single domain memory-based training – strategy based and process based CT	RCT; passive or active	COGNITIVE: a) memory domain (recognition, immediate recall, delayed recall, face-name recall, and paired associates); b) executive functioning (working memory, verbal fluency, reasoning, attention and processing speed); composite measures of cognitive function FUNCTIONAL/SUBJECTIVE: subjective cognitive function

Table 1 (continued)

Article N of studies	Population cognitive status/age	Intervention	Randomization/control group	Outcomes
(Metternich et al., 2010) *N* = 8	participants with SMC or the desire to improve their memory performance, there was no age restriction criteria, but mean age was in range from 60-78	– single domain memory training, mainly strategy- based – teaching different kinds of mnemonics which are commonly practiced between sessions, and sometimes information about memory and memory systems is provided	RCT; placebo, waitlist	COGNITIVE: objective memory (mostly declarative verbal long-term memory measures, in 1 case verbal-visual task) FUNCTIONAL7SUBJECTIVE: subjective memory, depressive symptoms, well-being- subjective quality of life
(Nguyen et al., 2021) *N* = 43	older adults with or without mild cognitive impairment, criteria was mean sample age of 60 years and over, results: mean 71.68 years	mostly multidomain, process-based CT including seven commercial training programs: BrainHQ, CogMed (the only single domain), Cog-niFit, Lumosity, Dakim, My Brain Trainer, and BrainGymmer. All programs have an adaptive difficulty component. Most interventions took place at participants' homes (58%)	Most studies were RCT (93%), active or/and passive controls	COGNITIVE: attention, executive functioning, fluid intelligence, language, memory, processing speed, and visuospatial ability FUNCTIONAL/SUBJECTIVE: objective tasks of everyday functioning Subjective measures of everyday functioning (including measures of mood, well-being, and perceptions of cognitive functioning)
(Sheng et al., 2020) *N* = 9	participants with a diagnosis of SCD aged 55 years or older (criteria)	– single- and multi-domain CT targeting different cognitive functions (memory, attention,..) – process-based and strategy-based	RCT; any kind of control condition (e.g., active control, wait-list control)	COGNITIVE: objective memory performance (immediate recall, delayed recall, recognition, and total memory score), global cognitive function FUNCTIONAL/SUBJECTIVE: subjective memory performance, psychological well-being, mood (depression and anxiety).
(Tetlow & Edwards, 2017) *N* = 21	healthy adults aged 55 and older (at least 50% of participants)	– process based, mostly multidomain CT – 14 commercially available, computerized CT programs: FitBrains, Lumosity, Memorado, NeuroNation, Happy Neuron, CogniFit, Brain Training 101, Brain Train Memory Gym Series, Scientific Brain Training Pro-Aging Well, Brain HQ, CogMed, NeuroActive, Dakim, and NeoCORTA	passive or active	COGNITIVE: attention, executive function, memory, processing speed, reasoning, verbal fluency, and visuospatial memory. FUNCTIONAL/SUBJECTIVE: qualitative measures of everyday function (subjective participant rating of performance and beliefs about their abilities), quantitative measures of everyday function (performance-based tasks similar to those that participants complete in their every-day activities)

Results

Study Selection

As shown in Figure 1, the initial search of databases identified 3039 citations. After duplication removal, 1746 citations remained, of which 1705 were excluded based on titles and abstracts (a detailed list and reasons for exclusions can be found in Supplemental materials (Table 2). A full-text review of 41 articles and a reference search identified eight articles eligible for the review.

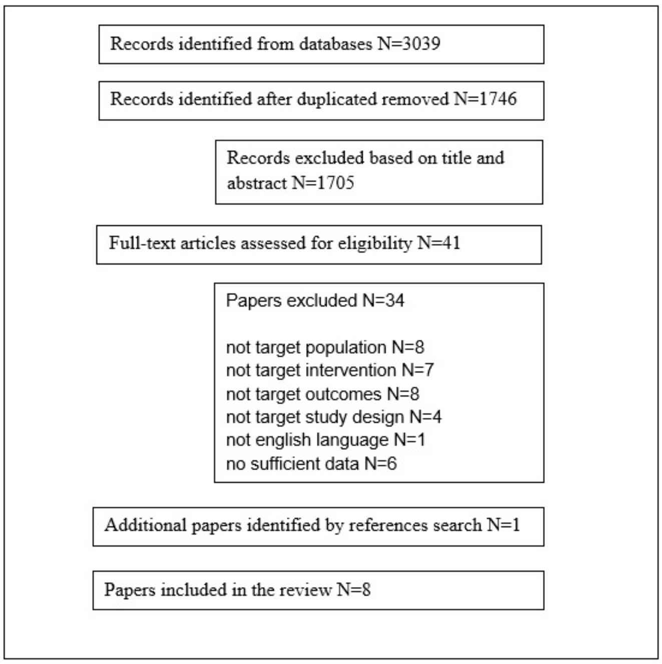
Characteristics of included reviews

The characteristics of the included systematic literature reviews with meta-analyses are presented in Table 1 and Table 2. The characteristics are described based on information regarding our inclusion criteria, available data, and our conclusions based on the available data. The latter mainly concerns the type of CT, as not all reviews used the (same) terminology for describing the type of CT.

The number of studies included in the meta-analyses ranged from 215 (of which 161 were healthy and 54 were with MCI) in a review by Basak and colleagues (Basak et al., 2020), to eight studies in a review by Metternich and colleagues (Metternich et al., 2010).

Type of population: Out of the eight meta-analyses, four reported data for healthy elderly reviews (Basak et al., 2020; Kelly et al., 2014; Nguyen et al., 2022; Tetlow & Edwards, 2017), three studies included elderly with MCI (Basak et al., 2020; Hill et al., 2017; Nguyen et al., 2022), and three studies comprise data for elderly with subjective memory (Metternich et al., 2010) or cognitive complaints (Bhome et al., 2018; Sheng et al., 2020).

Figure 1
Flow diagram for systematic literature review



Type of CT: Most of the reviews analyzed multidomain CT (*N* = 5) or presented combined results for single-domain and multidomain training (*N* = 6). Only one review (Basak et al., 2020) separately analyzed the effects of single-domain training for healthy elderly and for those with MCI, and only one study (Metternich et al., 2010) analyzed the effect of single-domain training in the population with SM/CC. For healthy elderly, two reviews analyzed process-based CT (Nguyen et al., 2022; Tetlow & Edwards, 2017), two presented data for combined process-based and strategy-based CT (Basak et al., 2020; Kelly et al., 2014), and none of the reviews showed separate results for strategy-based CT. Based on the available data, the reviews for elderly with MCI did not analyze the effects of strategy-based CT only. One review analyzed combined process-based and strategy-based CT (Basak et al., 2020) and two reviews analyzed the effects of process-based CT only (Hill et al., 2017; Nguyen et al., 2022). For populations with SM/CC, two studies analyzed combined strategy- and process-based CT (Bhome et al., 2018; Sheng et al., 2020), and one analyzed the effects of strategy-based training only (Metternich et al., 2010).

Type of control group and randomization: All studies included a passive and/or active control group, and all studies except one (Nguyen et al., 2022) included randomized control trials (RCT) only. In the review from Nguyen and colleagues (2022), eligibility criteria were broader, including studies that incorporate a pre-test–intervention–post-test design. Nonetheless, most of the included studies were RCT (93%; Nguyen et al., 2021).

Type of outcome: Our eligibility criteria included reviews with cognitive outcomes and at least one subjective/functional outcome, resulting in a broad list of cognitive and subjective/functional outcomes (see details in Figure 1).

Quality of meta-analyses

While assessing the quality of reviews, we only applied the AMSTAR-2 criteria (Shea et al., 2017) on data that were relevant for our review based on our eligibility criteria. Only three full reviews were analyzed (Basak et al., 2020; Nguyen et al., 2022; Tetlow & Edwards, 2017). None of the studies provided data that we classified as high confidence (Table 3). Out of eight reviews, only one was classified as moderate confidence (Basak et al., 2020), two were classified as low confidence (Bhome et al., 2018; Hill et al., 2017), while most of the studies, five out of eight (63%) were classified as critically low in confidence (Kelly et al., 2014; Metternich et al., 2010; Nguyen et al., 2022; Sheng et al., 2020; Tetlow & Edwards, 2017).

Regarding critical domains, all of the included reviews conducted a comprehensive literature search strategy (ITEM 4; partial or full yes). Of all the critical domains, the smallest number of reviews, only two out of eight (25%; Basak et al., 2020; Kelly et al., 2014) provided a list of excluded studies with a justification of exclusions (ITEM 7). Most reviews adhered to the remaining critical domains, although a considerable number of reviews (38%) did not provide a written protocol (ITEM 2; Metternich et al., 2010; Nguyen et al., 2022; Sheng et al., 2020) and did not inspect publication bias (ITEM 15;

Table 2
CT type by individual SLR included in our review

Article[1]	Number of studies	Single domain	Multidomain	Mixed	Process-based	Strategy-based	Both
Healthy elderly							
(Basak et al., 2020)	161	X	X	X			X
(Kelly et al., 2014)	31			X			X
(Nguyen et al., 2022)	37		X		X		
(Tetlow & Edwards, 2017)	21		X		X		
Total healthy (*N*)	250	1	3	2	2	0	2
Elderly with MCI							
(Basak et al., 2020)	54	X	X	X			X
(Hill et al., 2017)	17			X	X	N/A	
(Nguyen et al., 2022)	6		X		X		
Total MCI (*N*)	77	1	2	2	2	N/A	1
Elderly with (SM/CC)							
(Bhome et al., 2018)	11			X			X
(Metternich et al., 2010)	8	X				X	
(Sheng et al., 2020)	9			X			X
Total SM/CC (*N*)	28	1	0	2	0	1	2
Total (N)	355	3	5	6	4	1	5

Note. [1]Checks are based on available statistical data for specific type of CT

Table 3
Critical domains and overall quality/confidence of meta-analyses included in our review

Article	ITEM 2: written protocol	ITEM 4: comprehensive literature search strategy	ITEM 7: list of excluded studies with justification of exclusions	ITEM 9: assessing the risk of bias (RoB)	ITEM 11: appropriate methods for statistical combination of results	ITEM 13: accounting for RoB when interpretating/ discussing the results	ITEM 15: publication bias inspection	Overall confidence	Data of article analyzed
(Basak et al., 2020)	YES	P-YES	YES	P-YES	YES	YES	YES	MODERATE	full
(Bhome et al., 2018)	P-YES	P-YES	NO	P-YES	YES	YES	YES	LOW	partial
(Hill et al., 2017)	YES	P-YES	NO	YES	YES	YES	YES	LOW	partial
(Kelly et al., 2014)	YES	P-YES	YES	YES	YES	NO	NO	CRITICALLY LOW	partial
(Metternich et al., 2010)	NO	P-YES	NO	NO	NO	YES	NO	CRITICALLY LOW	partial
(Nguyen et al., 2022)	NO	P-YES	NO	YES	NO	YES	YES	CRITICALLY LOW	full
(Sheng et al., 2020)	NO	P-YES	NO	YES	YES	YES	YES	CRITICALLY LOW	partial
(Tetlow & Edwards, 2017)	P-YES	P-YES	NO	P-YES	YES	NO	NO	CRITICALLY LOW	full

38%; Kelly et al., 2014; Metternich et al., 2010; Tetlow & Edwards, 2017).

Effects of cognitive training (CT)

Healthy elderly

The cognitive outcomes of CT effects for healthy elderly were sorted into the following categories: overall (composite) cognitive function, general cognitive functioning, memory, executive function, attention, processing speed, visuospatial ability, and language (Table 4).

Two studies (Basak et al., 2020; Kelly et al., 2014) analyzed the effect of CT (composite: single-domain and multidomain, and strategy- and process-based CT) on overall cognitive functioning in healthy elderly, with Basak and colleagues (Basak et al., 2020) providing additional separate analyses for single-domain CT and multidomain CT. All analyses showed significant small effects of CT on overall cognitive function in healthy elderly. The evidence is of moderate confidence (Basak et al., 2020).

Three studies analyzed the effects of CT on general cognitive functioning in healthy elderly (Basak et al., 2020; Nguyen et al., 2022; Tetlow & Edwards, 2017), and only a moderate confidence review from Basak et al. (2020) showed significant small effects of CT (composite). Two reviews with critically low-confidence evidence (Nguyen et al., 2022; Tetlow & Edwards, 2017) showed non-significant effects of multidomain process-based training on general cognitive functioning in healthy elderly (Nguyen et al., 2022; Tetlow & Edwards, 2017).

Most of the analyzed effects of CT in healthy elderly were in the domain of memory. Most effects were significant. The effects of CT (composite) in healthy elderly were the following: a) small statistically significant effects on short-term memory (Basak et al., 2020), episodic memory (Basak et al., 2020), recognition (Kelly et al., 2014), face-name recall (Kelly et al., 2014), immediate recall (Kelly et al., 2014), and nonverbal memory (Nguyen et al., 2022), b) medium statistically significant effects on paired associates (Kelly et al., 2014), and 3) non-significant effect on delayed recall (Kelly et al., 2014).

Small and statistically significant effects of multidomain process-based CT in healthy elderly are found on verbal memory (Nguyen et al., 2022), non-verbal memory (Nguyen et al., 2021), and visuospatial memory (Tetlow & Edwards, 2017), while non-significant effects were found on combined memory (Tetlow & Edwards, 2017), and similarly, on overall memory (after adjustment; Nguyen et al., 2022). Nonetheless, evidence in the domain of memory is rated as critically low in confidence, except for the moderate confidence effects of CT (composite) on short-term and episodic memory (Basak et al., 2020).

In the domain of executive functions in healthy elderly, CT (composite) appears to have a small statistically significant effect on executive function (Basak et al., 2020) and working memory (Kelly et al., 2014; Nguyen et al., 2022). A review (Nguyen et al., 2022) of the effects of multidomain process-based CT in healthy elderly found a small statistically significant effect on working memory, while a small statistically significant effect on overall executive function did not remain significant after adjusting (Nguyen et al., 2022). Non-significant effects of multidomain strategy-based CT in healthy elderly were found on global executive function, cognitive flexibility, and inhibitory control in the review by Nguyen and colleagues (2022), and Tetlow & Edwards (2017) did not find significant effects for executive function and verbal fluency. Overall, in the domain of executive functions, most analyses (67%) did not provide statistically significant results, and all evidence is rated as critically low confidence, except moderate confidence evidence for the small positive effect of composite CT on executive function (Basak et al., 2020).

Regarding the effects of CT on attention in healthy elderly, the evidence is critically low in confidence and inconsistent. Tetlow & Edwards (2017) found a statistically significant medium effect of multidomain process-based training, while the effects were non-significant in the studies by Kelly et al. (2014) and Nguyen et al. (2022).

All reviews found statistically significant effects of CT in healthy elderly on processing speed (Basak et al., 2020; Kelly et al., 2014; Nguyen et al., 2022; Tetlow & Edwards, 2017). Only a small statistically significant effect of CT composite is of moderate confidence (Basak et al., 2020), while other evidence is rated as critically low in confidence (Kelly et al., 2014; Nguyen et al., 2022; Tetlow & Edwards, 2017). Modest confidence evidence suggests small statistically significant effects of CT (composite) on language in healthy elderly (Basak et al., 2020). A critically low-confidence review did not find effects of multidomain process-based CT on visuospatial ability in healthy elderly (Nguyen et al., 2022).

The subjective and functional outcomes of CT effects in healthy elderly were categorized into two domains: everyday functioning and subjective cognitive functioning. Basak et al., (2020) provided modest confidence evidence and found a small statistically significant effect of CT (composite) on subjective and objective everyday functioning in healthy elderly. Other evidence in this domain was rated as critically low: this included the following: multidomain process-based training in healthy elderly showed small statistically significant effects on subjective measures of everyday functioning (Nguyen et al., 2022) and, similarly, self-reported everyday functioning (Tetlow & Edwards, 2017), while the effects on objective tasks of everyday functioning (after adjustment; Nguyen et al., 2022) and, similarly, performance-based everyday functioning (Tetlow & Edwards, 2017) were non-statistically significant. Considering other subjective measures, the effect of CT (composite) on subjective memory (Kelly et al., 2014) appears to be small and significant in healthy elderly.

Elderly with mild cognitive impairment

The cognitive outcomes of effects of CT in elderly with MCI were classified into the following categories: overall cognitive function, general cognitive functioning, memory, executive function, attention, processing speed, visuospatial ability, and language (Table 5).

Table 4
Effects of CT on healthy elderly

Cognitive function	Specific function	Article	Type of CT	Effect size *g*, d^1 [95% *CI*]	*k*	Study confidence
overall effect on cognitive functioning	overall effect	Basak et al. (2020)	S, P-S	0.3 [0.23, 0.37]**	94	moderate
		Basak et al. (2020)	M, P-S	0.24 [0.15, 0.34]**	67	moderate
		Basak et al. (2020)	S-M, P-S	0,28 [0,22-0,34]**	161	moderate
	composite cognitive function	Kelly et al. (2014)	S-M, P-S	0,23 [0,09-0,37]**	5	critically low
general cognitive functioning	reasoning	Basak et al. (2020)	S-M, P-S	0,20 [0,11-0,28]*	75	moderate
	fluid intelligence	Nguyen et al. (2022)	M, P	-0,06 [-0.26, 0.15]	7	critically low
				adj 0.04 [-0.16, 0.25]	4	critically low
	reasoning	Tetlow and Edwards (2017)	M, P	adj −0.37[-0.88, 0.14]	4	critically low
memory	short term memory	Basak et al. (2020)	S-M, P-S	0,30 [0,15-0,46]*	60	moderate
	episodic memory	Basak et al. (2020)	S-M, P-S	0,30 [0,21-0,38]*	90	moderate
	recognition	Kelly et al. (2014)	S-M, P-S	0,47 [0,20,0,75]**	3	critically low
	face-name recall	Kelly et al. (2014)	S-M, P-S	0,44 [0,07, 0,81]*	4	critically low
	immediate recall	Kelly et al. (2014)	S-M, P-S	0,34 [0,09, 0,69]*	4	critically low
	delayed recall	Kelly et al. (2014)	S-M, P-S	-0,02 [-0,19, 0,16]	3	critically low
	paired associates	Kelly et al. (2014)	S-M, P-S	0,65 [0,25, 1,04]**	3	critically low
	memory overall	Nguyen et al. (2022)	M, P	0.26[0.14, 0.38]**	25	critically low
				adj 0.07 [-0.05, 0.19]	16	critically low
	verbal memory	Nguyen et al. (2022)	M, P	0.27 [0.13, 0.40]**	21	critically low
	nonverbal memory	Nguyen et al. (2022)	M, P	0.17 [0.05, 0.29]*	11	critically low
	visuospatial memory	Tetlow and Edwards (2017)	M, P	adj 0.25 [0,05, 0.46]*	13	critically low
	combined memory	Tetlow and Edwards (2017)	M, P	adj 0,12 [-0,01, 0.25]	14	critically low
executive function	executive functioning	Basak et al. (2020)	S-M, P-S	0,27 [0,20-0,34]*	116	moderate
	working memory	Kelly et al. (2014)	S-M, P-S	0,47 [-0,10-0,49]*	7	critically low
	executive function overall	Nguyen et al. (2022)	M, P	0.19 [0.09, 0.29]**	28	critically low
				adj 0.11 [-0.03, 0.25]	24	

Table 4 (continued)

Cognitive function	Specific function	Article	Type of CT	Effect size g, d^1 [95% *CI*]	k	Study confidence
	global executive function	Nguyen et al. (2022)	M, P	0.02 [-0.13, 0.18]	11	critically low
	cognitive flexibility	Nguyen et al. (2022)	M, P	0.06,[-0.08, 0.21]	10	critically low
	inhibitory control	Nguyen et al. (2022)	M, P	-0.08, [-0.27, 0.10]	8	critically low
	working memory	Nguyen et al. (2022)	M, P	0.37 [0.22, 0.52]**	23	critically low
	executive function	Tetlow and Edwards (2017)	M, P	adj 0,12 [0.00, 0.25]	14	critically low
	verbal fluency	Tetlow and Edwards (2017)	M, P	0,08 [-0.10, 0.26]	3	critically low
attention	attention	Kelly et al. (2014)	S-M, P-S	-0,33 [-1,14-0,49]	4	critically low
	attention	Nguyen et al. (2022)	M, P	0.27 [-0.02, 0.55]	13	critically low
	attention	Tetlow and Edwards (2017)	M, P	0.65[0.31, 0.99]**	10	critically low
processing speed	processing speed	Basak et al. (2020)	S-M, P-S	0,18 [0,10-0,25]*	96	moderate
	processing speed	Kelly et al. (2014)	S-M, P-S	0,82 [0,19, 1,45]*	3	critically low
	processing speed	Nguyen et al. (2022)	M, P	0.18 [0.02, 0.34]*	18	critically low
				adj 0.25 [0.07, 0.44]*	15	critically low
	processing speed	Tetlow and Edwards (2017)	M, P	0.26 [0.06, 0.45]**	6	critically low
visuospatial ability	visuospatial ability	Nguyen et al. (2022)	M, P	-0.01 [-0.31, 0.28]	7	critically low
				adj 0.09 [-0.24, 0.42]	6	
language		Basak et al. (2020)	S-M, P-S	0,18 [0,08-0,28]*	36	moderate

Table 4 (continued)

Functional/subjective outcomes	Specific function	Article	Type of CT	Effect size *g*, d^1 [95% *CI*]	*k*	Study confidence
everyday functioning	subjective and objective	Basak et al. (2020)	S-M, P-S	0.19 [0.08, 0.32]**	40	moderate
	objective tasks of everyday functioning	Nguyen et al. (2022)	M, P	0.12 [-0.01, 0.24]*	7	critically low
				adj 0.08 [-0.03, 0.21]	6	
	subjective measures of everyday functioning	Nguyen et al. (2022)	M, P	0.22 [0.09, 0.34]**	10	critically low
	performance-based everyday function	Tetlow and Edwards (2017)	M, P	0.06 [-0.15, 0.28]	4	critically low
	self-reported everyday function	Tetlow and Edwards (2017)	M, P	0.28 [0.14, 0.42]**	6	critically low
subjective cognitive function	subjective memory	Kelly et al. (2014)	S-M, P-S	0.14 [-0.01, 0.29]*	2	critically low

Notes. [1]only Tetlow and Edwards (2017); * $p < .05$; ** $p < .01$; Abbreviations: M, P – multi-domain process-based CT; S, P-S – single-domain, and mixed process-and strategy-based CT; M, P-S – multi-domain, and mixed process-and strategy-based; S-M, P-S – mixed single- and multi-domain, and process-and strategy-based CT; adj – adjusted.

The evidence for the effects in elderly with MCI on overall cognitive functioning was moderate confidence (Basak et al., 2020) and consistent (Basak et al., 2020; Hill et al., 2017), suggesting small and statistically significant effects of single-domain CT (Basak et al., 2020), multidomain CT (Basak et al., 2020), and CT in general (composite; Basak et al., 2020; Hill et al., 2017). The effects of CT composite in elderly with MCI were also small and significant in the domain of general cognitive functioning, specifically on reasoning (moderate-confidence evidence (Basak et al., 2020)) and global cognition (low-confidence evidence (Hill et al., 2017)).

In the domain of memory in elderly with MCI, moderate confidence evidence (Basak et al., 2020) was provided for CT composite and small statistically significant effects on short-term and episodic memory were found. A low-confidence review (Hill et al., 2017) for CT (composite) reveals a small statistically significant effect on verbal learning, a medium statistically significant effect on non-verbal learning, and non-significant effects on non-verbal memory and verbal learning (after adjustment). A critically low-confidence review (Nguyen et al., 2022) did not find statistically significant effects of multidomain process-based CT on memory overall for the elderly with MCI.

Regarding executive functions in the elderly with MCI, a moderate confidence review (Basak et al., 2020) indicates a small statistically significant effect on the executive functioning of CT (composite), while low confidence (Hill et al., 2017) and critically low-confidence reviews (Nguyen et al., 2022) did not find any effects on executive functioning. Low-confidence evidence (Hill et al., 2017) for CT (composite) reveals a medium statistically significant effect on working memory and a small statistically significant effect on attention, but not on processing speed, visuospatial skills, and language for the elderly with MCI. On the other hand, modest-confidence evidence (Basak et al., 2020) indicates a small statistically significant effect of CT (composite) on processing speed and language in the elderly with MCI.

Functional and subjective outcomes of CT for the elderly with MCI were found in the domain of everyday functioning. Moderate confidence evidence (Basak et al., 2020) is provided for small statistically significant effects of CT (composite) on subjective and objective everyday functioning. A low confidence review (Hill et al., 2017) found small statistically significant effects (after adjustment) of CT composite on psychosocial functioning, but not on instrumental activities of daily living (IADL).

Elderly with subjective memory/cognitive complaints

Reviews that inspected the effects of CT in elderly with SM/CC were rated as providing low-confidence (Bhome et al., 2018) or critically low-confidence evidence (Metternich et al., 2010; Sheng et al., 2020).

The cognitive outcomes of the effects of CT in elderly with SM/CC were grouped into two categories: general cognitive functioning, and memory (Table 6). While one review (Bhome et al., 2018) found small statistically significant effects of CT composite on objective cognitive performance, the other one (Sheng et al., 2020) did not find any effects of CT composite on global cognitive function. In the domain of memory in elderly with SM/CC, one review (Metternich et al., 2010) found small statistically significant effects of single-domain strategy-based CT on objective memory. The effects of CT composite in elderly with SM/SC, inspected in a review by Sheng and colleagues (Sheng et al., 2020), were small and statistically significant for total memory, but not for immediate recall, delayed recall, and recognition.

Subjective outcomes of CT in the population with SM/CC were sorted into three groups: psychological well-being, mood, and subjective cognitive function. Regarding psychological well-being, two reviews (Bhome et al., 2018; Sheng et al., 2020) found small statistically significant effects of CT (composite), while one review (Metternich et al., 2010) did not find a statistically significant effect of single-domain strategy-based training on well-being in elderly with SM/CC. In the domain of subjective cognitive function in elderly with SM/CC, only one review (Sheng et al., 2020) found a small statistically significant effect of CT (composite) on subjective memory II (higher score better memory), while non-significant effects were found for subjective memory I (higher score worse memory; Sheng et al., 2020), subjective memory (Metternich et al., 2010), and metacognition (Bhome et al., 2018) for elderly with SM/CC. Furthermore, no statistically significant effects were found for mood, specifically for depressive symptoms (Metternich et al., 2010), and depression and anxiety (Sheng et al., 2020) in elderly with SM/CC.

Near-transfer and far-transfer effects of CT

Considering the overall effects of CT on near-transfer and far-transfer measures, medium confidence evidence (Basak et al., 2020) suggests small, statistically significant near-transfer and far-transfer effects of CT composite for healthy elderly and those with MCI (Table 7). A critically low confidence review (Nguyen et al., 2022) also showed small statistically significant near-transfer effects of the multidomain process-based training in healthy elderly and those with MCI, but far-transfer effects were only statistically significant and small for healthy elderly, not for elderly with MCI. Moreover, although far-transfer effects were, overall, statistically significant for healthy elderly, when analyzed separately, small statistically significant effects were evident only on subjective measures of far transfer, but not on objective measures of far transfer. None of our included reviews analyzed near-transfer and far-transfer effects in the elderly with SM/CC.

Discussion

Given the massive number of studies examining the effectiveness of CT on slowing down or reversing cognitive decline that comes with aging and the onset of neurodegenerative processes, the aim of our review was to summarize the already existing reviews on this topic. Specifically, we wanted to synthesize the systematic literature reviews with meta-analyses considering the effectiveness of

Table 5
Effects of CT in elderly with mild cognitive impairment (MCI)

Cognitive function	Specific function	Article	Type of CT	Effect size *g* [95% *CI*]	*k*	Study confidence
overall effect on cognitive functioning		Basak et al. (2020)	S, P-S	0.27 [0.17, 0.36]*	18	moderate
		Basak et al. (2020)	M, P-S	0.29 [0.18, 0.4]**	36	moderate
		Basak et al. (2020)	S-M, P-S	0.27 [0.18, 0.37]**	54	moderate
		Hill et al. (2017)	S-M	0.35 [0.20, 0.51]**	17	low
general cognitive functioning	reasoning	Basak et al. (2020)	S-M, P-S	0,24 [0,06-0,43]*	11	moderate
	global cognition	Hill et al. (2017)	S-M	0,38 [0,14-0,62]**	12	low
memory	short term memory	Basak et al. (2020)	S-M, P-S	0,33 [0,10-0,56]*	17	moderate
	episodic memory	Basak et al. (2020)	S-M, P-S	0,34 [0,21-0,47]*	43	moderate
	verbal learning	Hill et al. (2017)	S-M, P-S	0,39 [0,14-0,63]**	11	low
				adj 0,20[-0,08-0,49]	8	
	verbal memory	Hill et al. (2017)	S-M	0,42 [0,21-0,63]**	12	low
	non-verbal learning	Hill et al. (2017)	S-M	0,50 [0,25-0,76]**	8	low
	non-verbal memory	Hill et al. (2017)	S-M	0,20 [-0,03-0,43]	7	low
	memory overall	Nguyen et al. (2022)	M, P	0.33 [-0.06, 0.72]	5	critically low
				adj 0.47 [-0.09, 1.03]	3	
executive function	executive functioning	Basak et al. (2020)	S-M, P-S	0,29 [0,16-0,43]*	33	moderate
	executive function	Hill et al. (2017)	S-M	0,20 [-0,05-0,44]	13	low
	working memory	Hill et al. (2017)	S-M	0,74 [0,32-1,15]**	9	low
				adj 0,58 [0,27-0,90]**	8	
	executive functioning	Nguyen et al. (2022)	M, P	0.04 [-0.22, 0.31]	5	critically low
				adj 0.11[-0.14, 0.36]	4	
attention	attention	Hill et al. (2017)	S-M	0,44 [0,20-0,68]*	6	low
processing speed	processing speed	Basak et al. (2020)	S-M, P-S	0,31 [0,07-0,55]*	20	moderate
	processing speed	Hill et al. (2017)	S-M	0,09 [-0,17, 0,35]	7	low
visuospatial ability	visuospatial skills	Hill et al. (2017)	S-M	0,18 [-0,23, 0,60]	5	low
language	language	Basak et al. (2020)	S-M, P-S	0,20 [0,08-0,33]*	18	moderate
	language	Hill et al. (2017)	S-M	0,41 [-0,10-0,92]	6	low

Table 5 (continued)

Functional/subjective outcomes	Specific function	Article	Type of CT	Effect size *g* [95% *CI*]	*k*	Study confidence
everyday functioning (EF)	subjective and objective EF	Basak et al. (2020)	S-M, P-S	0.26 [0.08, 0.44]**	21	moderate
	IADL	Hill et al. (2017)	S-M	0.21 [-0.18, 0.61]	6	low
	psychosocial functioning	Hill et al. (2017)	S-M	0.52 [0.01, 1,03]*	8	low
				adj 0.27 [0.01, 0,52]*	7	

Notes. $^{*}p < .05$; $^{**}p < .01$; Abbreviations: S-M – single-domain and multidomain CT; M, P – multi-domain process-based CT; S, P-S – single-domain, and mixed process-and strategy-based CT; M, P-S – multi-domain, and mixed process-and strategy-based; S-M, P-S – mixed single- and multi-domain, and process-and strategy-based CT; adj – adjusted.

Table 6
Effects of CT in elderly with subjective memory/cognitive complaints

Cognitive function (CF)	Specific CF	Article	Type of CT	Effect size *g* [95% *CI*]	*k*	Study confidence
general cognitive functioning	objective cognitive performance	Bhome et al. (2018)	S-M, P-S	0.13 [0.01, 0.25]	10	low
	global cognitive function	Sheng et al. (2020)	S-M, P-S	–0.01 [–0.23, 0.20]	4	critically low
memory	objective memory	Metternich et al. (2010)	S, S	0.46 [0.05, 0.87]*	4	critically low
	total memory	Sheng et al. (2020)	S-M, P-S	0.19 [0.00, 0.37]*	5	critically low
	immediate recall	Sheng et al. (2020)	S-M, P-S	0.04 [–0.21, 0.28]	3	critically low
	delayed recall	Sheng et al. (2020)	S-M, P-S	0.18 [–0.16, 0.52]	3	critically low
	Recognition	Sheng et al. (2020)	S-M, P-S	0.96 [0.23, 1.70]	1	critically low
Subjective/cognitive outcomes						
psychological well-being	psychological well-being	Bhome et al. (2018)	S-M, P-S	0.25 [0.05, 0.46]*	6	low
	well being	Metternich et al. (2010)	S,S	-0.03 [-0.79, 0.74]	1	critically low
	psychological well-being	Sheng et al. (2020)	S-M, P-S	0.27 [0.03, 0.52]*	3	critically low
mood	depressive symptoms	Metternich et al. (2010)	S,S	0.02 [-0.47, 0.52]	2	critically low
	depression and anxiety	Sheng et al. (2020)	S-M, P-S	–0.20 [–0.54, 0.14]	3	critically low
subjective cognitive function	Metacognition	Bhome et al. (2018)	S-M, P-S	0.06 [-0.12, 0.24]	6	low
	subjective memory	Metternich et al. (2010)	S,S	0.33 [-0.07, 0.73]	3	critically low
	subjective memory I (higher score worse memory)	Sheng et al. (2020)	S-M, P-S	–0.11 [–0.32, 0.10]	5	critically low
	subjective memory II (higher score better memory)	Sheng et al. (2020)	S-M, P-S	0.49 [0.22, 0.76]**	3	critically low

Notes. * $p < .05$; ** $p < .01$; Abbreviations: S-S – single-domain and strategy based CT; S-M, P-S – mixed single- and multi-domain, and process-and strategy-based CT.

Table 7
Near-transfer and far-transfer effects of CT in elderly

Healthy elderly		Article	Type of CT	Effect size *g* [95% *CI*]	*k*	Study confidence
Near transfer		Basak et al. (2020)	S-M, P-S	0.38 [0.14, 0.47]**	139	moderate
		Nguyen et al. (2022)	M, P	0.22 [0.12, 0.31]**	37	critically low
				adj 0.27 [0.17, 0.37]**	32	critically low
Far transfer	far transfer	Basak et al. (2020)	S-M, P-S	0.22 [0.15, 0.34]**	115	moderate
	far transfer overall	Nguyen et al. (2022)	M, P	0.16 [0.06, 0.26]**	22	critically low
	far transfer-objective measures	Nguyen et al. (2022)	M, P	0.09[-0.04, 0.22]	18	critically low
	far transfer-subjective measures	Nguyen et al. (2022)	M, P	0.22[0.09, 0.34]**	10	critically low
Elderly with MCI						
Near transfer		Basak et al. (2020)	S-M, P-S	0.27 [0.07, 0.46]*	38	moderate
		Nguyen et al. (2022)	M, P	0.32 [0.06, 0.57]*	6	critically low
Far transfer		Basak et al. (2020)	S-M, P-S	0.18 [0.04, 0.45]**	26	moderate
		Nguyen et al. (2022)	M, P	0.07 [-0.20, 0.33]	5	critically low

Notes. $^{*}p < .05$; $^{**}p < .01$; Abbreviations: M, P – multi-domain process-based CT; S-M, P-S – mixed single- and multi-domain, and process-and strategy-based CT.

different CT interventions for older adults, with or without the onset of cognitive decline, in improving cognitive and everyday functioning.

Generally, most systematic literature reviews with meta-analyses that inspect both the cognitive and the functional effects of CT in elderly that are at risk of cognitive decline provide low-confidence or critically low-confidence evidence, having one or more critical domains flaws by methodological standards for systematic reviews (AMSTAR-2; Shea et al., 2017). The exception is a moderate-confidence review without major flaws from Basak and colleagues (2020), providing data for healthy elderly and those with MCI. Although there is a need for higher-confidence evidence, some of the effects of CT are of modest confidence and appear to be more consistent through various reviews, suggesting CT can be beneficial for some aspects of cognitive and everyday functioning. Compared to other synthesized reviews (Gavelin et al., 2020; Sala et al., 2019), we have provided more a detailed analysis, thus providing more insights into the effectiveness of CT for various specific cognitive, subjective, and functioning outcomes.

In our review, regarding healthy elderly, consistent evidence, including a moderate confidence review, proved the small effects of CT (single-domain, multidomain and composite) on overall cognitive functioning, and small effects of CT (composite and multidomain process-based) on processing speed. There is no consistent evidence for the effects of CT on memory, executive functions and attention for healthy elderly; nonetheless, moderate confidence evidence proved small effects of CT (composite) on short-term memory, episodic memory, executive functioning, and, additionally on language (Basak et al., 2020). For elderly with MCI, consistent evidence, including a modest confidence review, was found for small effects on overall cognitive function and general cognitive functions for CT (composite), and small effects for single-domain and multidomain CT on overall cognitive function. For other domains of cognitive functioning, the effects were heterogeneous; nonetheless, moderate confidence evidence (Basak et al., 2020) suggests some efficacy of CT (composite) on memory (short-term and episodic memory), executive functioning, processing speed, and language.

That CT can improve cognitive performance in older adults is also implied by the results of a systematic overview by Gavelin et al. (2020), who provided consistent and modest-confidence evidence of the effects of CT on objective cognitive measures for healthy adults and those with MCI, and additionally for adults with Parkinson's disease. A second order meta-analysis by Sala et al. (2019) found that working memory training has a small significant effect on memory performance in healthy older adults and those with MCI; on the other hand, working memory training, as well as action and non-action video game training in older adults, were not beneficial for combined cognitive functioning outcomes (fluid reasoning, cognitive control, processing speed, and language) as a measure of far transfer. Regarding subjective and objective measures of functioning, Basak et al. (2020) provided moderate-confidence evidence of limited effectiveness of CT (composite) on subjective and objective measures of everyday functioning in healthy elderly and those with MCI. Although the evidence is of low confidence, reviews in which subjective and objective measures were analyzed separately consistently suggest that CT has effects only on subjective measures, but not on objective measures of everyday functioning (Hill et al., 2017; Kelly et al., 2014; Nguyen et al., 2022; Tetlow & Edwards, 2017).

Considering the overall effects of CT on near-transfer and far-transfer measures, medium-confidence evidence (Basak et al., 2020) suggests small statistically significant near-transfer and far-transfer effects of CT (composite) for healthy elderly and those with MCI, while evidence for multidomain process-based CT for healthy elderly and elderly with MCI is of critically low confidence (Nguyen et al., 2022), and indicates small effects for near transfer in both populations; far-transfer effects, however, are less convincing, showing a small significant effect only for a healthy population, and, specifically, only for subjective measures, but not objective ones. Effects other than cognitive functioning, which were inspected in another systematic overview (Gavelin et al., 2020), are less convincing, showing only small effectiveness of CT on psychosocial functioning in healthy older adults, while the effects were inconsistent for MCI; furthermore, no effects were proved on subjective cognitive and functional outcomes in healthy older adults and those with MCI (Gavelin et al., 2020).

Unfortunately, in our study, the effects of CT for the elderly with subjective cognitive/memory complaints are of low/critically low confidence, and are not consistent for specific domains of cognitive and subjective/functional outcomes. In order to derive conclusions on the effects of CT in this population, higher-confidence evidence is needed.

The basis for the scientific debate regarding CT is whether the effects are transferable to non-trained functions (i.e. far transfer). Thus, in order to contribute to this debate, our aim was to inspect and compare the effects of different cognitive training types. Nonetheless, there was a lack of variability of CT types in our study, as only two reviews analyzed single-domain CT (Basak et al., 2020; Metternich et al., 2010) and only one review inspected strategy-based CT only (Metternich et al., 2010), while other reviews analyzed CT as a general intervention, or inspected multi-domain process-based training only.

One concept concerning transfer effects which is typically discussed in the context of working-memory training is whether training gains are the result of improved efficiency or capacity. It is possible that the training gains indicate enhanced working memory efficiency (as a result of knowledge and skill acquisition, such as the use of specific strategies, chunk learning, etc.), but they can also be a result of expanded working-memory capacity (von Bastian & Oberauer, 2014). As the knowledge and skills are usually specific to the content learned, the enhanced working-memory efficiency can only lead to near transfer, but far-transfer effects can also be expected if working memory capacity is improved (Morrisom & Chein, 2011; von Bastian & Oberauer, 2014). A comparison of the effects of process-based and strategy-based training could potentially provide additional insights into this topic. Process-based CT focuses on expanding capacity, while strategy-based CT is primarily oriented toward improving efficiency; therefore, process-based CT should result in more generalizable effects, while strategy-based CT should have more domain-specific effects (Morrisom & Chein, 2011). However, due to the lack of sufficient data, we cannot derive any conclusions.

Similarly, if training implies learning domain-specific skills, the more specialized the skill, the less overlap between skills, and therefore the more difficult the transfer will be (Ericsson & Charness, 1994; Morrisom & Chein, 2011). Accordingly, in single-domain training, greater near-transfer effects should be expected compared to far-transfer effects, while multi-domain CT should result in more generalizable effects than single-domain CT, implying that it might be a more efficacious approach to improving more aspects of functioning. Results from some meta-analytical reviews support this notion (Lampit et al., 2020; Gavelin et al., 2020), but our review, contrary to that, suggests that single-domain training and multi-domain training have similar effects and that, regardless of the CT regime, effects are transferable to overall cognitive functions. These results are compliant with Taatgen's PRIMs theory (Taatgen, 2013), which serves as an explanation for the general effects of cognitive training. The theory proposes that when people learn specific cognitive tasks, the by-product of the learning process consists of general cognitive skills. That is because skills are broken into multiple small, primitive information-processing elements (PRIMs) that move and compare single pieces of information, some of which are task-specific, while some are task-general (Taatgen, 2013). Two tasks can be quite different, but still share the same general skills, i.e. the patterns of routing information through the cognitive system (Taatgen, 2013). The question whether there are comparable far-transfer effects of different CT regimes on non-trained functions (apart from overall cognitive function) in older adults remains open and is challenging, especially regarding measures of everyday functioning.

In recent years, there has been a crisis in science relating to the problem of the reliability and credibility of scientific evidence, including psychology and social sciences (Head et al., 2015; Lilienfeld & Waldman, 2017). One of the major reasons for this is that "p-hacking" and "publication bias" are a common occurrence in science, and, unfortunately, statistically significant results are prioritized over the accuracy of the studies (Head et al., 2015; Nosek et al., 2012). Additionally, a major problem in CT primary studies is that a large portion of them have poor statistical power due to small sample sizes, which often compromise the reliability of results (Gobet and Sala, 2020; Green et al., 2019). For example, in 120 studies that reported transfer effects, the average group size consisted of around 22 participants (Melby-Lervåg et al., 2016). Therefore, applying a meta-analysis or an overview of meta-analyses can be useful in providing more robust evidence that generates more reliable conclusions.

Generally, one way of addressing these problems is to focus on the quality of the methodology, rather than on the results of the study (Raj et al., 2017), so as to provide more consistent conclusions. When synthesizing results from different studies (as with the evidence about the effectiveness of CT), in order to deliver a more valid and reliable conclusion, it is strongly suggested that authors follow the guidelines on conducting a systematic literature review with meta-analysis (Higgins et al., 2019).

Similarly to what was previously noted on the poor variability of the types of CT, CT is often incorrectly treated as one uniform intervention; however, aside from the different possible types of cognitive training, there is also great heterogeneity in study designs, methods and training protocols for CT (Green et al., 2019; von Bastian & Oberauer 2014). There have been some efforts to improve methodological standards in behavioral interventions for cognitive enhancement (Green et al., 2019), but, unfortunately, there is still no clear direction, nor a "gold standard" of how CT research should be applied. The question, therefore, is whether it is justified to analyze CT in meta-analytical studies as a single type of intervention. Another reason to separately analyze the specific types of CT in reviews is to better understand the potentially different underlying mechanisms of their functioning.

Although there are many systematic literature reviews with meta-analysis that investigate the effects of CT on cognitive functions, there is a relatively small number of reviews focusing on the effects on everyday functioning apart from effects on cognitive functions. In order for CT to be considered an effective tool for slowing down or preventing cognitive decline and pathology, it should demonstrate its practical value outside laboratory conditions and measures, and should positively affect the everyday functioning of a person. We therefore believe that it is of great importance that a study on the effectiveness of CT be conducted which includes non-cognitive far-transfer measures, preferably with greater ecological validity, in order to confirm the practical value of CT interventions.

There is need for caution, because our conclusions are not based on statistically synthesized results, and we did not control for overlapping between primary studies, which could potentially overestimate the consistency between the various reviews and falsely lead to greater perceived precision of the analysis (Lunny et al., 2021).

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Supplementary materials

Table S1
Database search syntax and keywords

Database	Syntax (link) and keywords
Web of Science *N* = 1348	TS=(meta-analys* OR systematic review*) AND TS=(adult* OR healthy OR ageing OR elder* OR older OR senior* OR old OR geriatric OR MCI OR “mild cognitive impairment*” OR cognitive (impairment OR decline) OR “memory impairment” OR “*cognitive disorder” OR “impaired cognit*” OR “subjective memory” OR “cognit* complaint*”) AND TS=(“cognitive intervention*” OR “cognitive oriented intervention*” OR “cognition based intervention*” OR “cognitive training” OR “cognition-oriented training” OR “cognition-based training” OR “memory * training” OR “executive function training” OR “computerized training” OR “multimodal training” OR “multi-domain training” OR “mental training” OR “brain training” OR “cognit* rehabilitat*” OR “cognit* remediat*” OR “cognit* stimulat*” OR “cognit* enhanc*” OR “non-pharmacological Intervention*” OR “video gam*” OR videogam* computer gam*) AND TS=(“far-transfer” OR cogn* OR cognit*(subjective OR objective) OR function* OR ecologic* OR well-being OR real-life OR *ADL* OR every-day OR mood OR depression) Refined By:Languages: English https://www.webofscience.com/wos/alldb/summary/77070de0-95a4-46db-86d4-19b7dbbe0956-20fb2934/relevance/1
Scopus *N* = 1106	TITLE-ABS-KEY (“meta-analys*” OR “systematic review*”) AND TITLE-ABS-KEY (adult* OR healthy OR ageing OR elder* OR older OR senior* OR old OR geriatric) OR TITLE-ABS-KEY (mci OR “mild cognitive impairment*” OR “cognitive impairment” OR “cognitive decline” OR “memory impairment” OR “*cognitive disorder” OR “impaired cognition” OR “subjective memory” OR “cognitive complaint*”) AND TITLE-ABS-KEY (“cognitive intervention*” OR “cognition oriented intervention*” OR “cognition based intervention*” OR “cognitIVE training” OR “cognition oriented training” OR “cognitive based training” OR “memory training” OR “executive function training” OR “computerized training” OR “multimodal training” OR “multi-domain training” OR “mental training” OR “brain training” OR “cognitive rehabilitation*” OR “cognitive remediation*” OR “cognitive stimulation” OR “cognitive enhancement*” OR “non-pharmacological Intervention*” OR “video gam*” OR “computer gam*”) AND TITLE-ABS-KEY (“far-transfer” OR “subjective cognition” OR cogn* OR “objective cognition” OR function* OR ecologic* OR well-being OR real-life OR *adl* OR every-day OR mood OR depression) AND (LIMIT-TO (LANGUAGE , “English”)) https://www-scopus-com.ezproxy.lib.ukm.si/results/results.uri?sort=plf-f&src=s&sid=e5941b46a1132e8b14389deeb789b074&sot=a&sdt=a&cluster=scolang%2c%22English%22%2ct&sl=1147&s=TITLE-ABS-KEY+%28+%22meta-analys*%22+OR+%22systematic+review*%22+%29+AND+TITLE-ABS-KEY+%28+adult*+OR+healthy+OR+ageing+OR+elder*+OR+older+OR+senior*+OR+old+OR+geriatric+%29+OR+TITLE-ABS-KEY+%28+mci+OR+%22mild+cognitive+impairment*%22+OR+%22cognitive+impairment%22+OR+%22cognitive+decline%22+OR+%22memory+impairment%22+OR+%22*cognitive+disorder%22+OR+%22impaired+cognition%22+OR+%22subjective+memory%22+OR+%22cognitive+complaint*%22+%29+AND+TITLE-ABS-KEY+%28+%22cognitive+intervention*%22+OR+%22cognition+oriented+intervention*%22+OR+%22cognition+based+intervention*%22+OR+%22cognitIVE+training%22+OR+%22cognition+oriented+training%22+OR+%22cognitive+based+training%22+OR+%22memory+training%22+OR+%22executive+function+training%22+OR+%22computerized+training%22+OR+%22multimodal+training%22+OR+%22multi-domain+training%22+OR+%22mental+training%22+OR+%22brain+training%22+OR+%22cognitive+rehabilitation*%22+OR+%22cognitive+remediation*%22+OR+%22cognitive+stimulation%22+OR+%22cognitive+enhancement*%22+OR+%22non-pharmacological+Intervention*%22+OR+%22video+gam*%22+OR+%22computer+gam*%22+%29+AND+TITLE-ABS-KEY+%28+%22far-transfer%22+OR+%22subjective+cognition%22+OR+cogn*+OR+%22objective+cognition%22+OR+function*+OR+ecologic*+OR+well-being+OR+real-life+OR+*adl*+OR+every-day+OR+mood+OR+depression+%29&origin=searchadvanced&editSaveSearch=&txGid=99e39edce7dce89ce706268fd1752bae

Table S1 (continued)

Database	Syntax (link) and keywords
Medline (Pubmed) *N* = 312	(((“meta-analys*”[Title/Abstract] OR “systematic review*”[Title/Abstract]) AND (adult*[Title/Abstract] OR healthy[Title/Abstract] OR ageing[Title/Abstract] OR elder*[Title/Abstract] OR older[Title/Abstract] OR senior*[Title/Abstract] OR old[Title/Abstract] OR geriatric[Title/Abstract] OR MCI[Title/Abstract] OR “mild cognitive impairment*”[Title/Abstract] OR cognitive (impairment[Title/Abstract] OR decline[Title/Abstract]) OR “memory impairment”[Title/Abstract] OR “*cognitive disorder”[Title/Abstract] OR “impaired cognition”[Title/Abstract] OR “subjective memory”[Title/Abstract] OR “cognitive complaint*”[Title/Abstract])) AND (“cognitive intervention*”[Title/Abstract] OR “cognition oriented intervention*”[Title/Abstract] OR “cognitive based intervention*”[Title/Abstract] OR “cognitive training”[Title/Abstract] OR “cognition oriented training”[Title/Abstract] OR “cognitive based training”[Title/Abstract] OR “memory training”[Title/Abstract] OR “executive function training”[Title/Abstract] OR “computerized training”[Title/Abstract] OR “multimodal training”[Title/Abstract] OR “multi-domain training”[Title/Abstract] OR “mental training”[Title/Abstract] OR “brain training”[Title/Abstract] OR “cognitive rehabilitation*”[Title/Abstract] OR “cognitive remediation*”[Title/Abstract] OR “cognitive stimulation”[Title/Abstract] OR “cognitive enhancement*”[Title/Abstract]OR “non-pharmacological Intervention*”[Title/Abstract] OR “video gam*”[Title/Abstract] OR video gam*[Title/Abstract] OR computer gam*[Title/Abstract])) AND (“far-transfer”[Title/Abstract] OR cognition (subjective[Title/Abstract] OR objective[Title/Abstract]) OR cognit*[Title/Abstract] OR function*[Title/Abstract] OR ecologic*[Title/Abstract] OR well-being[Title/Abstract] OR real-life[Title/Abstract] OR ADL[Title/Abstract] OR every-day[Title/Abstract] OR mood[Title/Abstract] OR depression[Title/Abstract]) Filters applied: English. https://pubmed.ncbi.nlm.nih.gov/?term=longquery1829d14ae592cde16319&filter=lang.english&size=200
Cochrane Library *N* = 96	adult OR healthy OR ageing OR elder* OR senior* OR old* OR geriatric OR MCI OR “mild cognitive impairment*” OR cognitive (impairment OR decline) OR “memory impairment” OR “*cognitive disorder” OR “impaired cognition” OR “subjective memory” OR “cognitive complaint*” in Title Abstract Keyword AND “cognitive intervention” OR “cognition oriented intervention” OR “cognition based intervention” OR “cognition training” OR “cognition oriented training” OR “cognitive based training” OR “memory training” OR “executive function training” OR “computerized training” OR “multimodal training” OR “multi-domain training” OR “mental training” OR “brain training” OR “cognitive rehabilitation” OR “cognitive remediation” OR “cognitive stimulation” OR “cognitive enhancement” OR “non-pharmacological Intervention” OR “video game” OR “computer game” in Title Abstract Keyword AND “far-transfer” OR “subjective cognition” OR “objective cognition” OR cognit* OR function OR ecologic OR well-being OR real-life OR *ADL* OR every-day OR mood OR depression in Title Abstract Keyword - in Cochrane Reviews (Word variations have been searched) Cochrane reviews only https://www.cochranelibrary.com/advanced-search

Table S1 (continued)

Database	Syntax (link) and keywords
CINAHL $N = 154$	AB (meta-analysis* or systematic review*) AND AB (adult OR healthy OR ageing OR elderly OR older OR senior OR old OR geriatric OR MCI OR “mild cognitive impairment*” OR “cognitive AND (impairment OR decline)” OR “memory impairment” OR “*cognitive disorder” OR “impaired cognition” OR “subjective memory” OR “cognitive complaints” OR “memory complaint*”) AND AB (“cognitive intervention*” OR “cognition oriented intervention*” OR “cognitive based intervention*” OR “cognitive training” OR “cognition oriented training” OR “cognition based training” OR “memory training” OR “executive function training” OR “computerized training” OR “multimodal training” OR “multi-domain training” OR “mental training” OR “brain training” OR “cognitive rehabilitation*” OR “cognitive remediation*” OR “cognitive stimulation” OR “cognitive enhancement*” OR “non-pharmacological Intervention*” OR “video game” OR “computer game”) AND AB (“far-transfer” OR “cognition AND (subjective OR objective)” OR cognit* OR function* OR ecologic* OR well-being OR real-life OR ADL OR every-day OR mood OR depression) https://search-ebscohost-com.ezproxy.lib.ukm.si/login.aspx?direct=true&db=c8h&bquery=AB+(+meta-analysis*+or+systematic+review*+)+AN D+AB+(+adult+OR+healthy+OR+ageing+OR+elderly+OR+older+OR+senior+OR+old+OR+geriatric+OR+MCI+OR+%26quot%3bmild+cogni- tive+impairment*%26quot%3b+OR+%26quot%3bcognitive+AND+(impairment+OR+decline)%26quot%3b+OR+%26quot%3bmemory+impair- ment%26quot%3b+OR+%26quot%3b*cognitive+disorder%26quot%3b+OR+%26quot%3bimpaired+cognition%26quot%3b+OR+%26quot%3bsubjec- tive+memory%26quot%3b+OR+%26quot%3bcognitive+complaints%26quot%3b+OR+%26quot%3bmemory+complaint*%26quot%3b+)+AND+AB+(+ %e2%80%9ccognitive+intervention*%e2%80%9d+OR+%26quot%3bcognition+oriented+intervention*%26quot%3b+OR+%26quot%3bcognitive+based+in- tervention*%26quot%3b+OR+%26quot%3bcognitive+training%26quot%3b+OR+%26quot%3bcognition+oriented+training%26quot%3b+OR+%26quot%3b- cognition+based+training%26quot%3b+OR+%26quot%3bmemory+training%26quot%3b+OR+%26quot%3bexecutive+function+train- ing%26quot%3b+OR+%26quot%3bcomputerized+training%26quot%3b+OR+%26quot%3bmultimodal+training%26quot%3b+OR+%26quot%3bmulti-do- main+training%26quot%3b+OR+%26quot%3bmental+training%26quot%3b+OR+%26quot%3bbrain+training%26quot%3b+OR+%26quot%3bcog- nitive+rehabilitation*%26quot%3b+OR+%26quot%3bcognitive+remediation*%26quot%3b+OR+%26quot%3bcognitive+stimulation%26quot%3b+OR+%26qu ot%3bcognitive+enhancement*%26quot%3b+OR+%26quot%3bnon-pharmacological+Intervention*%26quot%3b+OR+%26quot%3bvideo+game%26quot%3b +OR+%26quot%3bcomputer+game%26quot%3b+)+AND+AB+(+%26quot%3bfar-transfer%26quot%3b+OR+%26quot%3bcognition+AND+(subjective+OR+- objective)%26quot%3b+OR+cognit*+OR+function*+OR+ecologic*+OR+well-being+OR+real-life+OR+ADL+OR+every-day+OR+mood+OR+depression+)&- cli0=RV&clv0=Y&cli1=LA99&clv1=eng&type=1&searchMode=Standard&site=ehost-live

Table S1 (continued)

Database	Syntax (link) and keywords
PsycINFO $N = 177$	AB (meta-analysis* or systematic review*) AND AB (adult OR healthy OR ageing OR elderly OR older OR senior OR old OR geriatric OR MCI OR “mild cognitive impairment*” OR “cognitive AND (impairment OR decline)” OR “memory impairment” OR “*cognitive disorder” OR “impaired cognition” OR “subjective memory” OR “cognitive complaints” OR “memory complaint*”) AND AB (“cognitive intervention*” OR “cognition oriented intervention*” OR “cognitive based intervention*” OR “cognitive training” OR “cognition oriented training” OR “cognition based training” OR “memory training” OR “executive function training” OR “computerized training” OR “multimodal training” OR “multi-domain training” OR “mental training” OR “brain training” OR “cognitive rehabilitation*” OR “cognitive remediation*” OR “cognitive stimulation” OR “cognitive enhancement*” OR “non-pharmacological Intervention*” OR “video game” OR “computer game”) AND AB (“far-transfer” OR “cognition AND (subjective OR objective)” OR cognit* OR function* OR ecologic* OR well-being OR real-life OR ADL OR every-day OR mood OR depression) Filter: english, peer reviewed https://search.ebscohost.com/login.aspx?direct=true&db=psyh&bquery=AB+(+meta-analysis*+or+systematic+review*+)+AND+AB+(+adu lt+OR+healthy+OR+ageing+OR+elderly+OR+older+OR+senior+OR+old+OR+geriatric+OR+MCI+OR+%26quot%3bmild+cognitive+im- pairment*%26quot%3b+OR+%26quot%3bcognitive+AND+(impairment+OR+decline)%26quot%3b+OR+%26quot%3bmemory+impair- ment%26quot%3b+OR+%26quot%3b*cognitive+disorder%26quot%3b+OR+%26quot%3bimpaired+cognition%26quot%3b+OR+%26quot%3bsub- jective+memory%26quot%3b+OR+%26quot%3bcognitive+complaints%26quot%3b+OR+%26quot%3bmemory+complaint*%26quot%3b+)+AND +AB+(+%e2%80%9ccognitive+intervention*%e2%80%9d+OR+%26quot%3bcognition+oriented+intervention*%26quot%3b+OR+%26quot%3b- cognitive+based+intervention*%26quot%3b+OR+%26quot%3bcognitive+training%26quot%3b+OR+%26quot%3bcognition+oriented+train- ing%26quot%3b+OR+%26quot%3bcognition+based+training%26quot%3b+OR+%26quot%3bmemory+training%26quot%3b+OR+%26quot%3bex- ecutive+function+training%26quot%3b+OR+%26quot%3bcomputerized+training%26quot%3b+OR+%26quot%3bmultimodal+train- ing%26quot%3b+OR+%26quot%3bmulti-domain+training%26quot%3b+OR+%26quot%3bmental+training%26quot%3b+OR+%26quot%3bbrain+train- ing%26quot%3b+OR+%26quot%3bcognitive+rehabilitation*%26quot%3b+OR+%26quot%3bcognitive+remediation*%26quot%3b+OR+%26quot%3b- cognitive+stimulation%26quot%3b+OR+%26quot%3bcognitive+enhancement*%26quot%3b+OR+%26quot%3bnon-pharmacological+Inter- vention*%26quot%3b+OR+%26quot%3bvideo+game%26quot%3b+OR+%26quot%3bcomputer+game%26quot%3b+)+AND+AB+(+%26qu ot%3bfar-transfer%26quot%3b+OR+%26quot%3bcognition+AND+(subjective+OR+objective)%26quot%3b+OR+cognit*+OR+function*+OR+ecolog- ic*+OR+well-being+OR+real-life+OR+ADL+OR+every-day+OR+mood+OR+depression+)&cli0=RV&clv0=Y&cli1=LA1&clv1=Y&lang=hr&type=1&search- Mode=Standard&site=ehost-live

Table S2
List of excluded full-text articles with reasons for exclusion

Article	Exclusion reason
Bruderer-Hofstetter, M., Rausch-Osthoff, A. K., Meichtry, A., Munzer, T., & Niedermann, K. (2018). Effective multicomponent interventions in comparison to active control and no interventions on physical capacity, cognitive function and instrumental activities of daily living in elderly people with and without mild impaired cognition - A systematic review and network meta-analysis. *Ageing Research Reviews*, *45*, 1–14. https://doi.org/10.1016/j.arr.2018.04.002	not target intervention
Chow, G., Gan, J. K. E., Chan, J. K. Y., Wu, X. V., & Klainin-Yobas, P. (2021). Effectiveness of psychosocial interventions among older adults with mild cognitive impairment: A systematic review and meta-analysis. *Aging & Mental Health*, *25*(11), 1986–1997.	not target intervention
Edwards, J. D., Fausto, B. A., Tetlow, A. M., Corona, R. T., & Valdes, E. G. (2018). Systematic review and meta-analyses of useful field of view cognitive training. *Neuroscience & Biobehavioral Reviews*, *84*, 72–91. https://doi.org/10.1016/j.neubiorev.2017.11.004	not target population
Ferreira-Brito, F., Ribeiro, F., Aguiar de Sousa, D., Costa, J., Caneiras, C., Carrico, L., & Verdelho, A. (2021). Are video games effective to promote cognition and everyday functional capacity in mild cognitive impairment/dementia patients? A meta-analysis of randomized controlled trials. *Journal of Alzheimer's Disease*, *84*(1), 329–341. https://doi.org/10.3233/JAD-210545	not target population
Gates, N. J., Rutjes, A. W., Di Nisio, M., Karim, S., Chong, L. Y., March, E., Martinez, G., & Vernooij, R. W. (2019). Computerised cognitive training for maintaining cognitive function in cognitively healthy people in late life. *Cochrane Database of Systematic Reviews*, *3*(3), Article CD012277. https://doi.org/10.1002/14651858.CD012277.pub2	not target outcomes (no data)
Gates, N. J., Rutjes, A. W., Di Nisio, M., Karim, S., Chong, L. Y., March, E., Martinez, G., & Vernooij, R. W. (2019). Computerised cognitive training for maintaining cognitive function in cognitively healthy people in midlife. *Cochrane Database of Systematic Reviews*, *3*(3), Article CD012278. https://doi.org/10.1002/14651858.CD012278.pub2	not target outcomes (no data)
Gates, N. J., Rutjes, A. W., Di Nisio, M., Karim, S., Chong, L. Y., March, E., Martinez, G., & Vernooij, R. W. (2020). Computerised cognitive training for 12 or more weeks for maintaining cognitive function in cognitively healthy people in late life. *Cochrane Database of Systematic Reviews*, *2*(2), Article CD012277. https://doi.org/10.1002/14651858.CD012277.pub3	not target outcomes (no data)
Gates, N. J., Vernooij, R. W., Di Nisio, M., Karim, S., March, E., Martinez, G., & Rutjes, A. W. (2019). Computerised cognitive training for preventing dementia in people with mild cognitive impairment. *Cochrane Database of Systematic Reviews*, *3*(3), Article CD012279. https://doi.org/10.1002/14651858.CD012279.pub2	not target outcomes (no data)
Hou, J., Jiang, T., Fu, J., Su, B., Wu, H., Sun, R., & Zhang, T. (2020). The long-term efficacy of working memory training in healthy older adults: A systematic review and meta-analysis of 22 randomized controlled trials. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *75*(8), e174–e188. https://doi.org/10.1093/geronb/gbaa077	not target outcomes
Jeong, P. Y., Sung, J. E., & Sim, H. S. (2014). Meta-analysis of cognition-focused intervention for people with mild cognitive impairment and dementia. *Communication Sciences and Disorders*, *19*(2), 199–212.	not english language
Jones, W. E., Benge, J. F., & Scullin, M. K. (2021). Preserving prospective memory in daily life: A systematic review and meta-analysis of mnemonic strategy, cognitive training, external memory aid, and combination interventions. *Neuropsychology*, *35*(1), 123-140. https://doi.org/10.1037/neu0000704	not target population
Joubert, C., & Chainay, H. (2018). Aging brain: The effect of combined cognitive and physical training on cognition as compared to cognitive and physical training alone - A systematic review. *Clinical Interventions in Aging*, *13*, 1267–1301.	not target outcomes
Jung, A. R., Kim, D., & Park, E. A. (2021). Cognitive intervention using information and communication technology for older adults with mild cognitive impairment: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *18*(21), Article 11535. https://doi.org/10.3390/ijerph182111535	not target outcomes
Karbach, J., & Verhaeghen, P. (2014). Making working memory work: A meta-analysis of executive-control and working memory training in older adults. *Psychological Science*, *25*(11), 2027–2037. https://doi.org/10.1177/0956797614548725	not target outcomes

Table S2 (continued)

Article	Exclusion reason
Kurz, A. F., Leucht, S., & Lautenschlager, N. T. (2011). The clinical significance of cognition-focused interventions for cognitively impaired older adults: A systematic review of randomized controlled trials. *International Psychogeriatrics*, *23*(9), 1364–1375. https://doi.org/10.1017/S1041610211001001	not target population
Lau, H. M., Smit, J. H., Fleming, T. M., & Riper, H. (2017). Serious games for mental health: Are they accessible, feasible, and effective? A systematic review and meta-analysis. *Frontiers in Psychiatry*, *7*, 209–209.	not target population
Li, H., Li, J., Li, N., Li, B., Wang, P., & Zhou, T. (2011). Cognitive intervention for persons with mild cognitive impairment: A meta-analysis. *Ageing Research Reviews*, *10*(2), 285–296. https://doi.org/10.1016/j.arr.2010.11.003	not target intervention
Liang, J. H., Xu, Y., Lin, L., Jia, R. X., Zhang, H. B., & Hang, L. (2018). Comparison of multiple interventions for older adults with Alzheimer disease or mild cognitive impairment: A PRISMA-compliant network meta-analysis. *Medicine (Baltimore)*, *97*(20), Article e10744. https://doi.org/10.1097/MD.0000000000010744	not target population
Lipardo, D. S., Aseron, A. M. C., Kwan, M. M., & Tsang, W. W. (2017). Effect of exercise and cognitive training on falls and fall-related factors in older adults with mild cognitive impairment: A systematic review. *Archives of Physical Medicine and Rehabilitation*, *98*(10), 2079–2096. https://doi.org/10.1016/j.apmr.2017.04.021	not target outcomes
Moreno, A., Wall, K. J., Thangavelu, K., Craven, L., Ward, E., & Dissanayaka, N. N. (2019). A systematic review of the use of virtual reality and its effects on cognition in individuals with neurocognitive disorders. *Alzheimer's & Dementia Journal*, *5*, 834–850. https://doi.org/10.1016/j.trci.2019.09.016	not target outcomes
Papp, K. V., Walsh, S. J., & Snyder, P. J. (2009). Immediate and delayed effects of cognitive interventions in healthy elderly: A review of current literature and future directions. *Alzheimer's & Dementia Journal*, *5*(1), 50–60. https://doi.org/10.1016/j.jalz.2008.10.008	not target outcomes (no data)
Reijnders, J., van Heugten, C., & van Boxtel, M. (2013). Cognitive interventions in healthy older adults and people with mild cognitive impairment: A systematic review. *Ageing Research Reviews*, *12*(1), 263–275. https://doi.org/10.1016/j.arr.2012.07.003	not target study design
Roheger, M., Hennersdorf, X. S., Riemann, S., Floel, A., & Meinzer, M. (2021). A systematic review and network meta-analysis of interventions for subjective cognitive decline. *Alzheimer's & Dementia Journal*, *7*(1), Article e12180. https://doi.org/10.1002/trc2.12180	not target outcomes (no data)
Sherman, D. S., Durbin, K. A., & Ross, D. M. (2020). Meta-analysis of memory-focused training and multidomain interventions in mild cognitive impairment. *Journal of Alzheimer's Disease*, *76*(1), 399–421. https://doi.org/10.3233/JAD-200261	not target outcomes
Smart, C. M., Karr, J. E., Areshenkoff, C. N., Rabin, L. A., Hudon, C., Gates, N., Ali, J. I., Arenaza-Urquijo, E. M., Buckley, R. F., Chetelat, G., Hampel, H., Jessen, F., Marchant, N. L., Sikkes, S. A. M., Tales, A., van der Flier, W. M., Wesselman, L., & and the Subjective Cognitive Decline Initiative Working, G. (2017). Non-pharmacologic interventions for older adults with subjective cognitive decline: Systematic review, meta-analysis, and preliminary recommendations. *Neuropsychology Review*, *27*(3), 245–257. https://doi.org/10.1007/s11065-017-9342-8	not target outcomes
Spencer-Smith, M., & Klingberg, T. (2015). Benefits of a working memory training program for inattention in daily life: A systematic review and meta-analysis. *PLoS One*, *10*(3), Article e0119522. https://doi.org/10.1371/journal.pone.0119522	not target population
Sprague, B. N., Freed, S. A., Webb, C. E., Phillips, C. B., Hyun, J., & Ross, L. A. (2019). The impact of behavioral interventions on cognitive function in healthy older adults: A systematic review. *Ageing Research Reviews*, *52*, 32–52. https://doi.org/10.1016/j.arr.2019.04.002	not target study design
Tsang, A. P. L., Au, A., & Lo, H. H. M. (2021). Prospective memory training for healthy older adults: A systematic review. *Clinical Gerontologist*, 1–17. https://doi.org/10.1080/07317115.2021.1950253	not target study design
Untari, I., Subijanto, A. A., Mirawati, D. K., Probandari, A. N., & Sanusi, R. (2019). A combination of cognitive training and physical exercise for elderly with the mild cognitive impairment. *Journal of Health Research*, *33*(6), 504–516. https://doi.org/10.1108/jhr-11-2018-0135	not target intervention
Vilela, V. C., Pacheco, R. L., Latorraca, C. O. C., Pachito, D. V., & Riera, R. (2017). What do Cochrane systematic reviews say about non-pharmacological interventions for treating cognitive decline and dementia? *Sao Paulo Medical Journal*, *135*(3), 309–320. https://doi.org/10.1590/1516-3180.2017.0092060617	not target study design

Table S2 (continued)

Article	Exclusion reason
Yang, C., Han, X., Jin, M., Xu, J., Wang, Y., Zhang, Y., Xu, C., Zhang, Y., Jin, E., & Piao, C. (2021). The effect of video game-based interventions on performance and cognitive function in older adults: Bayesian network meta-analysis. *JMIR Serious Games*, *9*(4), Article e27058. https://doi.org/10.2196/27058	not target intervention
Yang, H. L., Chan, P. T., Chang, P. C., Chiu, H. L., Sheen Hsiao, S. T., Chu, H., & Chou, K. R. (2018). Memory-focused interventions for people with cognitive disorders: A systematic review and meta-analysis of randomized controlled studies. *International Journal of Nursing Studies*, *78*, 44–51. https://doi.org/10.1016/j.ijnurstu.2017.08.005	not target population
Zhang, F., & Kaufman, D. (2016). Physical and cognitive impacts of digital games on older adults: A meta-analytic review. *Journal of Applied Gerontology*, *35*(11), 1189–1210. https://doi.org/10.1177/0733464814566678	not target intervention
Zhong, D., Chen, L., Feng, Y., Song, R., Huang, L., Liu, J., & Zhang, L. (2021). Effects of virtual reality cognitive training in individuals with mild cognitive impairment: A systematic review and meta-analysis. *International Journal of Geriatric Psychiatry*, *36*(12), 1829–1847. https://doi.org/10.1002/gps.5603	not target intervention