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Review Article

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A Systematic Review and Analysis of Each Domain of Executive Functions in Older Adults with Mild Cognitive Impairment

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Abstract

Introduction: Mild Cognitive Impairment (MCI) is regarded as an intermediate state between the normal cognitive decline associated with aging and more severe dementia. According to the diagnostic criteria for MCI established by the National Institute on Aging and the Alzheimer's Association, MCI is characterized by concerns regarding changes in cognition, impairment in one or more executive domains, and the preservation of independence in functional abilities. ***Aim:*** The aim of this systematic review was to establish the magnitude of impairment in each domain of executive function (working memory, attention, cognitive flexibility, inhibition, problem solving, and planning) in older adults with MCI. ***Methods:*** This review study used the guidelines of PRISMA (Preferred Reporting Items) for systematic review and meta-analysis of the included studies. Out of 2092 searched records, 10 clinical studies met the eligibility criteria and were included with data for systematic review and meta-analysis. According to Diamond's (2013) model, executive function measures were coded separately according to the following its components: working memory, inhibitory control, cognitive flexibility, planning, attention, and processing speed. ***Results:*** Global effect size (ES) for executive functions was significantly found (g=−0.28; 95% confidence interval [CI] = [−0.51; −0.06]; Z=−2.53; p= 0.01). Subgroup analysis revealed that ES was significant and large for working memory and moderate for cognitive flexibility. The effect size for attention, inhibitory control, and planning was found to be non-significant. ***Conclusion:*** Working memory and cognitive flexibility were more impaired in older adults with MCI as compared to inhibition, attention, and planning ability.

Keywords: ***Cognition, Executive functions, Mild cognitive impairment, working memory.***

Introduction

Over the last few decades, the cognitive changes associated with ageing have garnered the yearning of clinicians, resulting in the amelioration of diagnostic tools used to discriminate between physiological ageing processes and impending mental decline. On the other hand, a reduction in cognition beyond that associated with regular ageing is categorised by another ageing trajectory; the decline is generally noticed by those experiencing it and occasionally by those around them. In light of this, mild cognitive impairment (MCI) is considered the intermediate state between the normal decline of cognition because of ageing and dementia. There are two categories of MCI: amnestic and non-amnestic. Amnestic MCI, or clinically significant memory impairment, does not fall under the criteria of dementia. Patients and their relatives are usually aware of the developing forgetfulness. A subtle decline in executive functions (EFs) unrelated to memory is the hallmark of non-amnestic MCI.

Executive functions (EFs) are a set of cognitive aptitudes or mental skills that are necessary to pore over and accomplish a desire or attain a goal (Diamond, 2013a). A short perspective on the complexity of EFs would be as an umbrella that surrounds the cerebral skills that include inhibitory control, working memory, and cognitive flexibility. (Cristofori *et al*., 2019). The development of "higher-level executive functions," such as attention, planning, and processing speed, is supported by these three fundamental EFs. The capacity for inhibition is the capacity to regulate one's behaviour, ideas, or attention (interference control - selective or focused attention) (response inhibition - self-control and discipline). Working memory is the capacity to retain information and mentally manipulate, organise, or update it. Visual-spatial working memory and verbal working memory are the two categories that are separated. The term "cognitive flexibility" describes the capacity to shift between different mental focuses or tactics. Diamond indicated the distinct evolution of each executive component as well as the more intricate relationships between them. Inhibitory control and working memory cooperate with one another and coexist. They exhibit an early stage of development but a slow rate of growth. Cognitive flexibility develops much later in development and is built upon the other two (Diamond, 2013a).

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Impaired EFs lead to noteworthy restrictions in the performance of activities of the daily routine, which impairs the quality of life. According to population-based studies (Busse *et al*., 2006); (Di Carlo *et al*., 2007); (Lopez *et al*., 2003); (Manly *et al*., 2008)(States *et al*., 2013) 10 to 20% of people over the age of 65 are believed to have MCI, and the annual rate at which MCI develops into dementia varies from 8 to 15% per year, suggesting that it's crucial to recognise and treat this condition. The pathogenic event in MCI in current theories of early magnetic resonance (MR) alterations is hippocampal and cortical atrophy, which is intimately related to the genesis of memory impairment. A study (Reinvang *et al*., 2012) also reported that the results of MR analysis, which provides sensitive measurements of a variety of pathognomonic events, suggest that impaired brain connectivity may result in impairment of EFs. This is true for both the memory network of the brain, including the posterior cingulate, and also for the frontal networks. Both memory and non-memory (other EFs) are carried out by these networks.

According to the diagnostic criteria of MCI proposed by the National Institute on Ageing and the Alzheimer's Association, they include concern regarding a change in cognition, impairment in one or more executive domains, and preservation of independence in functional abilities and are not irrational. Within the commonly accepted framework, clinical manifestations may be in the memory (amnestic) or non-memory EF domains. Some studies (Amieva *et al*., 2003; Espinosa *et al*., 2009) found impairment in EFs in older adults with MCI, such as decreased working memory, inflexibility of thought, difficulty in problem solving, slowness in behavioural initiation, and poor planning strategies. Another study (Traykov *et al*., 2007) found impaired response inhibition, cognitive flexibility, and abstract thinking, whereas (Bélanger & Belleville, 2009; Borella *et al*., 2017); reported impaired inhibition and attention sharing in elderly patients with MCI. The findings of these studies highlighted the significance of EFs in patients with MCI.

Being the vital subject, the MCI has gotten many studies done on it so far, which are illuminating and noteworthy, but the same have been confined to those on the prevalence (Petersen, 2016), diagnosis (Peterson, 2011), and pathophysiology of executive dysfunctions in MCI (Jongsiriyanyong & Limpawattana, 2018; Reinvang *et al*., 2012); and do not focus on examination of EFs, necessitating the present study, which is designed to focus on clinical trials conducted on screening of EFs and envisages to establish the magnitude of impairment in each domain of EFs (working memory, cognitive flexibility, inhibitory control, attention, processing speed, and planning) in older adults with MCI. We separated the analysis in the current meta-analysis into five domains. Working memory, inhibitory control, and cognitive flexibility are three of the domains that were taken into consideration, along with the likelihood that attention, planning, and problem-solving may not overlap with the other three. In reality, it appears from the research data and our clinical experience that these components do not encompass the first three criteria. Therefore, the aim of the present study, based on the recent Diamond model of EFs (Diamond, 2013), was to clearly identify the magnitude of impairment for each domain of EFs: working memory, inhibitory control, cognitive flexibility, attention, planning, and processing speed in older adults with MCI.

Methods

Search Strategy

This review study used the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Available articles from inception to January 2011 to May 2022 (literature from a decade) were reviewed from the electronic searches of PubMed, Scopus, Research Gate, and Cochrane.

A list of keywords and MeSH terms was generated to identify studies (MCI, cognitive function, executive function, and mild cognitive impairment). These search keywords were linked with "AND" to ensure that at least one term from each field could be found in the results. The terms in each of the search fields were linked with "OR".

Eligibility Criteria

To be eligible for the current systematic review study, studies had to fulfil the following criteria: (a) Participants must also be older adults with MCI or in the early stages of MCI; (b) the MCI population was compared to a control group (a cognitively unimpaired population) that was matched at least by age, gender, or education level; (c) patients had no history of psychiatric or neurological disorders; and (d) at least one neuropsychological task or questionnaire was used to measure higher-level evaluability. The research was published in an English-language, peer-reviewed journal.

Data collection & Analysis

Study Selection: Out of the total records in 2092, after removing 1946 duplicates, 152 records were screened by one reviewer (SJ). Abstracts and titles were read, and 1803 studies were excluded, as shown in Figure 1. Fourteen studies were assessed by two reviewers (SJ and SS) independently according to the selection criteria to assess the characteristics and quality of the study. One article was once again removed from the total of 11 studies that were included in accordance with the eligibility criteria because we were unable to get the descriptive values for analysis.

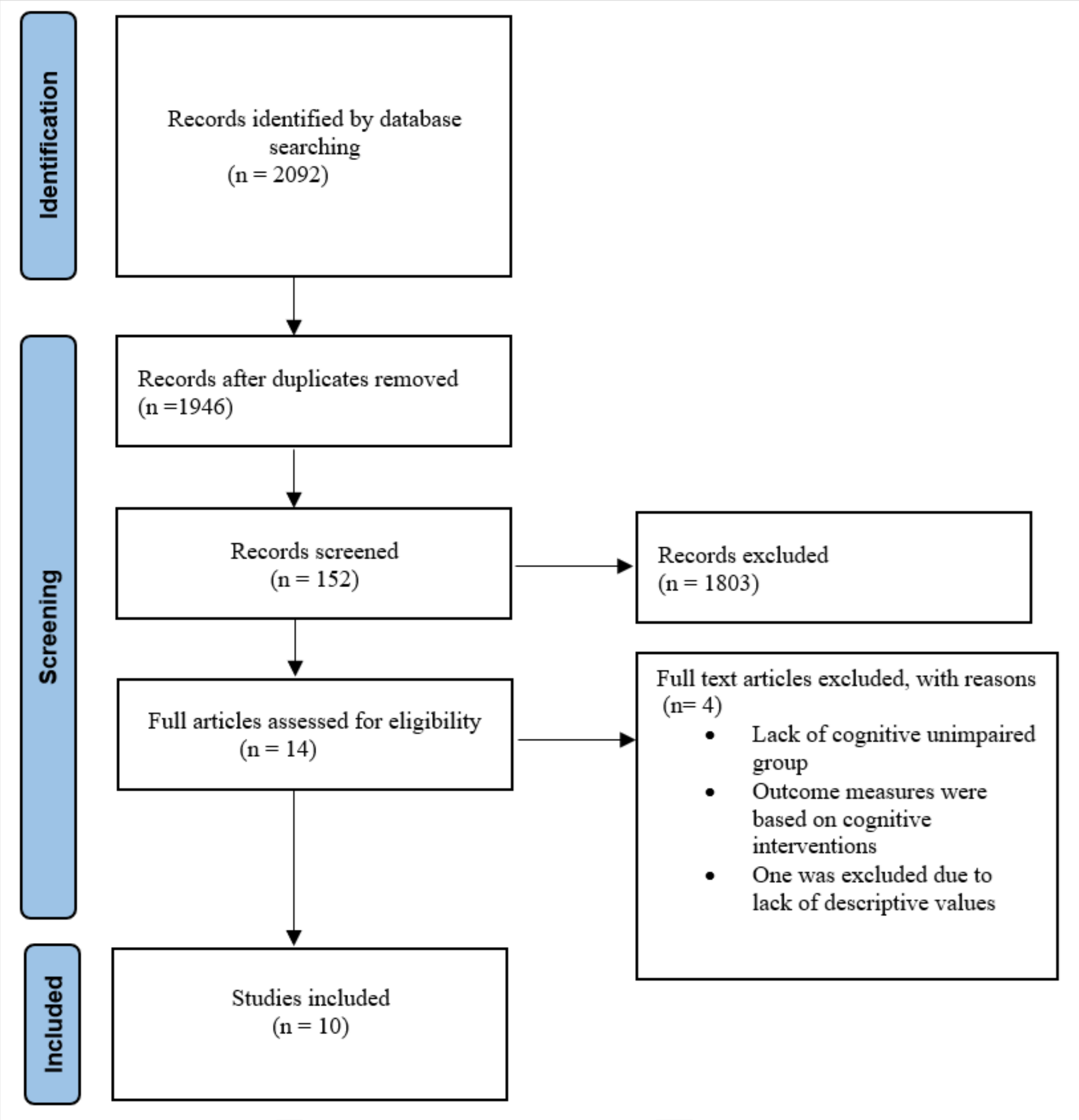

Figure 1: Flow chart showing selection of trials.

Data extraction and analysis: Two authors, SJ and SS, extracted data on the characteristics of the study (year, sample size, groups, age of participants, tool used for tasks performed, and outcome measures). The authors of that study were contacted through email if the reported data was ambiguous or insufficient. Descriptive data, such as the mean and standard deviation (SD) of the pertinent outcome measures for each group (MCI and controls), were recorded for the meta-analysis. If the studies included subgroups of control and MCI populations, mean scores for these populations were calculated. If the data was not presented in a descriptive manner, it was taken from the figures in the articles.

Data analysis was conducted with the Comprehensive Meta-Analysis software suite, version 3. In order to generalise beyond the studies, we performed a random-effects meta-analysis, which does not rely on the assumption of a common effect size (ES). I2, a ratio of true-effect variance to error variance, was determined. Low, moderate, or high heterogeneity would be indicated, respectively, by an I2 index of roughly 25%, 50%, or 75%. For every ES, we also derived a heterogeneity statistic (Cochran's Q-test). The p=.10 alpha level was chosen. If the p-value was less than 0.10, we came to the conclusion that the observed sample heterogeneity could not be entirely attributed to within-sample error. Additionally, we derived tau2, an estimate of the variance of real effects. We also utilised a funnel plot for the overall ES of EFs and Egger's test to check for funnel plot asymmetry.

Quality assessment of studies

Using the Downs and Black checklist (Downs & Black, 1998), the quality of each included study was evaluated. The 27 criteria on this checklist address issues with reporting quality, external and internal validity, and power. The two authors separately evaluated the quality of each paper, and disagreements were settled through discussion and agreement.

Results

Ten relevant studies were extracted, which are discussed for their quality, characteristics, and findings as mentioned in Table 1.

Table 1: Characteristics of included clinical trials

Studies	Groups, sample size, age in years (mean ± SD)	Task Performed	Assessed Construct (as stated in the study)	Variables	Main Findings (group differences)
(Fernandez *et al*., 2020)	MCI (94), (74.76± 6.00) Cognitive unimpaired (51) (71.20±4.50)	TAVEC Rey osterrieth complex figure test BNT WAIS-IV *Similarities* *Airthmetic,* *Reverse Digits,* *Letters and numbers* TMT Stroop Test Verbal fluency *Phonemic* *categories* Zoo map (BADS)	Memory Visual spatial ability Language Attention EFs Attention EFs EFs	Z score Z score Z score Z score Z score Z score Z score Z score	MCI groups showed significantly worse than cognitive unimpaired population in all tasks
(Seo *et al*., 2016)	Pre MCI (77), (72.64±4.67) Cognitive unimpaired (180), (71.94±4.19)	Forward and backward digit span test K-BNT RCFT SVLT *immediate recall; delayed recall; recognition score* RCFT *immediate recall; delayed recall; recognition score* Fluency tests *(animal and supermarket lists), phonemic fluency test* Stroop test *(color naming in color-word incongruent condition),* TMT (A & B)	Attention Language Visual spatial functions Memory Memory Frontal/EFs Frontal/EFs Frontal/EFs	Z score Z score Z score Z score Z score Z score Z score Z score	No difference has been found No difference has been found No difference has been found No difference found in groups in all SVLT trials Pre MCI: Significantly lower performance than CU No difference found in groups in delayed recall & recognition score Pre MCI: Significantly lower performance than CU Pre MCI: Significantly lower performance than CU No difference found between groups
(Rainville *et al*., 2012)	Stable MCI-51 (68.9±8.3); decliner MCI-30 (71.4±7.9); Healthy older adults (42) (69.9±7.3)	Tower of London task:	Planning	Total number of moves; percentage of success; Broken rules	MCI: significantly broke more rules than controls

(Gillis *et al*., 2013)	MCI (32), (71.41±9.55) Young controls (25), (20.52±2.40) Older Controls (34) (68.12±8.19)	RBANS: 5 Subtests TMT (A&B) EWCST WTAR WMS/KBNA	Immediate Memory, Visuospatial/Constructional, Language, Attention, Delayed memory EFs Cognitive flexibility Intelligence WM	Standard Score of all RBANS tests Total score Raw score Standard score Percentage of accuracy	MCI: Demonstrated significant deficits MCI: Demonstrated significant deficits MCI: Demonstrated significant deficits MCI: Demonstrated significant deficits MCI: Demonstrated significant deficits MCI: Demonstrated significant deficits No difference found in MCI and control group No difference found in MCI and control group No difference found in MCI and control group
(K. C. Chen *et al*., 2017)	MCI (33), (74.9±5.6); AD (26), (79.5±6.1); Healthy Controls (28) (73.7± 5.4)	CASI Reaction time assessment tool: SRT FRT	EFs Perception & response Inhibition	Total Score Response reaction time Inhibition cost reaction time	Significant difference between 3 groups, but lower scores in MCI No difference found in MCI and control group No difference found in MCI and control group
(Borella *et al*., 2017)	MCI (15), (72.73±5.28); Healthy Controls (18) (69.72±3.20)	Color stroop task Text with Distracters Proactive interference	Inhibition Inhibition Inhibition	Response time Correct answers Intrusion errors	MCI: performed worse than controls MCI: performed worse than controls MCI: significantly higher in errors than controls
(Ballesteros *et al*., 2013)	MCI(51), (81.9±4.7) Normal Controls (25) (81.2±4.0)	Uniform dataset battery: WAIS Digit Symbol TMT (A & B) Audio Recorded Cognitive Screen: Clock drawing HAT-A & HAT-B	Visuospatial Attention/EFs Visuaspatial Attention & EFs	Total Score Total Score Total Score Total Score (items correct)	MCI: performed worse than controls MCI: performed worse than controls MCI: performed worse than controls MCI: performed worse than controls
(Ballesteros *et al*., 2013)	MCI(20), (74.52±3.95); Young adults (20), (26.25±1.68); Older adults (20) (69.15±83.15)	E-prime 1.11 computer screen: Speed of processing (simple and choice reaction time) Implicit Memory (Repetition Priming) WCST	Processing speed Memory Executive control	Response time & SD Response time & SD Percentage of error	MCI: performed poor than both groups MCI: performed poor than both groups MCI: performed poor than both groups
(Saunders & Summers, 2011)	aMCI (52), (70.96±6.85); naMCI (29), (71.41±7.22) Controls (25) (69.19±5.75)	CANTAB: RTI *Simple RTI* *Choice RTI* MTS RVP IED SWM PAL SSP	Sustained attention Divided attention Ability to match visual samples Sustained attention Flexibility of thinking EFs EFs WM Episodic visual memory WM	Reaction time Reaction time Latency Latency Detection threshold Total errors Trials Strategy scores Total errors Errors Span length	aMCI & naMCI group displayed slower reaction time than controls in both RTI tests aMCI & naMCI: showed significantly slower latency aMCI & naMCI: showed significantly slower latency aMCI & naMCI: showed lower detection threshold aMCI: errors were significantly higher than both groups aMCI & naMCI: required more trials than controls aMCI & naMCI: highest scores than controls aMCI & naMCI: significantly done more errors than controls aMCI: significantly done higher number of errors aMCI & naMCI: significantly smaller span length than controls

(Kim *et al*., 2016)	EMCI, Early MCI (45), (70.39±9.81) LMCI, Late MCI (41), (73.95±7.25) Mild AD (41), (73.88±8.21) NE, Normal elderly (41) (72.73±6.19)	SNSB-II: Go – No Go test K-CWST COWAT *Animal* *Phonemics* *Supermarket* DSC KTMT-E *Part A* *Part B*	Inhibitory control Attention Verbal fluency EFs Frontal/EFs	Raw score Standard score Standard score Standard score Standard score Standard score Standard score Standard score	No significant difference found between EMCI & NE, but LMCI performed worse than NE No significant difference found between EMCI & NE, but LMCI performed worse than NE EMCI more impaired than NE, No difference found between EMCI & LMCI EMCI & LMCI impaired equally but more than NE EMCI more impaired than NE, No difference found between EMCI & LMCI EMCI & LMCI impaired equally but more than NE No significant difference found between groups No significant difference found between EMCI & NE, but LMCI performed worse than NE

Abbreviations: SD= Standard deviation, MCI = Mild cognitive impairment, TAVEC= Verbal Learning Test Espana - Complutense, BNT= Boston naming test, WAIS-IV= Wechsler Adult Intelligence Scale- IV, TMT= Trial making test, BADS= Behavioural Assessment of Dysexecutive Syndrome, EFs = Executive functions, AD= Alzheimer's disease, aMCI = amnestic mild cognitive impairment, naMCI= non amnestic mild cognitive impairment, K-BNT=Korean version of Boston naming test, RCFT= Rey complex figure test, SVLT= Shiraz verbal learning test, RBANS= Repeatable battery for the assessment of neuropsychological status, EWCST= Emory Short form of the Wisconsin Card Sorting Test, WTAR= Wechsler Test of Adult Reading , WMS/ KBNA = the Boston Revision of the Wechsler Memory Scale Mental Control subtest, CASI=Cognitive abilities screening instrument, SRT= Simple reaction time, FRT= Flanker reaction time, HAT-A&B= Hunter attentional task, WCST= Wisconsin Card Sorting Test, CANTAB= Cambridge Neuropsychological Test Automated Battery, RTI= Reaction time, MTS= Match to Sample Visual Search, RVP = Rapid visual processing, IED= Intra-Extra dimensional shift, SWM= Spatial working memory, PAL= Paired association learning, SSP= Spatial span, SNSB-I =Seoul Neuropsychological Screening Battery, K-CWST= Korean-Color Word Stroop Test, COWAT= Controlled Oral Word Association Test, DSC= Digit Symbol Coding, KTMT-E = Korean-Trail Making Test-Elderly's version

Summary of studies

The included studies were released from a decade (since 2011-2022). All were carried out in a variety of places, including Spain, Canada, Korea, the United States, Japan, China, and Australia. We have focused our analysis on studies spanning the past decade to ensure our conclusions are rooted in current literature and to provide a comprehensive overview of data over the past ten years for clarity.

Characteristics of studies

Study Design: Cross sectional clinical trials

Participants: Ten included studies comprised of 1154 participants, with sample sizes ranging from 33 to 257. Two studies (Ballesteros *et al*., 2013); (M. Meredith Gillisa, b, Kristen M. Quinnb, Pamela A.T. Phillipsb, 2013) also featured young adults along with the elderly in the control group, with a mean age of 20 years, while the majority of studies involved participants in the 65 to 80-year age range. Participants' age and education level were compared in all the included studies. A study (Y. X. Chen *et al*., 2021) included an AD group along with a control and an MCI group for the comparison. A study(Seo *et al*., 2016) included a pre-MCI group in comparison to a control group. In some studies (Rainville *et al*., 2012; Saunders & Summers, 2011; Seo *et al*., 2016); MCI is further classified (e.g., amnestic MCI, non-amnestic MCI, stable MCI, decliner MCI, early MCI, and late MCI). Lack of information on sample size calculation was a common limitation across all the studies.

Quality of trials: The comparable quality levels, as defined by the Downs and Black quality assessment scale, are exceptional (26-28), acceptable (20-25), fair (15-19), and poor quality (14). Out of the 10 included studies, we discovered that all of them met the scale's requirements for fair quality (Supplementary file 1). Two studies received a score of 15, four studies received a score of 16, and the other four studies received a score of 17.

Pre - Neuropsychological testing: Initial screening for the final recruitment, global cognitive functions were assessed by the Mini Mental State of Examination (MMSE) in the majority of the studies (K. C. Chen *et al*., 2017; Fernandez *et al*., 2020; M. Gillisa, 2013; Rainville *et al*., 2012; Seo *et al*., 2016). A study (García-García-Patino *et al*., 2020) also considered Addenbrooke's Cognitive Examination Revised through neuropsychological battery, whereas a study (Kim *et al*., 2016) used the Korean version of MMSE. The Geriatric Depression Scale (GDS) to measure depressive symptoms in older controls and MCI were considered in two studies (M. Gillisa, 2013; Rainville *et al*., 2012). Additionally, the Beck Depression Inventory-II was used for young controls in two studies (Borella *et al*., 2017; M.Gillisa, 2013). A study (Rainville *et al*., 2012) used the Hachinski scale to record the risks of vascular factors. Dementia was also investigated through the clinical dementia rating scale in some of the studies (K. C. Chen *et al*., 2017; Kim *et al*., 2016; Sewell, 2013; Seo *et al*., 2016) and the Mattis Dementia Rating Scale were used by a study (Saunders & Summers, 2011). In a self-reported format, the Subjective Memory Complaints and the Geriatric Depression Scale were also used.

Another study (García-García-Patino *et al*., 2020) used the Lawton & Brody, ECOG Scale, Blessed Scale, and the Neuropsychiatric Inventory Questionnaire, and another study (Ballesteros *et al*., 2013) used the Barcelona Scale, Reisberg Global Deterioration Scale, and Blessed Dementia Scale.

Outcome measures: The neuropsychological assessment of domains of EFs (attention, visuospatial, language, working memory, cognitive flexibility, inhibition, processing speed, and planning) and the tools used are mentioned in Table 1.

Effect of EFs

Overall effect of EFs: The overall effect of EF was small and significant (k = 10; g = 0.28; 95% confidence interval [CI] [0.51; 0.06]; Z = 2.53; p = 0.01), indicating overall impairment of EFs in older adults with MCI when compared to the cognitively unimpaired older population. The Q test revealed significant heterogeneity across included studies (I2 = 66.57%; tau2 = 0.06), and the I2 test revealed significant heterogeneity (Q (9) = 26.92; p = 0.001).

The results of the funnel plot showed asymmetry (**Figure 2**). Egger's test was non-significant (Egger's intercept: 0.01; p > 0.05). One of the factors contributing to funnel plot asymmetry and publication bias is study variability (Sterne *et al*., 2011).

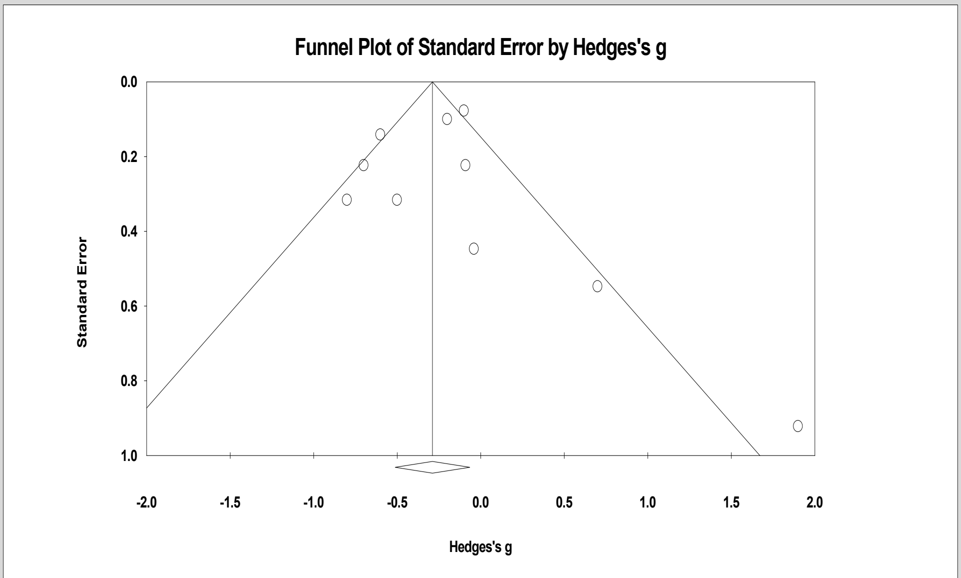

Figure 2: Funnel plot of standard error by hedges's g.

Working Memory: Working memory's global ES was found to be large and significant (k = 2; g = 1.1; 95% CI [0.87; 0.39]; z = 2.4; p =.01). The Q-test was significant (Q (2) = 6.6; p =.01), and the I2 test revealed significant heterogeneity between samples (I2 = 85.02%; tau2 = 0.3). Overall, ES was not seen as significant between these two tests (k = 2; g = -0.6; 95% CI [-1.73; 0.48]; z=-1.11; p

>0.05), whereas high heterogeneity between samples was found through the Q test (q (1) = 23.8; p<0.001) and the I2 test (I2 = 95.81%; tau2 = 0.6). Five tasks were conducted for visual and spatial memory. However, results of ES were non-significant (k = 5; g = 0.2; CI [-0.6; 1.08]; z = 0.48; p > 0.05), but the Q test was significant (Q (4) = 91.8; 0.001), and similarly, I2 indicates high heterogeneity (I2 = 95.64 %; tau2= 0.9) between samples. Forest plot results for working memory and visual spatial memory are shown in figures 3a and 3b.

Study name	Subgroup within study	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Gillis et al	Working memory	WMS/KBNA	-0.684	0.253	0.064	-1.180	-0.187	-2.698	0.007
Saunders & Summers	Working memory	SSP	-1.646	0.274	0.075	-2.183	-1.109	-6.007	0.000
			-1.159	0.481	0.231	-2.102	-0.216	-2.410	0.016

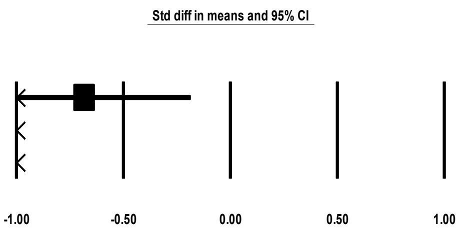

Figure 3a: Forest plot of studies group for working memory

Study name	Subgroup within study	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Std Residual	Std Residual	Std Residual
Fernandez et al	VisualSpatial	Rey ost FT	-0.714	0.179	0.032	-1.065	-0.363	-3.991	0.000	-1.05		
Seo et al	Visual spatial	RCFT	-0.016	0.136	0.019	-0.283	0.251	-0.118	0.906	-0.26		
Sewell et al	Visual Spatial	Clock drawing	-0.998	0.257	0.066	-1.502	-0.494	-3.879	0.000	-1.35		
Saunders & Summers	Visual memory	PAL	0.814	0.249	0.062	0.326	1.302	3.272	0.001	0.67		
Saunders & Summers	Visual spatial	MTS	2.067	0.292	0.085	1.495	2.638	7.086	0.000	2.03		
			0.216	0.447	0.199	-0.660	1.091	0.483	0.629			

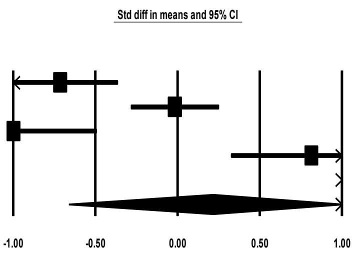

Figure 3b: Forest plot of studies group for visual spatial memory

Inhibition: The global ES for tasks performed in response to inhibition or to assess inhibitory control was not found to be significant (k = 3; g = -0.28; 95% CI [-0.98; 0.40]; z = -0.8; p > 0.05). There was significant heterogeneity between samples, as indicated by the Q test (p = 0.005), [Q (2) =10.49], and the I2 test (I2 =80.94%; tau2=0.3). However, it is pertinent to note that this conclusion stems from the analysis of three studies. Forest plot results are shown in Figure 3c.

Study name	Subgroup within study	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Chen et al	Inhibition	FRT	0.383	0.259	0.067	-0.125	0.892	1.479	0.139
Borella et al	Inhibition	Proactive Interference	-0.903	0.367	0.135	-1.622	-0.184	-2.462	0.014
Kim et al	Inhibition	Go N Go test	-0.457	0.224	0.050	-0.896	-0.019	-2.044	0.041
			-0.297	0.358	0.128	-0.999	0.404	-0.830	0.406

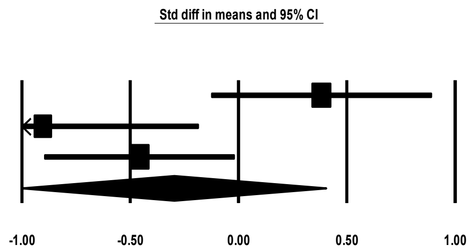

Figure 3c: Forest plot of studies group for inhibition

Cognitive Flexibility: The overall ES for cognitive flexibility was moderate and significant (k=3; g= 0.6; 95% CI [0.35; 0.9]; z = 4.1; p<0.001). The Q test was not significant and I2 showed homogeneous results (Q (2) = 2.25; p >0.05; I2 = 10.1%; tau2 = 0.008). However, it is imperative to acknowledge that the scope of this result is confined to the conclusions drawn exclusively from three studies. Forest plot results are shown in Figure 3d.

Study name	Subgroup within study	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Gillis et al	Cognitive flexibility	EWCST	0.713	0.254	0.065	0.215	1.210	2.805	0.005
Ballesteris et al	Cognitive flexibility	WCST	0.305	0.318	0.101	-0.319	0.928	0.958	0.338
Saunders & Summers	Cognitive flexibility	IED	0.899	0.251	0.063	0.408	1.391	3.587	0.000
			0.684	0.163	0.026	0.365	1.002	4.204	0.000

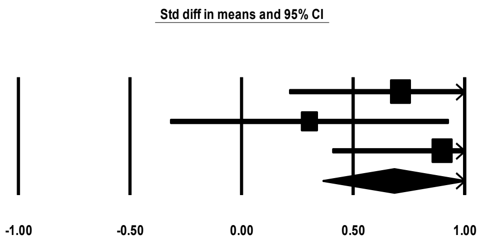

Figure 3d: Forest plot of studies group for cognitive flexibility

Processing Speed: The results of ES for processing speed were significant but small (k=3; g= 0.2; 95% CI [2.9; 3.7]; z= 2.29; p = 0.02). The Q test was also significant, and I2 showed high heterogeneity between samples (Q (2) = 33.03; p <0.001; I2 = 93.94%; tau2 = 2.1). An ample number of tests to assess processing speed were not documented in the studies we have included; thus, the results were derived from a limited number of studies. Forest plot results are shown in Figure 3e.

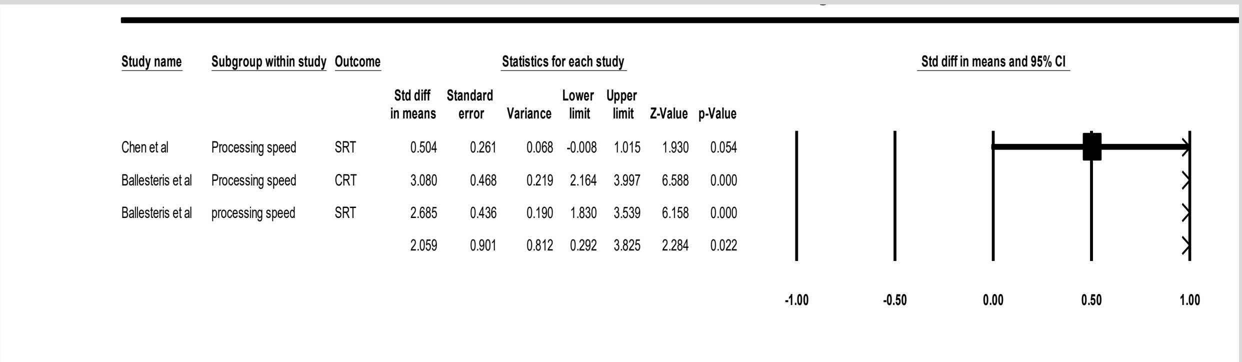

Figure 3e: Forest plot of studies group for processing speed

Attention: Seven tasks were performed for the examination of attention. There was no significant difference for ES observed between these tasks (k= 7; g= -0.029; 95% CI [-0.43; 0.37]; z= -0.14; p > 0.05). Whereas there was significant between-sample heterogeneity (I2 = 87.73%; tau2 = 0.2; Q (6) = 48.91; p <0.001).

Planning: Only one test, each for intelligence and planning abilities, was administered. However, the MCI population performed worse in comparison to the cognitively unimpaired population.

General Executive Control: Four tests were used to gauge participants' general executive abilities. The global ES for these abilities was moderate and significant (k=5; g= -0.7; 95% CI [-1.18; -0.23]; z= - 2.91; p= 0.004). There was also high heterogeneity between samples (Q (4) = 27.77; p= <0.001); (I2 = 85.59; tau2= 0.2).

Discussion

This is the first systematic and analytical review providing information on the quality, characteristics, and findings of the clinical studies that are focused on the screening of domains of EFs (working memory, inhibition, cognitive flexibility, and planning) in older adults with MCI. It was set out to quantify the degree to which each EF was compromised in this population. A total of 10 studies reporting 35 tests or tasks for the assessment of EFs were included in the review and analysis.

The findings showed that not all studies found impairment in all domains of EFs in older adults with MCI when compared to the cognitively unimpaired population. These results are somewhat in line with other previous studies (Corbo & Casagrande, 2022) that suggested executive function impairments are not always present in people with mild cognitive impairment as compared to elderly individuals in good cognitive health. However, the overall ES of EFs in older adults with MCI was found to be significant, and results also revealed heterogeneity was observed in the majority of the studies.

Effect of domains of EFs in MCI: Subgroup analyses revealed that ES differed according to the particular executive functioning component.

Depending on the type of working memory, many kinds of working memory deficits exist. Two studies(M. Gillisa, 2013; Saunders & Summers, 2011) used two different tests to assess generalised working memory (WMS/KBNA, the Boston Revision of the Wechsler Memory Scale Mental Control subtest; SSP, spatial span); another studies(García-García-Patino *et al*., 2020; Sewell, 2013; Saunders & Summers, 2011; Seo *et al*., 2016) used different five tasks for the assessment of visual or verbal working memory. The ES for working memory is significant and larger than that for visual-spatial working memory and verbal learning memory, even though the visual working memory deficit appears to be widespread in older adults. These studies' recruited populations may have influenced the results in different ways. In one study (Saunders & Summers, 2011), the MCI population was exclusively amnestic. Previous studies (Kirova *et al*., 2015) have shown that the amnestic MCI population is more likely to develop Alzheimer's disease, which may explain why working memory is impaired more frequently than in the cognitively healthy population.

Inhibitory control was examined by three studies (Borella *et al*., 2017; K. C. Chen *et al*., 2017; Kim *et al*., 2016) with three different tasks (Go-No-Go test; FRT, Flanker reaction time; and Proactive interference). Individual studies of these tests revealed significant results when MCI was compared to the normal cognitive population, although ES was not significant for inhibitory control, according to the current data. Despite this, a noteworthy finding was made in past research (Bélanger & Belleville, 2009). Differentiating between MCI cases with a stable cognitive profile and those who have a propensity for rapid worsening may be made easier by identifying inhibitory deficits in those cases. In addition, it has been proposed (Borella *et al*., 2017) that one of the primary factors behind age-related cognitive loss is a decline in inhibitory function. Despite this, it is possible that differences in the psychometric properties of EF tasks are to blame if ES was not found to be significant in the current study.

Our findings showed that the ES for cognitive flexibility was considerable and moderate, with cognitive flexibility being more severely reduced in older adults with MCI than in the cognitively unimpaired population. Three different tests (EWCST, Emory short form of the Wisconsin Card Sorting Test; WCST, Wisconsin Card Sorting Test; IED Intra-extra dimensional set shift) were used to assess cognitive flexibility in three different studies (Ballesteros *et al*., 2013; M. Gillisa, 2013; Saunders & Summers, 2011). Indeed, one interesting finding was reported (Ballesteros *et al*., 2013) that even more cognitive flexibility impairment is seen in MCI as age increases. Processing speed was assessed with two tests in two different studies (Ballesteros *et al*., 2013; M. Gillisa, 2013) .ES was small but significant, and revealed that MCI has a slower processing speed than the normal population. Slower processing speed reflects MCI-related deficits and is a factor in ordinary cognitive ageing (Daugherty *et al*., 2020).

On the other hand, ES for attention was found to be non-significant in current data. Although seven different tests (Stroop word; digit span forward & backward; TMT trail making test; HAT-A&B hunter attention task; CTRI choice reaction time; KTMT-E Korean version of trail making test) were used for the assessment of attention in six different studies(Fernandez *et al*., 2020; García-García-Patino *et al*., 2020; Kim *et al*., 2016; M. Gillisa, 2013; Sewell, 2013; Saunders & Summers, 2011; Seo *et al*., 2016) ,In response to the current surroundings, attention is a dynamic phenomenon that shifts. Results could be affected because the attention deficits vary according to the type of attention (selective, sustained, divided, and alternative attention). Previous studies (Treviño *et al*., 2021) conducted on the construct validity of neuropsychological tests for the measurement of attention documented tests that can be used for the assessment of alternative attention, such as Trail Making Test Versions A and B (TMT-A, TMT-B), Digit Symbol Coding, Letter Cancellation, and Spatial Span; however, they also reported, undoubtedly, that "forward and backward digit span" tests should not be used for the measurement of attention. For sustained attention, tests such as the sustained attention to response task (SART) and the Conners continuous performance test (CPT) can be used, and the classic Stroop test can be used for the measurement of divided attention. In current data, in order to measure divided attention, the CTRI test was employed, and the Stroop word was used for selective attention. However, given that not all tests delivered statistically significant results and that some studies employed unsuitable tests, this data should be viewed with caution. A study (Seo *et al*., 2016) used "digit span forward and backward tests," which are not specific for attention. Despite this distinction, this test has been used in neuropsychological batteries.

On the other hand, planning was only assessed with one test, "TOL, Tower of London". In previous literature (Rainville *et al*., 2012), it was noted that MCI individuals had a higher rate of rule-breaking and desertion than cognitively unimpaired participants while performing activities. It would not be fair to have non-significant ES data for planning. Of course, more testing would be needed to determine the overall significance of the ES because planning ability is a core component of EFs.

From a theoretical perspective, according to biological theory, MCI causes changes to the hippocampus, thalamus, and posterior white matter. In fact, the prefrontal cortex and its subcortical connections play a major part in the broad cerebral network that is linked to executive functioning. The findings of the current study should motivate future neurophysiological research to concentrate on EF investigations that will enrich our knowledge of this fascinating topic.

From a clinical perspective, our findings highlight the requirement that older adults with MCI get a thorough early neuropsychological assessment in order to find early indications of EF impairments and alert the MCI entourage.

Finally, due to the lack of data, some variables in the majority of studies, such as gender, education level, and socioeconomic status, could not be analysed. Future research might therefore examine the impacts of various variable moderators to ascertain whether there is a relationship between these variables and executive performance in older adults with MCI.

Conclusion

To sum up, the current study reported that older adults with MCI had lower EF levels than the cognitively unimpaired older population. Subgroup analyses revealed that executive functioning impairment varied depending on the particular component of EFs. Working memory and cognitive flexibility appear to be more affected than inhibitory control and attention in older people.

Declarations

Ethical Statement

This is a systematic review with analysis based on previous published literature. There was no direct participation of human subjects or animals, therefore, approval from an Institutional Ethics Committee was not required for the present study. All included studies were thoroughly reviewed in accordance with ethical principles. Due acknowledgment has been given to the original authors. This review was steered in compliance with accepted standards of academic veracity and research ethics.

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Conflict of interest

Authors declare no conflict of interest.

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