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Review

Higher-Level Executive Functions in Mild Cognitive Impairment: A Systematic Review

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Abstract

Mild Cognitive Impairment (MCI) is a clinical syndrome characterized by a moderate decline in one or more cognitive functions with a preserved autonomy in daily life activities [1]. MCI exhibits cognitive, behavioral, psychological symptoms [2]. The executive functions (EFs) are key functions for everyday life and physical and mental health and allow adapting the behavior to external changes [3-5]. Higher-level executive functions develop from basic EFs (inhibition, working memory, attentional control, and cognitive flexibility). They are planning, reasoning, problem-solving, and fluid intelligence (Gf) [3].

This systematic review investigates the relationship between higher-level executive functions and healthy and pathological aging, assuming the role of executive functions deficits as a predictor of cognitive decline. The systematic review was conducted according to the PRISMA Statement [6-7]. A total of 73 studies were identified.

The results indicate that 65.8% of the studies confirm significant EFs alterations in MCI (100% problem solving, 71.4% fluid intelligence, 56.8% planning, 50% reasoning). These results seem to highlight a strong prevalence of higher-level executive functions deficits in MCI elderly than in healthy elderly.

Keywords: Mild Cognitive Impairment; Ageing; Elderly; Executive Functions; Higher-Level Executive Functions; Planning; Reasoning; Fluid Intelligence; Problem Solving

1. Introduction

Mild Cognitive Impairment (MCI) is a syndrome characterized by a clinical profile intermediate between healthy aging and pathological aging. Individuals with MCI do not meet the diagnostic criteria of dementia, but they have worse cognitive functioning than physiological and normal aging [1]. The most common onset symptom is memory impairment, as in Alzheimer's disease (AD), followed by other impairments [1]. However, cognitive deficits can be detected in cognitive functions other than memory. Petersen et al., [8] divided MCI into four groups based on the number and the type of impaired functions.

The most studied type is amnesic MCI, in which the subject has a memory disorder that can be at a single domain (aMCI) or multiple domains (aMCI - md). In the latter

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case, there are other impairments in addition to the memory deficits. On the other hand, if the subject does not have a memory deficit, we speak of non-amnestic MCI, which can be at a single (naMCI) or multiple (naMCI - md) domain based on the functions involved [8]. In 8-12% of cases, MCI evolves into Alzheimer's disease. Hence, studying this syndrome is fundamental to predicting AD progression [8].

People with aMCI exhibit a reduced thickness of the entorhinal cortex, fusiform gyrus, and hippocampus compared to naMCI and healthy elderly, and reduced thickness of cingulate gyrus and amygdala compared to healthy elderly. A decreased thickness of precuneus is present in both MCI types [9]. These alterations are similar to the Alzheimer's disease modifications, thus confirming how the MCI is a transitional phase between healthy and pathological aging from an anatomical point of view [10]. The patients with Mild Cognitive Impairment show behavioral and psychological symptoms, in addition to cognitive impairments involving memory and executive functions deficits [2].

The executive functions (EFs) are key functions for everyday life and physical and mental health, which allow adapting the behavior to external changes. The EFs are coordinated and integrated by different neural systems [3-5]. Executive functions deficits are the most common cognitive diseases, which can be found in several pathologies [11]. The Prefrontal Cortex (PFC) is the main area regulating EFs [3, 5], and its damage can lead to the dysexecutive syndrome. This syndrome may be characterized by behavioral symptoms (e.g., social, sexual, and food behavior disorders, confabulation, and anosognosia) and/or cognitive symptoms (e.g., planning, shifting, theory of mind, and sustained attention disorders) [11]. Godefroy et al. [11] observe that planning is the most compromised cognitive ability in MCI and AD.

According to Diamond's model, the EFs have three major components: inhibition, working memory, attentional control, and cognitive flexibility. Higher-level executive functions develop from these components. They are planning, reasoning, and problem-solving. Fluid intelligence (Gf) is considered a synonym of the latter two functions [3].

Planning is the ability to think about the future to achieve a goal through a series of intermediate steps [12]. Shallice & Burgess [13] have described the planning process via four steps: 1) goal articulation; 2) plan formulation; 3) marker creation and triggering; and 4) evaluation of initial goals achievement. The planning ability involves the right frontal area, the left frontal lobe, and sustained attention and inhibition of automatic responses [14].

Reasoning is the ability to convert implicit information into explicit ones, clarify the process if necessary [15], and come to conclusions [16]. It can be divided into inductive and deductive reasoning, and the involved areas are left inferior and middle frontal gyrus, left middle and lateral temporal gyrus, left superior temporal and cingulate gyrus [16].

Problem solving is the capacity to achieve a goal through a sequence of cognitive operations or insight [17]. Ordinary problem solving is regulated by the Frontoparietal Cognitive Control Network, which includes the middle frontal gyrus, inferior frontal gyrus, and inferior parietal lobule. The insight in problem solving is regulated by the

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same areas that regulate ordinary problem solving but with the addition of the anterior cingulate cortex and temporo-parietal junction [17].

Fluid Intelligence is the ability to solve problems via pre-existent acquired information [3, 18]. The most involved areas are the left anterior frontal lobe, the inferior parietal lobule, and the left fronto-parietal regions, which are part of the Dorsal Attention Network (DAN). The DAN selects the internal stimuli based on goals or expectations and directs them to the appropriate cognitive or motor response. The Gf is sensitive to physiological aging but can be stimulated by schooling, education, behavioral training, and stimulant drugs [19-20].

This systematic review aims to investigate the relationship between higher-level executive functions and healthy and pathological aging, assuming the role of executive functions deficits as a predictor of cognitive decline.

2. Materials and Methods

The review process was conducted according to the PRISMA Statement [6-7].

2.1 Research Strategies

A systematic search of the international literature was conducted in the following electronic databases by selecting articles published in peer-review journals: PsycINFO, Scopus, MEDLINE, and Web of Sciences. The last search was conducted on 13 July 2021.

A list of keywords and MeSH terms was generated to identify studies ("mild cognitive impairment" AND "executive function*"); ("mild cognitive impairment" AND "reasoning"); ("mild cognitive impairment" AND "problem solving"); ("mild cognitive impairment" AND "planning"); ("mild cognitive impairment" AND "fluid intelligence"). Restrictions were made, limiting the research to academic publications with English and Italian full text, without restrictions regarding gender and ethnicity. Additionally, the bibliographical references of retrieved papers, reviews, and meta-analyses were screened manually to assess whether they included relevant studies in the review. The number of selected articles is shown in Table 1.

Database	**N°**
PsychINFO	1581
MEDLINE	4067
Scopus	2881
Web of Sciences	2740

Table 2. Number of selected articles in databases.

2.2 Eligibility Criteria

A total of 11.269 articles were obtained from the search procedure. The first step allowed 5.337 duplicates to be eliminated using the Mendeley software. Then, the list of potential articles produced by systematic research was revised. The reading of the title

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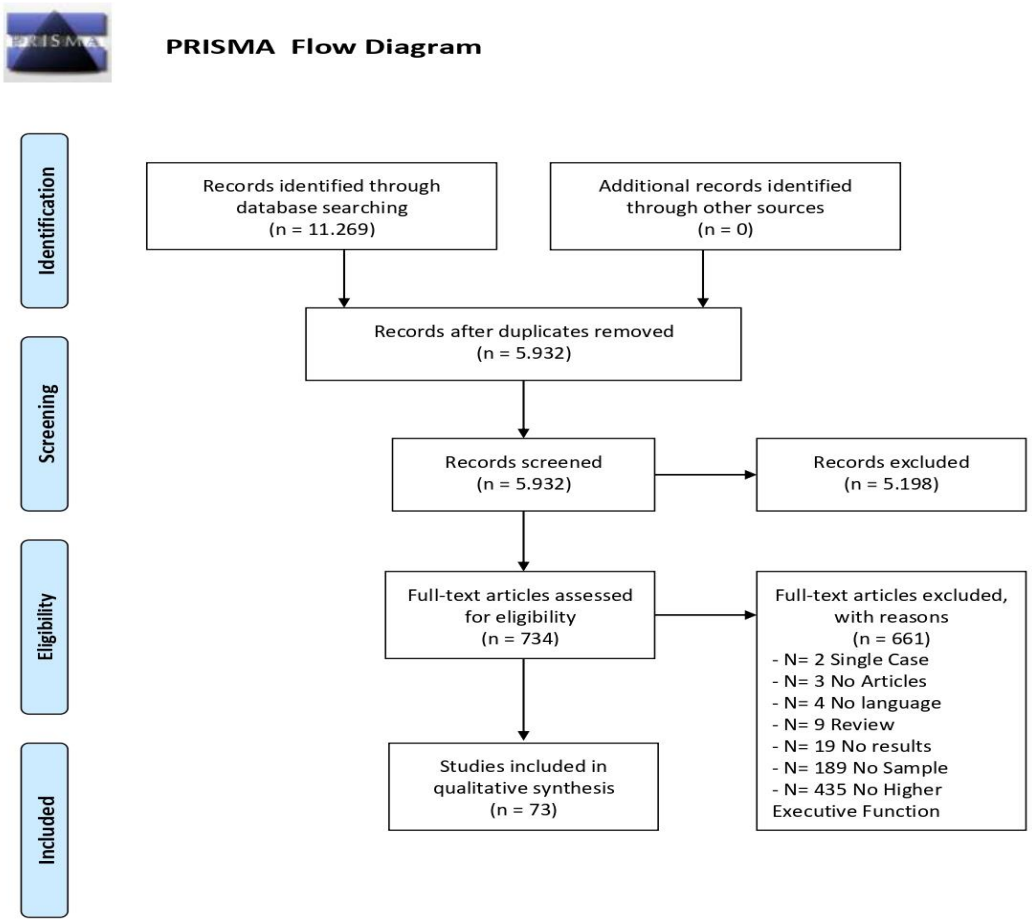
and abstract allowed the first exclusion of 5.198 non-inherent studies. A further selection was made by reading the full text (See Figure 1).

The inclusion criteria were: adult population (age equal to or higher than 50 years), diagnosis of Mild Cognitive Impairment; healthy subjects; use of higher-level executive functions measurements.

The exclusion criteria were: participants with medical conditions that could potentially influence the investigated relationship (for example, metabolic disorders; cardiovascular disorders; chronic disorders; cancer); participants diagnosed with dementia (Alzheimer Disease; Parkinson's Disease; Vascular Dementia; Frontotemporal Dementia; Dementia with Lewy Bodies; Huntington's Disease), psychiatric disorders, neurological disorders, strokes; use of drugs that affect the nervous system and traumatic brain injury; methodological flaws; lack of essential data; assessment made by caregivers; MCI participants included in healthy elderly or AD groups; reviews, dissertations, editorials, comments, replies; trials; age < 50 years and animal models.



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, PRISMA Statement [6-7]

2.3 Data Collection

According to the PICOS approach [6], the following information was extracted from each study: authors and year of publication; characteristics of participants (including age, gender, Mini Mental State Examination – MMSE score); diagnostic criteria; experimental paradigm; results.

The extracted data are included in Table 2.

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2.4 Quality Assessment

A quality assessment was carried out to analyze the eligibility of each article to reduce the risk bias. The analysis used five criteria to screen each study selected for systematic review: sampling bias, executive function measurements, diagnostic criteria, selective reporting bias, and methodological bias. Each criterion score ranges from 1 (low risk) to 3 (high risk). The overall quality shall be calculated by adding all the scores obtaining a global score ranging from 5 to 15. The study was considered at low risk of bias if the score was 5, while a score in the 6-10 interval was considered an indicator of a moderate risk of bias. The quality assessment was subdivided into planning, reasoning, fluid intelligence, and problem solving measurements. The risk of bias is reported in Figure 2.

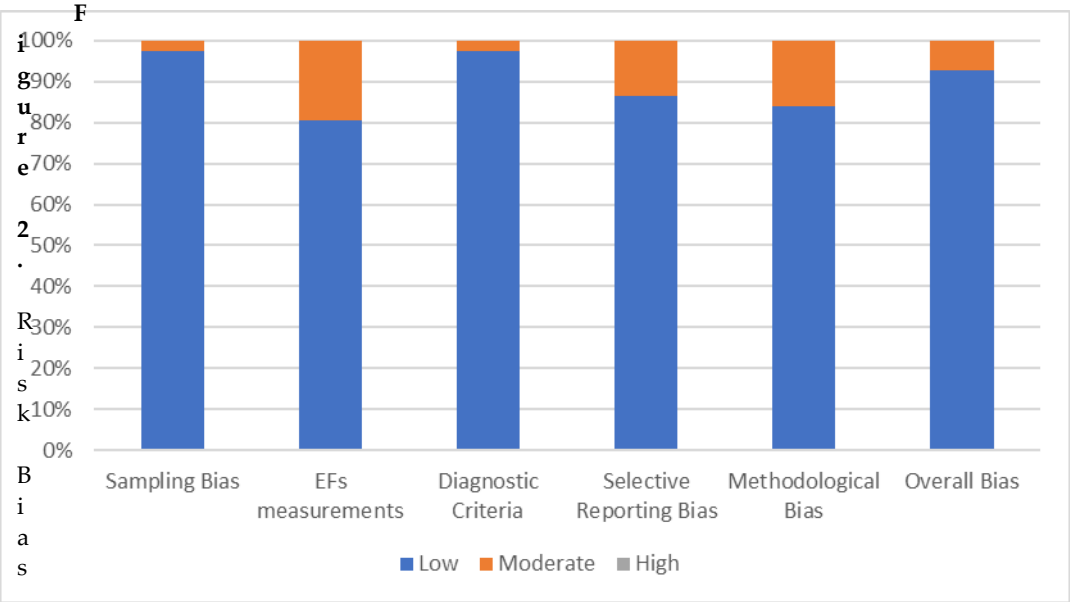

Figure 2. Risk Bias

of selected articles, considering all higher executive functions.

2.4.1 Quality Assessment of Planning

Figure 3 shows the percentage of articles adopting planning tests fulfilling each quality criterion by the risk of bias assessment. On average, the quality of the studies was good since 36 out of 37 studies (97.3%) exhibited low scores on the risk of bias. The high percentage of studies with low or no risk of bias increases the validity of this systematic review. Despite one study (2.7%) showing moderate scores, no study reports a moderate risk of bias in more than two items. A large percentage of the studies adopted valid and reliable tools to measure planning and included an appropriate sample size. Moreover, most studies were adequately controlled for confounding variables. The higher risk bias was in the "EFs measurements" and the lower in "methodological bias". In the overall bias, the score ranged from 5 to 7 for every article included.

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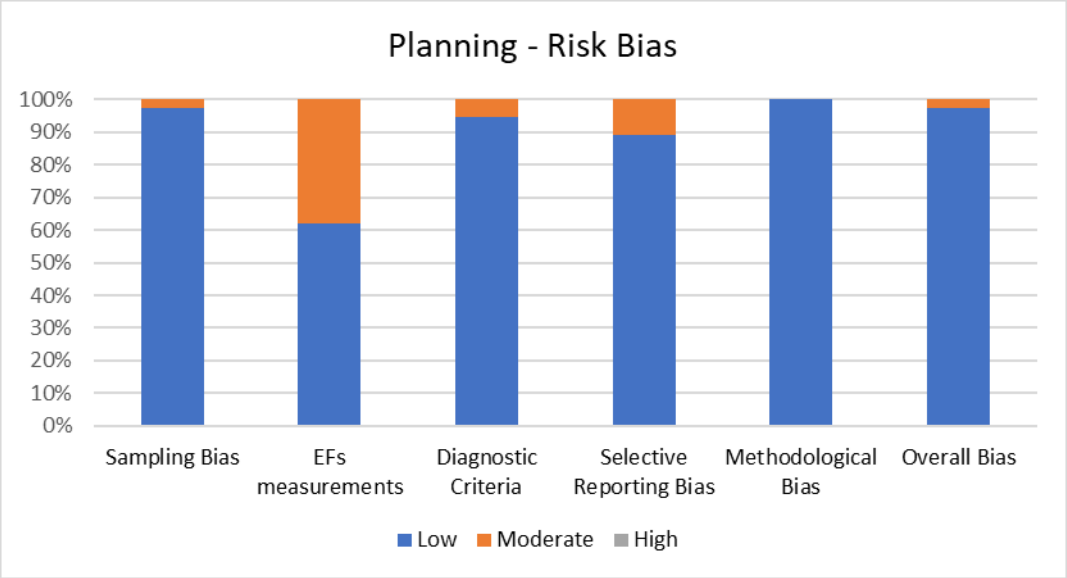
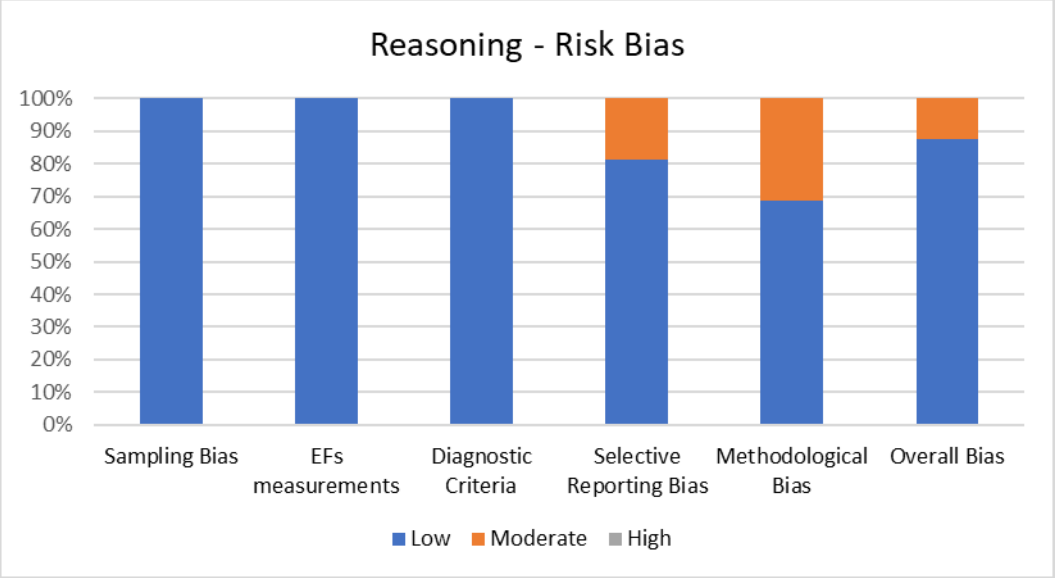


Bias for Planning.

2.4.2 Quality Assessment of Reasoning

Figure 4 shows the percentage of articles adopting reasoning tests fulfilling each quality criterion of risk of bias assessment. On average, the quality of the studies was good since 28 out of 32 studies (87.5%) exhibited low scores on the risk of bias. The high percentage of studies with low or no risk of bias increases the validity of this systematic review. Despite four studies (12.5%) showing moderate scores, no study reports a moderate risk of bias in more than two items. A large percentage of the studies used valid and reliable tools to measure reasoning and included an appropriate sample size. Moreover, most studies were adequately controlled for confounding variables. The higher risk bias was in the "methodological bias" and the lower in "sampling bias" "EFs measurements" and "diagnostic criteria". In the overall bias, the score ranged from 5 to 7 for every article included.



B
ias for Reasoning.

2.4.3 Quality Assessment of Fluid Intelligence

Figure 5 shows the percentage of articles adopting fluid intelligence measurements fulfilling each quality criterion of risk of bias assessment. On average, the quality of the studies was good since 6 out of 7 studies (85.7%) exhibited low scores on the risk of bias.

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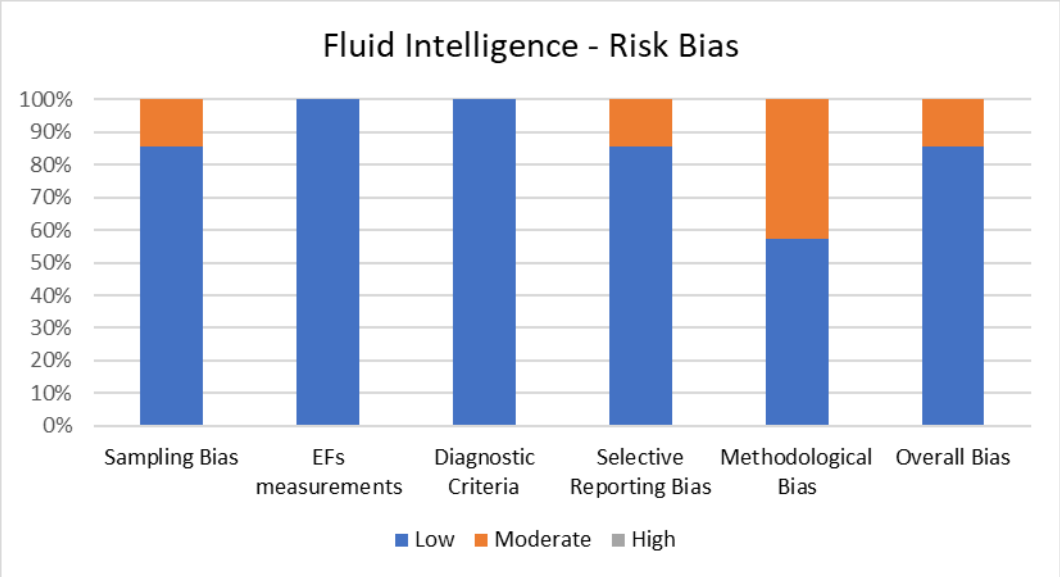
The high percentage of studies with low or no risk of bias increases the validity of this systematic review. Despite 1 study (14.3%) showing moderate scores, no study reports a moderate risk of bias in more than two items. A large percentage of the studies used valid and reliable tools to measure fluid intelligence and included an appropriate sample size. Moreover, most studies were adequately controlled for confounding variables. The higher risk bias was in the "methodological bias" and the lower in "EFs measurements" and "diagnostic criteria". In the overall bias, the score ranged from 5 to 7 for every article included.



Bias for Fluid Intelligence

2.4.4 Quality Assessment of Problem Solving

Figure 6 shows the percentage of articles adopting a problem solving task fulfilling each quality criterion of risk of bias assessment. On average, the quality of the studies was good since 6 out of 6 studies (100%) exhibited low scores on the risk of bias. The high percentage of studies with low or no risk of bias increases the validity of this systematic review. No study reports a moderate risk of bias in more than one item. A large percentage of the studies used valid and reliable tools to measure problem solving and included an appropriate sample size. Moreover, most studies were adequately controlled for confounding variables. The higher risk bias was in the "EFs measurements" and the lower in "sampling bias", "methodological bias" and "diagnostic criteria". In the overall bias, the score ranged from 5 to 6 for every article included.

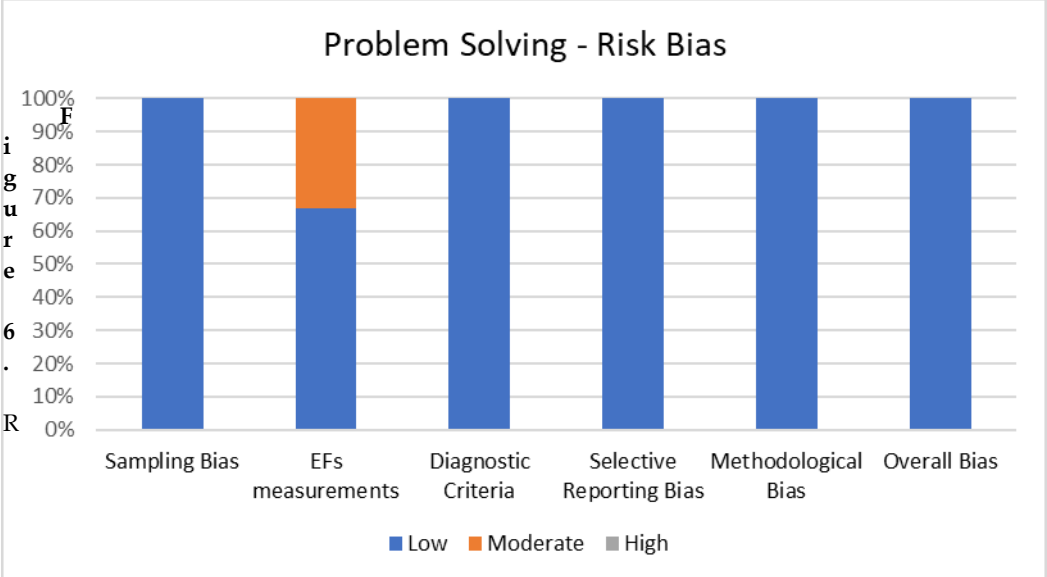


Figure 6. R

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isk of Bias for Problem Solving.

3. Results

3.1 Studies Selection

The flow chart shows the number of studies identified from the databases and the number of studies examined, assessed for eligibility, and included in the review with the reasons for possible exclusions (see Figure 1). A total of 73 studies were identified.

Of the 73 selected studies, 30 analyzed planning, 31 reasoning, 6 fluid intelligence, and 6 problem solving. Nine studies used different executive function measures.

Results will be presented in four subsections.

Authors	Group	N°	Age (SD)	(%F)	MMSE (SD)	Diagnostic Criteria	Test	Results
Ambra et al., [21]	aMCI HC	15 31	69.4 (7.59) 69.2 (7.2)	33.33 45.16	- -	[22]	RCPM	No difference in planning has been found
Ávila et al., [23]	HC aMCI aMCI+	26 38 29	70.58 (7.17) 73.03 (7) 77 (7.43)	- - -	26.85 (3.04) 26.58 (2.03) 23.52 (3.17)	[2]	TOL	No difference in planning has been found
Beaver et al., [24]	HC MCI MCI+	65 19 33	72.34 (8.78) 70.53 (9.35) 71.37 (8.39)	63.1 52.6 48.5	- - -	[25-26]	Zoo Map Test	No difference in planning has been found
Benavides-Varela et al., [27]	MCI HC	43 37	75.44 68.89	42 46	26.39 (2.84) 28.73 (1.17)	[25]	RPM	MCI: lower abstract reasoning than HC
Berlot et al., [28]	HC MCI	20 25	74 (6.5) 76.8 (7.3)	50 44	- - 26 (1.7)	[29]	Tower Test (D-KEFS)	MCI: higher rule violations than HC
Beversdorf et al., [30]	MCI HC	26 20	67.5 (8.9) 68.0 (8.3)	53.85 70	26.1 (1.7) 28.8 (1.4)	MMSE > 24 CDR = 0.5	Matchstick Problem	MCI: lower visuo-spatial problem solving than HC
Bharat et al., [31]	MCI HC	56 59	68.76 (7.59) 67.13 (5.62)	30.4 32.3	27.74 (2.43) 30.83 (0.64)	[1]	TOH	MCI: higher time than HC
Borella et al., [32]	MCI HC	15 18	72.73 (5.28) 69.72 (3.20)	60 61.11	27.4 (1.45) 29.5 (0.62)	[1, 33]	RCPM	MCI: lower logical reasoning than HC
Burton et al., [34]	HC aMCI naMCI aMCI+ naMCI+	158 6 39 19 28	73.57 (4.72) 79.5 (5.65) 77.54 (5.61) 82 (5.04) 79.57 (4.86)	- - - - - 68.42	28.92 (1.17) 26.83 (2.48) 28.67 (1.26) 28.16 (1.26) 28.68 (1.09)	[2, 35]	Block Design	HC: performed better than naMCI, naMCI+ and aMCI+
Chang et al., [36]	HC MCI-na MCI-pa	36 24 22	69.33 (4.09) 71.54 (8.85) 72.82 (7.83)	58.33 58.33 50	- - -	[26]	Matrix Reasoning	MCI-pa < MCI-na < HC
Chao et al., [37]	HC MCI	65 54	68.69 (6.8) 73.46 (9.3)	61.6 54.6	- -	[2, 38]	Matrix Reasoning	Matrix Reasoning MCI: lower rea-

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							Similarities	soning than HC Similarities No difference in reasoning has been found
Chow et al., [39]	HC aMCI aMCI+	52 34 20	75.19 (6.4) 76.41 (6.42) 79.15 (5.57)	48.07 58.82 30	- - -	[35]	Matrix Reasoning	aMCI+: lower reasoning than HC
De Oliveira et al., [40]	HC MCI	61 38	70.66 (6.55) 72.32 (7.94)	57.37 63.15	28.38 (1.48) 25.79 (2.74)	[2]	Block Design RCPM	Block Design MCI: lower fluid intelligence than HC RCPM MCI: lower fluid intelligence than HC
De Paula et al., [41]	MCI HC	60 60	73.7 (8.9) 74.1 (5.6)	53.33 55	24.23 (3.43) 27.08 (2.96)	[25]	TOL (Portella [42] & Krikorian version [43])	Portella et al., [42] MCI: lower planning than HC Krikorian et al., [43] MCI: lower planning than HC
Djordjevic et al., [44]	HC MCI	33 51	73.7 75.4	48.5 51	28.7 27.26	[33, 45]	Similarities Block Design	Similarities No difference in verbal abstract reasoning has been found Block Design No difference in nonverbal reasoning has been found
Dwolatzky et al., [46]	HC MCI	39 30	73.41 (8.0) 77.15 (6.43)	66.67 43.33	29.03 (1.11) 27.63 (1.54)	[33]	Pictorial Puzzles 2x2	MCI: lower accuracy in problem solving task than HC
Econoumou et al., [47]	MCI HC	31 27	73.58 (6.17) 70.56 (8.87)	- -	28.10 (1.47) -	[33]	Matrix Reasoning	MCI: lower fluid intelligence than HC
Espinosa et al., [48]	HC MCI	50 50	72.26 (7.85) 74.30 (6.93)	74 44	28.38 (1.68) 26.06 (2.68)	[33]	Action Program Test Key Search Test Zoo Map Test	Action Program Test MCI: lower planning than HC Key Search Test No difference in planning has been found Zoo Map Test MCI: lower planning than HC
Garcia –	HC	124	73.17 (8.6)	60.48	28.49 (1.4)	[1]	TOL	MCI: lower plan-

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Alvarez et al., [49]	MCI	48	76.68 (10.3)	43.75	25.96 (2.03)			ning than HC
García et al., [50]	MCI HC	5 5	82 (6.38) 74.25 (6.86)	40 40	24 (1.41) 28.25 (2.06)	Memory impairment; normal daily living; no dementia	Abstraction	MCI: lower abstraction than HC
Griffith et al., [51]	HC MCI	21 21	66.7 (7.2) 68.1 (8.8)	66.67 52.38	29.3 (1.0) 28.4 (1.2)	[33, 52]	CLOX – 1	No difference in planning has been found
Guild et al., [53]	HC aMCI	48 14	70.65 (4.47) 73.07 (6.44)	54.17 85.71	28.88 (1.36) 28.14 (1.46)	[54]	Block Design Matrix Reasoning	Block Design No difference in IQ has been found Matrix Reasoning No difference in visuo-spatial reasoning has been found
Hellmuth et al., [55]	HC MCI	41 10	68.2 (7.2) 68.9 (8.8)	68.29 50	29.6 (0.6) 28.6 (1.8)	CDR ≥ 0.5	3 Similarities & 3 Proverbs	No difference in abstraction has been found
Heuer et al., [56]	HC MCI	118 36	69.4 (0.57) 72.9 (1.12)	58.47 50	29.54 (0.64) 28.77 (0.24)	CDR ≥ 0.5	3 Similarities & 3 Proverbs	MCI: lower abstraction than HC
Jefferson et al., [57]	HC MCI	40 40	72.3 (5.5) 74.3 (7.5)	60 48	29.3 (0.9) 27.8 (1.8)	[1-2]	Similarities Matrix Reasoning	Similarities MCI: lower verbal abstract reasoning than HC Matrix Reasoning MCI: lower non-verbal abstract reasoning than HC
Jin et al., [58]	HC aMCI	13 13	62.6 (7.0) 63.6 (7.8)	30.77 30.77	29.1 (0.6) 25.9 (1.8)	MMSE > 24	Sudoku	MCI: lower accuracy in problem solving complex task
Junquera et al., [59]	HC aMCI aMCI+ naMCI	51 26 50 18	71.2 (4.5) 74.73 (4.53) 75.61 (6.46) 72.24 (6.14)	- - - - 74.48	28.94 (1.36) 28.54 (1.27) 26.20 (2.99) 27.77 (2.45)	[1-2]	Zoo Maps Test Similarities	Zoo Maps Test aMCI+: lower planning than HC and aMCI naMCI: lower planning than HC Similarities aMCI+: lower planning than HC naMCI: lower planning than HC
Kramer et al., [60]	HC aMCI	35 86	73.0 (5.3) 75.0 (6.1)	- -	29.5 (0.8) 28.5 (1.5)	[33]	2 similarities & 2 proverbs	No difference in abstract reasoning has been found
Levinoff et al., [61]	HC MCI	40 73	74.1 (7.1) 74.0 (7.3)	- -	28.7 (1.2) 27.7 (1.9)	[62]	Similarities Block Design	Similarities MCI: lower in ab-

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								stract verbal reasoning than HC Block Design No difference in fluid intelligence
Li et al., [63]	HC aMCI	28 29	71.25 (6.43) 73.76 (6.42)	60.71 62.07	27.61 (1.95) 26.07 (2.33)	[1, 25]	Similarities	aMCI: lower abstract reasoning than HC
Li et al., [64]	HC aMCI	111 111	73.56 (8.62) 75.30 (7.12)	65.8 66.7	26.0 (4.44) 25.28 (3.47)	CDR = 0	Block Design	aMCI: lower planning than HC
Li et al., [65]	HC aMCI naMCI	123 106 37	66.26 (9.96) 74.24 (8.05) 71.46 (9.63)	69.1 48.6 67.6	28.5 (1.42) 26.03 (2.6) 27.35 (2.20)	[1]	Similarities	aMCI: lower abstract reasoning than HC
Lindbergh et al., [66]	HC MCI	35 25	74.7 (5.97) 78.6 (5.22)	66.7 92	- - MMSE > 20	[25, 29]	Tower test (D-KEFS)	MCI: lower planning than HC
Lui et al., [67]	HC MCI	93 92	74.2 (6.5) 77.8 (6.8)	85.25 71.74	26.6 (2.5) 25.3 (2.6)	[25]	ACED money management MacCAT-T	ACED MCI: lower reasoning than HC MacCAT-T No difference in reasoning has been found
Lussier et al., [68]	HC MCI	26 22	72.0 (6.4) 75.8 (6.5)	69 36	- -	[1-2]	TOL	MCI: lower planning than HC
Metzler-Baddeley et al., [69]	HC MCI	20 46	74.0 (6.5) 76.8 (7.3)	50 44	- - MMSE ≥ 24	[29]	TOL	MCI: higher rule violation than HC
Moreira et al., [70]	HC MCI	26 32	68.42 (8.39) 68.03 (7.29)	61.54 46.87	29.62 (0.7) 27.69 (1.31)	[71]	Proverbs	MCI: lower abstraction than HC
Muñoz-Neira et al., [72]	HC MCI	30 14	71.93 (7.06) 71.71 (7.16)	50 42.9	28.77 (1.14) 26.29 (2.13)	[2]	Similarities	No difference in abstraction has been found
Nishi et al., [73]	MCI HC	30 15	69.8 (7.3) 70.9 (4.2)	73.33 60	26.5 (2.1) 29.1 (1.6)	MMSE ≥ 24 CDR = 0.5 NINCDS-ADRDA [74]	RCPM	MCI: lower reasoning than HC
Nordlund et al., [75]	HC MCI	112 35	67.0 (5.5) 64.0 (8.2)	- -	29.3 (1.1) 28.5 (1.5)	MMSE < 25	Similarities	No difference in verbal abstraction has been found
Nordlund et al., [76]	HC MCI	60 60	66.5 (6.2) 66.4 (6.8)	46.67 46.67	29.3 (1.1) 28.4 (1.3)	MMSE <25	WCST-CV Similarities	WCST-CV MCI: lower planning than HC Similarities No difference in abstraction has been found
Nordlund et al., [77]	HC MCI	50 73	65.1 (6.1) 60.7 (6.8)	54 52.05	29.3 (1.0) 28.6 (1.3)	MMSE < 25	WCST-CV Similarities	WCST-CV MCI: lower planning than HC Similarities

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								No difference in abstraction has been found
Okonkwo et al., [78]	HC MCI	43 43	66.76 (7.40) 69.54 (8.22)	62.79 44.19	29.38 (0.89) 28.54 (1.46)	[1]	CLOX – 1	No difference in planning has been found
Okonkwo et al., [79]	HC MCI	56 60	64.63 (8.5) 68.05 (6.77)	67.9 56.7	29.55 (0.76) 28.37 (1.5)	[25]	CLOX – 1 DRS – 2 Conceptualization Cognitive Competency Test	CLOX – 1 No difference in planning has been found DRS – 2 Conceptualization No difference in abstraction has been found Cognitive Competency Test No difference in verbal reasoning has been found
Pa et al., [80]	HC aMCI	36 26	64.8 (8.2) 68.0 (6.6)	63.89 50	29.8 (0.6) 28.7 (1.2)	[81]	Matrix Reasoning Similarities	Matrix Reasoning No difference in reasoning has been found Similarities No difference in reasoning has been found
Pa et al., [82]	MCI HC	57 40	69.8 (9.3) 65.2 (8.9)	47.37 50	28.4 (1.5) 29.8 (0.5)	[2]	Abstraction	No difference in abstraction has been found
Papp et al., [83]	HC aMCI	92 59	67.4 (8.8) 69.9 (8.1)	65.2 45.8	29.2 (1.01) 27.7 (1.35)	MMSE 24 – 30 CDR ≤ 0.5	Groton Maze Learning Test	MCI: higher exploratory errors, rule-breaks errors and lower difference in errors between trial 1 – trial 2
Pertl et al., [84]	MCI HC	22 29	75 73	50 65.52	27 29	[1, 29]	CLOX - 1	MCI: lower planning than HC
Pertl et al., [85]	HC MCI	19 17	74 79	- 70.59	29 27	[1, 29]	CLOX – 1	No difference in planning has been found
Peters et al., [86]	HC MCI	20 22	72.0 (6.9) 70.4 (7.1)	70 59.1	29.6 (0.5) 28.1 (1.4)	[26]	TOL	No difference in planning has been found
Rainville et al., [87]	HC MCI	42 51	69.9 (7.3) 68.9 (8.3)	- -	29.4 (0.9) 28.0 (1.6)	[88]	TOL	MCI: higher rule breakings and abandoned than HC
Royall et al., [89]	HC MCI	45 40	75.8 (6.0) 78.6 (6.7)	75.6 72.5	27.8 (2.1) 24.8 (2.9)	CDR < 3 MMSE < 10	CLOX – 1	MCI: lower planning than HC

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Sánchez – Benavides et al., [90]	HC MCI	30 23	72.1 (4.7) 72.9 (7.4)	51 61	28.8 (1.2) 26.3 (2.1)	[91]	TOL – Drexel Version	No difference in planning has been found
Sánchez – Benavides et al., 2014 [92]	HC MCI	356 79	64.9 (9.3) 72.8 (6.5)	59.6 57	28.7 (1.5) 25.7 (2.2)	[74]	TOL - Drexel Version	MCI: lower total correct than HC MCI: higher total moves, total initiation time, total execution time and total solving time than HC
Sanders et al., [93]	HC MCI	37 37	70.27 (7.93) 72.89 (9.01)	65.57 45.94	- -	[25-26]	Zoo Map Test	MCI: higher total errors than HC
Schmitter-Edgecombe et al., [94]	MCI HC	38 38	70.58 (8.6) 69.34 (7.95)	55.26 71.05	- -	[25-26]	Zoo Map Test	MCI: lower planning than HC
Schmitter-Edgecombe et al., [95]	HC MCI	51 51	70.94 (8.1) 70.98 (8.42)	- -	- -	[25-26]	CLOX – 1	MCI: lower planning than HC
Serra et al., [96]	aMCI HC	16 13	72.5 (6.5) 64.1 (10.5)	37.5 30.77	25.3 (1.2) 28.9 (1.3)	[25]	RCPM	No difference in reasoning has been found
Serra et al., [97]	aMCI naMCI HC	15 13 28	70.9 (9.0) 68.6 (5.7) 63.4 (8.9)	27 77 37	25.4 (1.7) 26.3 (1.6) 28.4 (1.7)	[1-2]	RCPM	No difference in reasoning has been found
Serrao et al., [98]	HC MCI	38 61	67.37 (5.89) 68.92 (6.49)	- -	27.88 (0.62) 26.03 (0.44)	[1-2]	Matrix Reasoning	MCI: lower IQ than HC
Sheldon et al., [99]	aMCI HC	16 16	74.4 (7.4) 75.1 (5.7)	69 38	29.5 (0.7) 28.4 (1.2)	[1]	Means-Ends Problem Solving Test	MCI: lower problem solving than MCI
Sherod et al., [100]	HC MCI	85 113	67.2 (8.2) 70.3 (7.4)	65 57	29.4 (0.9) 28.1 (1.9)	[25]	CLOX – 1 DRS – 2 Conceptualization Cognitive Competency Test	CLOX – 1 No difference in planning has been found DRS – 2 Conceptualization MCI: lower abstraction than HC Cognitive Competency Test MCI: lower abstraction than HC
Tabert et al., [101]	HC MCI	83 148	66.9 (9.1) 67.0 (9.9)	59.4 55	29.3 (0.8) 27.5 (2.2)	[33]	Similarities Mattis Identities and Oddities	Similarities MCI: lower verbal abstract reasoning than HC Mattis Identities and Oddities No difference in

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								nonverbal abstract reasoning has been found
Tam et al., [102]	MCI HC	24 24	73.88 (10.8) 73.25 (9.03)	50 62.5	27.22 (1.65) 28.63 (1.38)	MMSE > 24	CLOX - 1	No difference in planning has been found
Tripathi et al., [103]	MCI HC	22 20	68.18 (5.7) 68.65 (6.0)	27.27 25	28.0 (2.37) 30.0 (1.0)	[1]	TOH	No difference in planning has been found
Urbanowitsch et al., [104]	HC MCI	143 63	73.94 (0.99) 74.21 (1.03)	52.45 50.79	28.91 (1.12) 28.07 (1.41)	[105]	Similarities	MCI: lower reasoning than HC
Weakley et al., [106]	MCI HC	32 64	69.34 (8.6) 68.13 (9.16)	66 72	- -	[1]	Zoo Map Test	No difference in planning has been found
Wu et al., [107]	HC aMCI	16 13	67.75 (5.64) 69.0 (5.69)	50 53.85	29.13 (1.09) 26.23 (2.05)	[1]	Matrix Reasoning Block Design	Matrix Reasoning No difference in IQ has been found Block Design MCI: lower IQ than HC
Zamarian et al., [108]	HC MCI	18 18	65.1 (4.6) 69.0 (7.5)	61.11 55.55	29.8 (0.4) 26.9 (1.2)	[1]	CLOX - 1	MCI: lower planning than HC
Zhang et al., [109]	HC MCI	32 32	73.5 (8.5) 73.7 (8.2)	- -	28.7 (1.8) 27.4 (2.0)	[33]	Trail Making Test (B-A) Porteus Maze Test Verbal Fluency Test (fruits & animals)	Trail Making Test MCI: lower planning than HC Porteus Maze Test MCI: lower planning than HC Verbal Fluency Test MCI: lower planning than HC
Zhang et al., [110]	aMCI HC	34 36	67.9 (6.7) 67.4 (5.0)	58.82 50	28.3 (0.5) 29.5 (0.7)	[1]	Abstraction – MoCA CDT	Abstraction No difference in abstraction has been found Clock Drawing Test No difference in planning has been found
Zheng et al., [111]	aMCI HC	34 36	67.9 (6.7) 67.4 (5.0)	58.82 50	28.3 (1.5) 29.5 (0.7)	[35]	CDT	No difference in planning has been found
Zheng et al., [112]	aMCI HC	50 48	69.8 (6.8) 69.2 (5.1)	68 60.41	27.9 (1.5) 29.5 (0.7)	[35]	CDT	No difference in planning has been found

Table 2. Results of selected studies

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SD= standard deviations; **MMSE**= Mini Mental State-Examination; **MCI**= Mild Cognitive Impairment; **aMCI**= amnesic Mild Cognitive Impairment; **naMCI**= non amnesic Mild Cognitive Impairment; **MCI+**= Mild Cognitive Impairment multiple domains; **aMCI+**= amnesic Mild Cognitive Impairment multiple domain; **naMCI+**= non amnesic Mild Cognitive Impairment multiple domains; **MCI-na**= normal awareness for memory deficits; **MCI-pa**= poor awareness for memory deficits; **RCPM**= Raven's Progressive Coloured Matrices; **RPM**= Raven's Progressive Matrices; **TOL**= Tower of London; **TOH**= Tower of Hanoi; **Tower Test (D-KEFS)**= Tower test (Delis-Kaplan Executive Function System); **CDT**= Clock Drawing Test; **WCST-CV**= Wisconsin Card Sorting Test – Computer Version; **MoCA**= Montreal Cognitive Assessment; **CDR**= Clinical Dementia Rating Scale; **NINCDS-ADRDA**= National Institute of Neurological and Communicative Disease and Stroke/Alzheimer's Disease and Related Disorders Associations; **AACD**= Ageing-Associated Cognitive Decline; **DSM**= Diagnostic and Statistical Manual of Mental Disorders; **CLOX-1**= Clock Drawing Task; **DRS-2**=Dementia Rating Scale-2; **ACED money management**= Assessment of Capacity for Everyday Decision-Making money management; **MacCAT-T**= The MacArthur Competence Assessment Tool for Treatment.

3.2 Planning (N=37)

Thirty-seven studies have measured planning in healthy elderly and MCI participants with an overall sample of 3.491 participants (1.919 HC and 1.572 MCI) with a mean age that ranges from 60.7 years [77] to 79 years [85].

Thirteen studies used "CLOX-1" or "Clock Drawing Test (CDT)" [51; 78, 79, 84, 85, 89, 95, 100, 102, 108, 110, 111, 112]; two studies used the "Wisconsin Card Sorting Test – Computer Version (WCST – CV)" [76-77]; ten studies used the "Tower of London (TOL)" [23, 28, 41, 49, 68, 69, 86, 87, 90, 91], six studies used "Zoo Map Test" [24, 48, 59, 93, 94, 106], two studies used "Tower of Hanoi (TOH)" [31, 103]; one study used "Raven's Coloured Progressive Matrices (RCPM)" [21]; one study used "Tower Test (D-KEFS)" [66]; one study used "Groton Maze Learning Test" [83]; one study used "Trail Making Test (B-A)" [109]; one study used "Porteus Maze Test" [109]; one study used "Verbal Fluency Test (fruits and animals version)" [109]; one study used "Action Program Test" [48]; and one study used "Key search Test" [48].

Fifteen studies did not report any significant difference between groups [21, 23, 24, 51, 78, 79, 84, 85, 90, 100, 102, 103, 105, 110, 111, 112]. One study [48] performed three tests to assess planning ability and observed a worse performance in MCI in only two of them (Action Program Test and Zoo Map Test). The remaining twenty-one studies reported poor performance in MCI than healthy subjects [28, 31, 41, 49, 59, 66, 68, 69, 76, 77, 83, 84, 85, 89, 92, 93, 94, 95, 108, 109].

Nine studies [28, 31, 41, 49, 66, 68, 69, 87, 92] of the thirteen that analyzed the planning abilities with tower tests ("Tower of London", "Tower of Hanoi" and "Tower Test (D-KEFS)") highlighted a poorer performance in MCI than healthy groups. Metzler-Baddeley et al., [69] and Berlot et al., [28] observed more rule violations during the performance of the task in MCI, while Bharath et al., [31] reported a longer time to complete the test. De Paula et al., [41] used two versions of "Tower of London" (designed by Krikorian et al., [43] and Portella et al., [42]) and observed a lower planning ability in MCI subjects. Rainville et al., [87] pointed out a higher rule breaking and abandonment rate in MCI. Sánchez – Benavides et al., [91] saw in Mild Cognitive Impairment subjects a higher total moves, total initiation time, total exclusion time, total solving time, and lower total correct rates than healthy subjects. Also, Garcia-Alvarez et al., [49], Lindbergh et al., [66], and Lussier et al., [68] found poor planning in Mild Cognitive Impairment subjects.

Four studies [84, 89, 95, 108] that used "CLOX-1" found a lower planning capacity in Mild Cognitive Impairment samples.

Three studies used the "Zoo Map Test" [59, 93, 94]. Sanders et al., [93] highlighted higher total errors in MCI than healthy controls. Junquera et al., [59] analyzed the differences between healthy subjects, aMCI, naMCI, and aMCI multiple domains: aMCI multiple domains showed lower planning than healthy elderly and aMCI single domain, while naMCI subjects showed a poor planning ability than healthy elderly. Sanders et al., [93] observed decreased planning ability in MCI compared to healthy elderly.

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Espinosa et al., [48] analyzed the differences between healthy subjects and MCI using the "Zoo Map Test" and "Action Program Test", in both tests, MCI had lower planning than healthy controls. Nordlund et al., [76-77] found a poor planning ability, assessed with the "Wisconsin Card Sorting Test – Computer Version (WCST – CV)", in MCI subjects than healthy elderly. Papp et al., [83] used the "Groton Maze Learning Test" to evaluate planning and underlined that participants with MCI exhibit higher exploratory errors, more rule-breaks errors, and reduced differences between trial 1 and trial 2 than healthy subjects. Zhang et al., [109] evaluated the differences between healthy subjects and MCI with "Trail Making Test (B-A)", "Porteus Maze Test" and "Verbal Fluency (fruits and animals)", and in each test, Mild Cognitive Impairment showed lower planning than healthy elderly.

3.3 Reasoning (N=32)

Thirty-two studies measured reasoning in healthy elderly and Mild Cognitive Impairment subjects, with an overall sample of 3.371 participants (1.676 HC and 1.695 MCI) and a mean age ranging from 60.7 years [77] to 82 years [50].

Seventeen studies used "Similarities" [37, 45, 55, 56, 57, 59, 60, 61, 63, 65, 72, 75, 76, 77, 80, 101, 104]; six studies used "Matrix Reasoning" [36, 37, 39, 53, 57, 80]; four studies used "Raven's Coloured Progressive Matrices (RCPM)" [32, 73, 96, 97]; four studies used "Proverbs" [55, 56, 60, 70]; two studies used "Cognitive Competency Test" [79, 100]; two studies used "Abstraction – MoCA" [50, 110]; two studies used "DRS–2 Conceptualization" [79, 100]; one study used "ACED Money Management" [67]; one study used "MacCAT-T" [67]; one study used "Block Design" [44]; one study used "Mattis Identities and Oddities" [100]; one study used "Raven's Progressive Matrices (RPM)" [27]; one study used "Abstraction (Wechsler et al., 1997, Kramer et al., 2003 [113-114])" [82].

Fifteen studies did not report any significant difference between samples [44, 53, 55, 56, 60, 72, 75, 76, 77, 79, 80, 82, 96, 97, 110].

Three studies [37, 67, 101] performed two tasks each and observed lower reasoning ability in MCI participants in only one of them.

The remaining fourteen studies reported differences between MCI and healthy subjects [27, 32, 36, 39, 50, 57, 59, 61, 63, 65, 70, 73, 100, 104].

Seven studies used "Similarities" [57, 59, 61, 63, 65, 101, 104] to assess reasoning in healthy elderly and Mild Cognitive Impairment samples and reported lower performance in reasoning in MCI subjects. Junquera et al., [59] analyzed the differences between healthy subjects, aMCI, naMCI and aMCI multiple domains: both aMCI multiple domains and naMCI showed lower reasoning than healthy elderly. Four studies used "Matrix Reasoning" [36, 37, 39, 57] to evaluate MCI and healthy subjects, and in each study, a decreased reasoning in Mild Cognitive Impairment subjects was highlighted. In particular, Chang [36] observed a higher performance in healthy subjects than MCI with normal awareness for memory (MCI-na), which in turn were better than MCI with poor awareness for memory (MCI-pa). Two studies used "Raven's Coloured Progressive Matrices – RCPM" [32, 73] and observed a reduced reasoning ability in Mild Cognitive Impairment participants, as well as Benavides-Varela et al., [27] that used "Raven's Progressive Matrices – RPM". Sherod et al., [100] analyzed the differences between healthy subjects and MCI with the "DRS – 2 Conceptualization" and "Cognitive Competency Test", and in both tests MCI had lower abstraction than healthy controls. Lui et al., [67] used "ACED Money Management" and reported a reduced reasoning ability in Mild Cognitive Impairment. Moreira et al., [70] used "Proverbs" to evaluate the reasoning in healthy elderly and MCI participants and observed higher abstraction ability in healthy subjects than MCI. García et al., [50] used "Abstraction (MoCA)" and pointed out a reduced ability in abstraction in MCI subjects.

3.4 Fluid Intelligence (N=7)

Seven studies have measured fluid intelligence in healthy elderly and Mild Cognitive Impairment subjects, with an overall sample of 682 participants (341 HC and 341

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MCI) and a mean age ranging from 67.37 years [98] to 75.3 years [64]. Five studies used "Block Design" [40, 53, 61, 64, 107] and three studies used "Matrix Reasoning" [47, 98, 107] and one study used "Raven Coloured Matrices" to evaluate fluid intelligence.

Two studies [53, 61] did not report any significant difference between samples, one study performed multiple tests and showed conflicting results [105], while the others [40, 47, 64, 98] reported lower performance in fluid intelligence in MCI subjects.

3.5 Problem solving (N=6)

Six studies have assessed problem solving in MCI and a control group, with an overall sample composed of 344 participants (236 MCI and 108 HC) and a mean age ranging from 62.6 years [58] to 82 years [34]. Each study [30, 46, 58, 83, 99] used a different task to evaluate problem solving, and they all showed differences between the samples.

Beversdorf et al., [30] used the "Matchstick Problem" to evaluate visuospatial problem solving and highlighted lower capacity in the MCI sample to solve problems. Burton et al., [34] used "Block Design" to evaluate problem solving ability in healthy elderly, aMCI single and multiple domains, naMCI single and multiple domain participants and observed better performance in healthy subjects than amnesic Mild Cognitive Impairment multiple domains, non-amnesic Mild Cognitive Impairment single, and multiple domains, but not to aMCI single domain subjects. Dwolatzky et al., [46] used "Pictorial Puzzles (2x2)" and reported a reduced accuracy in Mild Cognitive Impairment. Jin et al., [58] evaluated problem solving with "Sudoku (Nikoli Publishing)" and highlighted a decreased accuracy in complex tasks in aMCI subjects compared to healthy subjects. Papp et al., [83] used the "Groton Maze Learning Test" to evaluate problem solving and underlined that participants with MCI have higher exploratory errors, more rule-breaks errors, and a lower difference between trial 1 and trial 2 than healthy subjects. Sheldon et al., [99] used the "Means-Ends Problem Solving Test" and observed a reduced problem solving ability in MCI subjects.

4. Discussion

The purpose of this systematic review was to investigate the relationship between higher-level executive functions and healthy and pathological aging, assuming the role of executive functions deficits as a predictor of the general cognitive decline. Results showed that not all the studies found a prevalence of higher-level executive functions deficits in individuals with Mild Cognitive Impairment diagnosis compared to healthy elderly; however, 64.4% of the studies confirm a significant presence of alterations in MCI (100% problem solving, 71.4% fluid intelligence, 56.8% planning, 50% reasoning).

Despite the scarce number of observations that do not allow reliable conclusions, the evaluation of problem solving showed significant results. These data must be interpreted with caution because the studies [30, 34, 46, 58, 83, 99] used different tasks to evaluate this ability. One interesting finding was observed by Burton et al. [34] that compared healthy subjects, amnesic Mild Cognitive Impairment single and multiple domains, and non-amnesic Mild Cognitive Impairment single and multiple domains to analyze problem solving. According to the literature, the authors reported lower problem solving capacity in participants with aMCI multiple domains and naMCI single and multiple domains compared to healthy elderly, while the aMCI single domain subjects did not report any significant difference with the others. These results could be attributed to the Mild Cognitive Impairment [1], in which the only impaired cognitive domain is memory. On the other hand, Jin et al. [58] found a significant difference between aMCI and healthy control group; the author reported a positive linear correlation between blood oxygen levels in the posterior cingulate cortex (PCC) and precuneus in aMCI subjects during simple (r=0.95) and complex (r=0.90) problem solving tasks. In addition, healthy elderly showed a deactivation of these areas while the aMCI showed an activation. These regions are included in the Default Mode Network (DMN) and, taking into account the close re-

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lationship with the hippocampus, these activations in aMCI may be explained as a compensatory memory mechanism.

The results of fluid intelligence must be interpreted with caution due to the small number of studies that measured this variable [40, 47, 53, 61, 64, 98, 107]. A possible source of error about fluid intelligence ability is linked to the type of assessment carried out: this review includes studies that evaluated the intelligence quotient employing tests commonly used to assess fluid intelligence.

Despite this, Li et al., [64], through the means regression and the cluster analysis, observed that the "Block Design" test could predict conversion from a healthy state to amnesic Mild Cognitive Impairment. Another important finding is observed by Wu et al., [106] that studied, in amnesic Mild Cognitive Impairment and healthy elderly, the Resting State-Executive Control Network (RS-ECN), a network that is adjacent to DMN and the other major attention networks and with which it shares some anatomical areas. The aMCI showed a decreased functional connectivity of anterior cingulate cortex (ACC), inferior parietal lobule (IPC), lateral parietal and anterior insula, precuneus, middle frontal gyrus, left and right dorsal lateral prefrontal cortex (DLPFC); these regions are strictly involved in Ventral Attention Network and more generally in executive functions. Moreover, the author [107] also observed increased functional connectivity of different areas of the Default Mode Network, the Ventral Attention Network (VAN), and the Dorsal Attention Network: the right anterior prefrontal cortex (aPFC), left and right ventral lateral prefrontal cortex (VLPFC), superior parietal cortex, posterior parietal lobule, occipital and temporal Even if these regions are not involved in fluid intelligence, they are still implicated in planning, reasoning, problem solving, abstract thinking and other executive functions, with particular reference to the DLPFC. The overall results of fluid intelligence, although not uniform, pursued a trend towards higher prevalence of this ability deficit in Mild Cognitive Impairment.

The results about planning are projected to highlight a negative trend in MCI that reported lower ability than healthy elderly. However, these data must be interpreted with caution because not all tests provided statistically significant results, and some studies used inappropriate tests. In particular, some studies used the "Clock Drawing Test" and "CLOX-1", which are not specific for planning evaluation but are instead typically used in neuropsychological batteries to investigate other cognitive functions. The "Clock Drawing Test" is commonly used to assess praxis and visuospatial skills, while the "CLOX-1" is the version that evaluates the executive functions (e.g., goal selection, planning, selective attention, and motor sequencing) [115]. Despite this distinction, four studies [52, 111, 112, 113] used the "Clock Drawing Test" to assess executive functions, and neither of these reported any significant difference between MCI and healthy elderly. In addition, the studies that used "CLOX – 1" [78, 79, 84, 99, 101] did not report significant differences between MCI and healthy subjects; only a few of studies [84, 89, 95, 108] highlighted lower planning ability in pathological aging. These results could be explained by the low sensitivity of this test in discriminating between MCI and healthy elderly. However, the studies that used the "Clock Drawing Test" and the "CLOX-1" were included too, since both original validations [115-116] considered the test adequate to assess planning ability.

On the other hand, the "Zoo Map Test" and the tower tests ("Tower of London", "Tower of Hanoi", and "Tower Test (D-KEFS)") seem well to discriminate the differences between healthy and MCI participants. Junquera et al., [59] analyzed the differences between healthy subjects and single and multiple domain aMCI and naMCI participants. Subjects with aMCI multiple domains and single and multiple domains naMCI subjects exhibited lower planning ability than healthy elderly. Two studies [69; 28] observed more rule violations during tasks in MCI; in addition, Rainville et al., [87] pointed out a higher rule breaking and abandonment rate in MCI than healthy participants. Metzler-Baddeley et al., [69] have also observed a correlation between the number of rule violations in the TOL and the variation of mean diffusivity in the bilateral anterior cingulum and the fornix.

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Although not all results showed a statistically significant difference, many reasoning deficits can be observed in MCI. Most studies used the "Similarities" test to evaluate reasoning, which identifies the relationship between a couple of words. Seven of these studies [57, 59, 61, 63, 65, 101, 104] reported significant differences between healthy and Mild Cognitive Impairment elderly. Chang [36] compared healthy and MCI participants with and without awareness for memory problems and observed a higher performance in healthy subjects than in MCI with normal awareness for memory (MCI-na), which in turn were better than MCI with poor awareness for memory (MCI-pa). In addition, MCI-pa showed reduced white matter integrity of left dorsal frontal–striatal tract, right dorsal frontal–striatal tract, left anterior thalamocortical radiations–ventral part, corpus callosum–inferior parietal lobule, and corpus callosum–ventral prefrontal regions. Nishi et al., [73] found a correlation between reasoning task execution and reduced glucose reuptake in the right middle frontal gyrus and higher activation in the same area.

Not all the studies that analyzed higher-level executive functions highlighted significant differences. Generally, it may be concluded that elderly with Mild Cognitive Impairment exhibit poorer performance than healthy elderly. Due to small observations, problem solving and fluid intelligence results do not allow reliable conclusions. Despite this, the results appear promising, showing higher executive function deficits in MCI. Though numerous and highlighting a worse performance in MCI, planning and reasoning results do not always show significant differences between groups. This could be related to the use of low sensitivity measures to discriminate MCI from normal aging.

4.1 Limits

Despite the encouraging results, this review holds some limitations. The major limitation is the lack of quantitative analysis (meta-analysis), which is difficult to carry out because of the large number of different tests and diagnostic criteria adopted by the studies. The absence of a standardized protocol to evaluate the higher-level executive functions represents another limitation, leading to the administration of rarely used tests and, consequently, to hardly generalizable results. An additional limiting factor of this review is the task impurity and, therefore, the difficulty of separately evaluating each higher-level EF. For example, the "Matrix Reasoning" is used to evaluate: reasoning [37, 39, 80], visuospatial reasoning [53], non-verbal abstract reasoning [57], intelligence quotient [98, 106] and fluid intelligence [47]. A further limit can be related to publication bias. Lastly, this review is based on Diamond's model [3], and therefore it focuses on some executive functions excluding all others, such as decision-making.

5. Conclusions

The results of this systematic review seem to highlight a higher prevalence of higher-level executive functions disease in elderly with Mild Cognitive Impairment than in healthy elderly, confirming results already observed with other executive functions, such as cognitive and motor inhibition, conflict control, and cognitive flexibility [117], although some of these EFs are also compromised in healthy elderly [118]. MCI shows modifications over every aspect investigated in this research, highlighting significant differences that could worsen the quality of life. As far as we know, this study is the first to evaluate these aspects in healthy and MCI elderly. Certainly, a future goal will be to establish and create a standardized protocol to discriminate MCI from healthy elderly. Such a protocol should accurately measure reasoning, planning, problem solving, and fluid intelligence since these functions are treated as a single construct included in executive functions. An important goal for the next studies will be to figure out if higher-level executive functions diseases are early symptoms of Mild Cognitive Impairment or, on the other hand, MCI leads to poorer higher-level executive functions abilities as a consequence of the more significant alterations of the nervous system occurring in pathologically older age than in healthy elderly.

6. Patents

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