
# Executive functions in the elderly with Mild Cognitive Impairment: A systematic review on motor and cognitive inhibition, conflict control and cognitive flexibility



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# Executive functions in the elderly with Mild Cognitive Impairment: A systematic review on motor and cognitive inhibition, conflict control and cognitive flexibility


## Abstract

**Background**: Mild Cognitive Impairment (MCI) is a syndrome characterised by mild cognitive decline, on one or more domains, but which does not compromise daily functions. Several studies have investigated the relationship between MCI and deficit in executive functions (EFs) but, unlike robust evidence in the mnestic domain, the nature of executive deficits in the MCI population remains uncertain.

**Objectives**: This systematic review aims to evaluate EFs in patients with MCI, considering inhibition (motor and cognitive), conflict control and cognitive flexibility.

**Method**: The databases used for the search were PUBMED, PsycINFO, PsycARTICLES and MEDLINE. Eligibility criteria: use of specific paradigms for EFs assessment ("Wisconsin Card Sorting Test", "Stroop Task", "Go/No-Go Task", "Flanker Task"); age over 65, studies published in English. Exclusion criteria: presence of dementia; psychiatric disorders; stroke; cranial trauma; inclusion of participants with MCI in groups with healthy elderly or those with dementia.

**Results**: Fifty-five studies were selected, namely: Stroop Task (N=30), WCST (N=14), Go/No-Go (N=9), Flanker Task (N=2). Results have shown in people with MCI deficits in all the EFs considered.

**Conclusions**: The results of this review support the applicability of the four experimental tasks examined for the study of EFs in people with MCI. These paradigms are useful in research, diagnosis and therapeutic purposes, allowing obtaining an articulated EFs profile that can compromise the daily life in elderly. These EFs are not generally evaluated by standard assessment of MCI, but their evaluation can lead to a better knowledge of MCI and help in the diagnosis and treatment.

**Keywords**: Executive functions, Mild Cognitive Impairment, Wisconsin Card Sorting Test, Stroop Task, Go/No-Go Task, Flanker Task

## Introduction

Mild Cognitive Impairment (MCI) was initially defined as a transitional phase between physiological ageing and dementia, and it was described by light amnesic dysfunctions (Petersen et al., 1999). Subsequently, the impairment of other cognitive domains such as attention, visual-spatial abilities, the speed of information processing and executive functions (EFs) was recognised (Winblad et al., 2004).

Currently, MCI is considered to be a clinically heterogeneous syndrome characterised by mild cognitive impairment on one or more domains but which does not compromise standard daily functions (Petersen et al., 2004).

For the classification of MCI, according to the current definitions (Albert et al., 2011; DSM 5, American Psychiatric Association, 2013; Petersen, 2004; Petersen et al., 2018; Winblad et al. 2004), clinical data have to indicate a mild impairment in cognitive abilities. This information is generally collected through an interview directly to the subject or his/her family members. Then the subjective cognitive disorder must be confirmed by objective cognitive measures, provided by batteries of neuropsychological tests (Petersen et al., 2014).

Furthermore, although the mnestic domain has maintained a central role, the evolution of the construct has highlighted the importance of differentiating the manifestations of the pathology according to the different compromised cognitive domains. The most recent classifications take into account both the type and the number of compromised domains (Petersen, 2004). This allowed to highlight the presence of different types of MCI, namely: MCI with impairment of the mnestic field (amnesic MCI: a-MCI single domain); MCI with central impairment of the mnestic domain and simultaneous weakening of other domains (a-MCI multiple domain); MCI with impairment of a non-mnestic domain (na-MCI single domain); MCI with multiple impairment of non-mnestic domains (na-MCI multiple domain; Petersen, 2004; see Figure 1).

**[INSERT FIGURE 1 ABOUT HERE]**

The prevalence of MCI is estimated in a range from 3% to 42%; this high variability would seem to depend on the MCI definition, the tests used to evaluate it, and the normative values used (Ward, Arrighi, Michels,

& Cedarbaum, 2012). Many studies (Bruscoli & Lovestone, 2004; Daly et al., 2000; Forlenza et al., 2009) show a high conversion rate of MCI in one type of dementia. It makes an early diagnosis very important since it allows bringing benefits from a medical, a psychological and a social point of view (Ashford et al., 2007). Progression in Alzheimer's disease would appear to be predicted by the deficit in both amnesic and EFs domains (Brandt et al., 2009).

EFs are higher-order functions that allow modifying and adjusting behaviour consequently to context changes (Miyake & Friedman, 2012). According to Diamond's model (2013), the three main components of EFs are inhibition, working memory (WM) and cognitive flexibility. From these necessary skills can be developed other higher-level functions such as reasoning, problem-solving and planning. Inhibitory control consists in the ability to inhibit dominant responses and includes self-control (intended as behavioural inhibition) and interference control (selective attention and cognitive inhibition) (Diamond, 2013). Inhibitory control also includes attentional control, such as needed when there is conflictual information. WM allows working with information that is no longer perceptually available and is divided into verbal and visual-spatial WM. Cognitive flexibility is the ability to change perspective, both from a spatial and an interpersonal point of view.

In the last sixty years, many experimental paradigms have developed that can be used for the study of EFs. Among these, in this review will be considered the *Go/No-Go Task*, the *Stroop Task*, the *Flanker Task* and the *Wisconsin Sorting Card Test*. These paradigms are usually recognised as the golden standard task to evaluate inhibitory control, conflict control and cognitive flexibility respectively (e.g., Diamond, 2013). The working memory will be disregarded in this review because it concerns the domain of memory, very different from that of the attention to which the other EFs considered refer, and therefore it would require a specific review.

The *Go/No-Go Task* (Newmann & Kosson, 1986) is an experimental test used to evaluate the inhibitory motor system, which involves the response to a given stimulus (Go stimulus) and the inhibition in the presence of another similar stimulus, but with other characteristics (No-Go stimulus). The number of false alarms (i.e., the responses to no-go stimuli) represents the critical motor inhibition information.

The *Stroop Task* (Stroop, 1935) is used to evaluate the cognitive inhibitory system in a conflictual situation. The aim of the task, in its standard version, is to indicate the colour of the ink with which words are written

ignoring the meaning of the word itself, which usually means a colour. The trials may have incongruent conditions (ink colour different from the meaning of the word; for example, the word GREEN presented with RED ink) or congruent (ink colour equal to the meaning of the word). The cognitive inhibition information is given by the difference, in accuracy and reaction times (RTs), between the responses in incongruent and congruent trials (Stroop effect).

The *Flanker Task* (Eriksen & Eriksen, 1974) requires interference control. In the classical version of the Task, the participants must focus their attention on the central stimulus (e.g. a letter or an arrow) and ignore the distractors (Flankers) that are presented side by side with the target stimulus and can be identical (congruent) or different (Incongruent). The flanker effect (or conflict effect) is given by the difference, in accuracy and RTs, between the responses in incongruent and congruent trials (Kramer, 2015).

The *Wisconsin Sorting Card Test* (WCST) (Millner, 1963; Nelson, 1976) is used as a measure of cognitive flexibility based on external feedback, the ability to maintain a mental set and categorical thinking. The WCST includes four stimulus cards and 64 answer cards. The participant's task is to match the response cards (according to criteria of colour, form, or number) to the stimulus cards deducing the correct rule used, unknown to him/her, based on the feedback received from the experimenter. The classification criteria are pre-established and change when the participant provides ten correct answers. The number of errors (e.g., the percentage of global errors, perseverative errors, non-perseverative errors, failure to maintain set, etc.) allow measuring cognitive flexibility.

The development of these types of tasks has opened the possibility of an objective assessment of complex functions, such as executive ones (Gilbert & Burgess, 2008).

EFs mainly refer to two neural circuits, one frontoparietal and one operculum-cingulate, located in the associative cortex of the frontal lobe. From an anatomical-functional point of view, these areas can be subdivided into three operative units: the dorsomedial cortex, with working memory functions necessary for the selection and maintenance of behavioural objectives in memory; the mesial cortex, dedicated to the integration of the emotional and motivational aspects essential for the continuation of the action; and the orbital cortex, with mainly inhibitory functions both on behaviour and on instinctual drives (Petersen & Posner, 2012). The EFs are modulated by dopaminergic, noradrenergic, serotonergic and cholinergic inputs (Logue & Gould, 2014).

The deficits of EFs interfere with the cognitive abilities necessary for a useful acquisition and recall of information (Stuss & Alexander, 2000). Executive control could interfere with the organisation and processing of information and with the ability to resist to the effects of interference, affecting the ability to implement coding and recall strategies (Stuss & Alexander, 2000).

Many studies have investigated the presence of impaired EFs in elderly with MCI, showing that an executive type deficit is common in patients with MCI (Perry, Watson & Hodges, 2000; Ready, Ott, Grace & Cahn-Weiner, 2003) and that this impairment predicts a worse prognosis (Bennys, Rondouin, Benattar, Gabelle, & Touchon, 2011; Chen et al., 2013). Furthermore, the subtype of MCI with an executive deficit could represent an early stage of the AD, independently of the amnesic MCI subtype (Storandt, 2008).

However, unlike the robust evidence coming from the deficit in episodic memory (Bäckman, Jones, Berger, Laukka, & Small, 2005; Belleville, Chertkow, & Gauthier, 2007; Dudas, Clague, Thompson, Graham, & Hodges, 2005; Fujishima et al., 2014; Pike & Savage, 2008), the exact nature of executive deficits in the population with MCI remains uncertain. Some studies show that only some of the executive domains (e.g. planning/problem solving, working memory or inhibition) seem to be compromised (Brandt et al., 2009; Traykov et al., 2007).

The variability in the experimental tasks used makes hard determining, with some reliability, what are the aspects of executive control compromise.

The heterogeneity of the measures considered is one of the main problems in the study of EFs impairment in MCI. The general aim of this review is to analyse the weakening of some aspects of EFs in MCI by identifying any changes in the elderly with MCI compared to the healthy population. With the aim to outline a homogeneous framework in this review, it was decided to consider only studies that used specific paradigms (i.e., Go/No-Go Task; Stroop Task; Flanker Task; Wisconsin Sorting Card Test respectively) to highlight the difficulties of people with a diagnosis of MCI. We chose these behavioural tasks because they were more commonly used and are considered as a golden standard to evaluate specific aspects of executive functions, in particular considering inhibitory and interference control, conflict control and cognitive flexibility (Diamond, 2013). These specific aspects of executive functions, assessed through these tasks, would appear to be associated with a larger impairment of daily life activities and be associated with a diagnosis of dementia (for a review see Guarino et al., 2018). However, these aspects are often assessed

independently, resulting in a lack of a possible overview and this view do not provide useful information for the discrimination between MCI and healthy elderly people. Furthermore, another specific aim is to establish whether the selected task can allow catching the condition of MCI and whether they can be used in the MCI diagnosis.

## Method

The review was performed according to the PRISMA-Statement (Liberati et al., 2009; Moher, Liberati, Tetzlaff, & Altman, 2009). However, the protocol has not been registered.

### Research Strategies

A systematic analysis of the international literature was made, selecting articles published in peer-review journals using the PubMed, PsycINFO, PsycARTICLES and MEDLINE databases. The last research was conducted on 4 July 2018. Restrictions were made, limiting the research to publications in English with participants over 65 years of age. Studies of human populations have been included, with no restrictions on gender and ethnicity. The search strategy used the following keywords: "Mild Cognitive Impairment", "Stroop task", "Stroop test", "Flanker task", "Go/No-Go task", "Wisconsin Card Sorting Test".

The syntax used in the research is presented in Table 1.

### Eligibility criteria

Three authors (GA; FG; GJ) independently reviewed the list of potential articles produced by research strategies. Then, the studies that respected the following characteristics were selected: MCI diagnosis of the participants, use of cognitive measures of interest to the research (Stroop task, Go/No-Go task, WCST, Flanker Task) and the inclusion of a control group.

Studies were excluded if they included patients with diagnosis of dementia caused by Parkinson's disease; vascular dementia; frontotemporal dementia; Huntington's disease; stroke; cranial trauma; psychiatric disorders; articles that used experimental tasks different from those selected; studies in which participants diagnosed with MCI were included in groups with healthy elderly or those with dementia. The reading of title and abstract allowed the first exclusion of non-inherent studies. The examination of the complete text let for a further selection: to minimise the risk of bias we excluded the studies that included the selected test

(Go-NoGo; Stroop Task; Flanker Task; WCST) in the diagnosis of MCI. Furthermore, studies with methodological errors and important missing data (selective reporting bias and attrition bias) were not included.

The disagreements have been resolved with consensus methods. In case of lack of consensus among the researchers, a supervisor (CM) was used.

**Data collection process**

From each of the included studies, in line with the PICOS approach (Liberati et al., 2009), information on authors and year of publication; number and characteristics of the participants (age, years of education, gender, score at MMSE); criteria used for the diagnosis of MCI; experimental paradigm used; results of the studies have been extracted. The extracted data have been included in tables 2,3,4,5.

**Results**

**Selection of studies**

The flowchart shows the bibliographic databases used, the number of studies examined, the assessment for eligibility and inclusion in the review, further the reasons for possible exclusions have also been reported (Figure 2).

**[INSERT FIGURE 2 ABOUT HERE]**

A total of 49 studies were identified to be included in the review. Six of these have used combinations of the paradigms of our interest; the results will then be presented taking into account the different tasks considered. Specifically, 2 studies used the Flanker Task (see Table 2); 9 studies used the Go/No-Go Task (see table 3); 14 studies used the Wisconsin Card Sorting Test (see table 4), and 30 studies used the Stroop Task (see table 5).

**[INSERT TABLE 2, 3, 4, 5 ABOUT HERE]**

**Results of selected studies**

In the selected studies the paradigms of our interest were usually inserted in a battery of neuropsychological evaluation of MCI. For this reason, many articles allow obtaining only partial information regarding the results of the experimental tests.

**Results from Flanker Task (n= 2)**

The two studies which met the eligibility criteria were aimed to analyse the ability to control the conflict considering, in one case, only participants with MCI (Wylie, Ridderinkhof, Eckerle, & Manning, 2007) and in the other also patients with AD (Wang et al., 2013). Both studies do not show significant differences in age and years of education between the groups, while they show a lower MMSE in the group with MCI than the control group (Wylie et al., 2007; Wang et al., 2013) and a higher MMSE in the MCI than in the AD group (Wang et al., 2013).

**The standard version of the Flanker Task**

One study used the standard version of the Flanker Task (Wylie et al., 2007) highlighting a higher difficulty for participants with MCI in resolving incongruent trials, in fact, elderly with MCI showed slower RTs and worse accuracy than healthy controls in the incongruent trials.

**The modified version of the Flanker Task**

The second study (Wang et al., 2013) used a modified version of the Eriksen's Flanker Task, which consisted of four conditions: (a) target and flankers were arrows pointed in the same direction (congruent trials), (b) target and flankers pointed in different directions (incongruent trials), (c) the flankers were substituted by the sign "+" (neutral trials), (d) the target was presented without flankers. These conditions allow Authors to calculate conflict control, considering "perceptual interference" and "response interference". Perceptual interference was computed by comparing the RTs and accuracy in the condition in which the target was presented with the performance obtained in the neutral trials; such conditions differ only for the presence of the flankers. The response interference was measured by comparing the incongruent stimuli with the neutral ones, in this case, the stimuli are not perceptually different but differ for congruence. Results showed that both groups with cognitive impairment (MCI and AD) were more distracted by flankers than healthy controls. Both groups showed difficulty in inhibiting irrelevant responses. However, subjects with MCI were more impaired in resolving perceptual conflict, since irrelevant perceptual information would seem to influence the perceptive processing of the stimuli; while patients with AD showed higher difficulty in the resolution of both perceptual and response interferences.

**Results from Go/No-Go Task (N= 9)**

The studies that met the eligibility criteria were aimed at analysing the ability to inhibit the response in patients with MCI, and some studies also examined different typologies of MCI, i.e., MCI single and multiple domains (Cid-Fernandez, Lindin, & Diaz, 2014; 2017)

Only one study (Dwolatzky et al., 2003), out of the nine, highlighted significant differences between groups for both age and years of education. Considering MMSE, some studies did not report differences between the groups; others showed lower scores in the groups with MCI compared to the healthy control group (see table 3); only one study used the MOCA (Zunini et al., 2016) to evaluate the general neurocognitive state.

**The standard version of the Go/No-Go task**

The four studies using the standard version of Go/No-Go task (see table 3) show worse performance in the elderly with MCI than in healthy control group by considering accuracy and RTs (see table 3). Only one study (Sung, Kim, Jeong, & Kang, 2012) did not show significant differences between participants with MCI and healthy elderly.

**Modified versions of the Go/No-Go task**

Cid-Fernandez et al. (2014; 2017) performed two studies using a modified version of Go/No-Go task (derived from a version of Escera, Alho, Winkler, & Näätänen, 1998) in which visual (No-Go) and auditory (Go) stimuli were presented. In the first study (Cid-Fernandez et al., 2014), the authors found slower RTs and a worse accuracy in the aMCI group compared to controls. In the second (Cid-Fernandez et al., 2017), multiple domains MCI presented slower RTs and worse accuracy than controls, while participants with single domain MCI obtained mean scores significantly different than healthy participants in the accuracy but not in the RTs.

Two studies (Mudar et al., 2016; Nguyen et al., 2017) used two different Go/No-Go tasks: the Single Car Test (SiC), which included a simple categorization, in which a machine was used as a Go target and a dog as a No-Go target and the more complex Object Animal Task (ObA) that included objects (Go) and animals (No-Go). These tasks did not show differences between elderly with MCI and healthy controls in the RTs. However, considering the accuracy, participants with MCI had worse performance than the control group in the No-Go trials than in the Go trials (Mudar et al., 2016), a higher number of both commission errors (Mudar et al., 2016) and false alarms (Nguyen et al., 2017).

Only one study (Zhang, Han, Verhaeghen, & Nilsson, 2007) using a modified version of the Go/No-Go Task (Colour Word Version) showed no significant differences between the two groups.

**Results from WCST (N= 14)**

Studies that met the eligibility criteria were aimed to investigate cognitive flexibility based on external feedback, as well as the ability to maintain a mental set and categorical thinking in people with MCI compared to both healthy control group and patients with AD (see table 4).

Among the included studies, only one shows significant differences between people with MCI and healthy elderly for both age and years of education (Ballesteros, Mayas, & Reales, 2013). Some studies showed a lower MMSE score in the group with MCI compared to the control group and higher MMSE score in the group with MCI than in the group with AD (see table 4). Two studies (Chen et al., 2009; Chen & Chang, 2016) did not use the MMSE to estimate general cognitive impairment, within these, one (Chen et al., 2009) measured the intelligent quotient (IQ), which did not reveal significant differences between MCI and control groups, while people with MCI had a higher IQ than patients with AD.

**The standard version of the WCST**

Ten studies used the standard version of WCST, in the paper version or computerised version (see table 4). Generally, the group with MCI compared to the control group showed a higher frequency of perseverative errors (see table 4). However, people with MCI presented also a reduced number of completed categories, fewer conceptual responses, a higher number of attempts to complete the first category, a higher presence of non-perseverative errors or fewer correct answers (see table 4). Two studies did not show significant differences between people with MCI and healthy controls (Rabin et al., 2006; Carter, Caine, Burns, Herholz, & Lambon Ralph, 2011). Only one (Chiu et al., 2014) of the two studies comparing people with MCI and patients with the AD (Chen et al., 2009; Chiu et al., 2014) showed a better performance in people with MCI than in patients with the AD.

**The modified version of the WCST**

Four studies used a modified version of WCST (Nelson, 1976) (see table 4). In this case, still, people with MCI presented, compared to the control group, more perseverative errors and a lesser number of completed

categories (see table 4). A single study (Guild et al., 2014) did not show any difference in the measures considered (number of completed categories and series failure).

The study of Nagahama et al. (2003) found general better performance in the group with MCI than in the group with the AD, while people with MCI reported a significantly higher number of non-perseverative errors compared to patients with the AD.

**Results from the Stroop Test (N= 30)**

Studies that met the eligibility criteria were aimed to evaluate the inhibitory system and the effect of interference in a conflictual condition in people with MCI compared to a healthy control group or a group of patients with AD (see table 5).

In the selected studies some of them highlight significant differences between groups considering age (Nystrom, Wallin, & Nordlund, 2014; Ramos-Goicoa, Galdo-Alvarez, Diaz, & Zurron, 2016), years of education (Baek, Kim, H. J, & Kim, S., 2012; H Dodge et al., 2015; Li et al., 2013; Puente, Faraco, Terry, Brown, & Miller, 2014) or both (Martin et al., 2016; Sanchez-Benavides et al., 2014; Chen et al., 2013). Concerning the MMSE, some studies did not show significant differences (Baek et al., 2012; Belleville et al., 2007), while in one study (Chen & Chang, 2016) it is not used to evaluate the general cognitive impairment.

Given the adoption of different versions of the Stroop Task (see table 5), the results will be presented trying to group similar versions.

Eighteen studies were conducted using a paradigm similar to the standard version of the Stroop Colour Interference Test (SCIT; Stroop, 1935).

The analysis of the number of correctly named words indicates a worse performance in the group with MCI than in the control group (see table 5). One study does not show significant differences (Zhang et al., 2007). Comparison of the group with MCI and the group with AD showed no differences only in one study (Sanchez et al., 2014), while in the other researches a better performance in the group with MCI than in the group with AD was found (see table 5). Considering the different typologies of MCI, two studies reported similar performances in elderly with amnesic and non-amnesic MCI (Wang, Guo, Zhao, & Hong, 2012) and in people with MCI single domain and multiple domains (Chang et al., 2015). Another study (Li et al., 2013) showed between-group differences, both in RTs and accuracy. Amnesic MCI single domain presented better

performance than the other two groups, whereas the performance between amnesic MCI multiple domain and non-amnesic MCI was similar.

Six studies have used the Stroop Color-Test Victoria Version (see table 5). Patients with MCI, compared to controls, presented slower RTs and a higher number of errors (see table 5). One study (Lopez et al., 2006) showed a higher interference effect in the group with MCI multiple domains. A single study (Belleville et al., 2007), using this type of experimental test, did not show any difference between elderly with MCI and controls. Two studies, using a modified version of the Stroop Task (Puente et al., 2014, Ramos et al., 2016), did not show significant differences in RTs or accuracy. Another study (Duong et al., 2006) used both the standard Stroop version and the Stroop-Picture Naming test. The latter would seem to differentiate the performances of the groups better. The group of participants with MCI presented a worse accuracy than the control group, but a better accuracy than the group with AD. There were no differences considering RTs. Two studies (Balanger, Belleville, & Gauthier, 2010; Zheng et al., 2012) have adopted a modified version of the Stroop Test by adapting it from Kane & Engle (2003), but only one of them (Balanger et al., 2010) found significantly slower RTs in incongruent trials in the elderly with MCI compared to the control group.

## Discussion

### Summary of the evidence

Despite the low number of observations that do not allow reliable conclusions, the Flanker task has shown difficulty in patients with MCI in responding to incongruent trials. The source of this failure would seem to derive from an inefficient response inhibition, which does not allow a correct resolution of the conflict. In particular, Wylie and colleagues (2007) who, adopting a distribution analysis to verify the activation-suppression hypothesis, show that patients with MCI have a higher interference effect due to a larger inhibition of response rather than an increased activation induced by incongruent flankers. This result is reinforced by a good selection of samples that do not show significant between groups differences regarding some influential variables (Wylie et al., 2007). This impairment would seem to be emphasised when the conflict is perceptual (Wang et al., 2013).

The analysis of the results obtained by the group with MCI in the Go-NoGo task indicates the presence of a cognitive decline, characterised by ineffectiveness in the motor inhibition of the response, which is reflected

in slower RTs and fewer correct answers. In general, people with MCI showed lower accuracy in both the Go and the NoGo trials (see table 3). These results would seem to suggest a difficulty in detection of target stimuli (Go) and in inhibitory control (No-Go), or a general attentional impairment, in patients with MCI. This result does not appear to be associated with physiological cognitive decline, but it would seem to be rather a prerogative of cognitive impairment (e.g. Vallesi, 2011), in fact, healthy older adults, compared to young adults, show less accuracy only in the Go trials (Hsieh, Wu, & Tang, 2016). Deficits in inhibitory control are associated with a diagnosis of AD and often represent the most noticeable impairments (for a review see Amieva, Phillips, Della Sala, & Henry, 2004). These results are confirmed by some studies that, using neurophysiological measures, suggest that the neurocognitive mechanisms related to the ability to hold a target and inhibit a motor-type response are less efficient in MCI (Zunini et al., 2016). These conclusions are strengthened by a good sample selection carried out in the examined studies, in fact, only one research (Dwolatzky et al., 2003) presents some differences regarding relevant variables such as years of education and age.

This aspect is of fundamental importance for clinical practice since an early analysis of these characteristics would allow the implementation of interventions aimed at maintaining skills. Also, in this case, the task displays an adequate sensitivity for the assessment of the inhibitory control and an adequate ability to discriminate people with MCI from healthy elderly. Furthermore, it allows also distinguishing the different types of MCI (Cid-Fernandez et al., 2017).

The WCST would seem to be a valid test to discriminate people with MCI from healthy elderly, according to cognitive flexibility based on external feedback. The WCST scores that would appear to be more discriminative for participants with MCI are perseverative errors (the number of reiterate incorrect responses) and the completion of the categories (the final completed categories). In fact, from the selected studies it would seem that the elderly with MCI commit a higher number of perseverative errors and complete fewer categories than controls. These results are replicated by studies using the classic version and those using the modified version of the WCST. Although the revised version of WCST would seem the golden standard to evaluate individuals with different neurological diseases (e.g., Parkinson's disease, chronic alcoholism, Alzheimer's disease; Nagahama et al., 2003; Silva-Filho, Pasian & Vale, 2007), to assess people with MCI even the standard version of WCST shows an adequate sensitivity in discriminating people

with MCI from healthy people. The only study that showed no significant differences between groups did not perform specific statistical comparisons between the groups; however, given the reported means one could hypothesise a worse performance of the group with MCI compared to the control group (Rabin et al., 2006).

One study comparing MCI and AD groups (Nagahama et al., 2003) reported interesting findings. In this study, the elderly with MCI committed a higher number of non-perseverative errors than the patients with AD. This result would highlight a cognitive strategy characterised by strategic choices inconsistent with external demands that would seem connected to multiple cognitive impairments (Nagahama et al., 2003). Naturally, more specific research is needed to determine which cognitive processes contribute to the different profile obtained in WCST by people with MCI.

The selected studies show that the most used experimental paradigm is the Stroop Task. This high use of the Stroop Task is since it is generally inserted in a complete neuropsychological battery.

The Stroop Task is sensitive to catch dysfunctional executive processes, in particular, impairment in cognitive inhibition. In some studies (e.g., Ye et al., 2012), where the Stroop test was administered with other tasks measuring further EFs, it would appear to have higher discriminative power than the other tests. In particular, a worse performance at the Stroop Task would seem to be associated with higher severity of amnesic deficits (Seo, Kim, Lee, & Choo, 2016). The adoption of this test could allow greater discrimination between amnesic and non-amnesic MCI. However, given the extensive use of different versions of the same test, the results, although quite homogeneous, cannot be fully generalised. Some studies did not show differences in performance between groups. For example, a study (Ramos-Goicoa et al., 2016) did not report significant differences in both accuracy and reaction times. However, the authors adopted a simplified version of the Stroop, which could have facilitated the task by reducing its sensitivity. Another of the studies that did not show any difference (Zhang et al., 2007) adopted different criteria for the classification of participants with MCI (considering as cut-off for the inclusion of participants in the group with MCI, a performance less than 1.0 SD below mean, rather than 1.5 SD) that could have influenced their findings.

The cognitive inhibition of the response assessed by the Stroop task would seem to be an essential function to monitor in the cognitive decline process that allows discriminating people with MCI from those with AD.

The analysis of the sensitivity of these tasks, widely used in the study of EFs, is necessary to plan an effective experimental protocol aimed to evaluate the efficiency of some cognitive processes in elderly, patients with MCI and preclinical phases of the AD.

In general, the result of the review would seem to highlight that the EFs in elderly with MCI can be analysed in a discreetly effective way by the selected paradigms. To our knowledge, this is the first review to examine the use of these tasks for the assessment of specific EFs aspects in patients with MCI. Identifying suitable experimental paradigms to highlight the characteristics of MCI could be very useful in the diagnosis and in the implementation of neuropsychological interventions aimed at enhancing cognitive skills or slowing down their decline. In fact, despite the standard neuropsychological measures (e.g., Carlesimo et al., 1996; Nasreddine et al., 2005) are fundamental to compare clinical and non-clinical populations, they are not often sufficiently exhaustive or always applicable to an explicit definition of the diagnosis or to establish the specific profile characterising people with cognitive decline.

**Limitations**

Although the experimental paradigms analysed in this systematic review would seem to indicate an acceptable sensitivity in highlighting EFs impairment in patients with MCI, some methodological limitations do not allow unambiguous conclusions. Among these, we include the use of different versions of the same task that often makes demanding to compare the results of various researches. Other significant limits are the low number of participants and the not unique and standardised classification of both patients with MCI and healthy elderly. Moreover, the experimental tasks used to evaluate EFs domain itself inevitably involve other cognitive processes causing the phenomenon of the Task Impurity, which make even more arduous to compare the various findings (Myake et al., 2000). Furthermore, given the lack of clear and unambiguous criteria for the definition of MCI, the classification is carried out with very different and often not comparable criteria.

With the aim to reduce these methodological limitations, a standard protocol for both the diagnosis of MCI and the evaluation of the EFs could be useful; it will make the obtained results more generalizable.

Moreover, the lack of quantitative analysis carried out through a meta-analysis would have given higher force to the results of this systematic review. Another limit could be indirectly linked to the publication bias.

The choice to include only academic articles published in peer-review journals may have limited the selection of only those studies that have obtained results in line with the literature. So, the results may have an overestimation of the relationship. Also, the choice to select only the studies published in English could have led to the elimination of studies conducted on other populations.

Given the characteristics typically associated with MCI, it was not possible to check the selection bias, as the groups often had significant differences in some demographic characteristics at the baseline (e.g. age, gender). The differences within the studies regarding these characteristics may have influenced the results.

**Conclusions**

The absence of a standard protocol has encouraged the use of more experimental task to evaluate the impairment in executive functions. This heterogeneity is one of the main problems that would seem to concern the study of the impairment of EFs in MCI. One of the aims of this review was to highlight whether the tasks considered as the golden standard for the evaluation of specific executive functions (inhibitory and interference control, conflict control and cognitive flexibility) had a discriminatory power compared to the diagnosis of MCI and therefore to highlight the possibility of using them for the diagnosis. Indeed, the results of this study would seem to indicate how the use of these tasks could provide relevant information from a clinical point of view emphasising the deterioration of people with MCI compared to healthy older adults. The computerised versions of some of these tasks (Go/No-Go, Stroop Task, Flanker Task) that allow a more accurate measurement of reaction times and accuracy provide information that is more discriminative and more sensitive than the condition of executive deterioration, suggesting the use of these tasks in neuropsychological batteries aimed at understanding the characteristics of MCI. To date, in clinical practice, these tasks are not widely used, although similar results have been shown even in the presence of a diagnosis of dementia (Guarino et al., 2018).

The results of this systematic review generally support the applicability of the four selected experimental tasks to assess EFs in people with MCI not only for research but also for diagnostic and therapeutic purposes. The joint use of the experimental paradigms analysed in this study could allow obtaining a profile of the different aspects of the EFs, often treated in the literature as a unitary construct. An essential aim of future research should pursue the realisation of clear criteria for the classification of MCI and the standardisation of

the experimental tasks. The adoption of a standard classification would allow a more straightforward comparison between the different studies and to a higher generalisation of the results. However, there are too many variables and factors that could influence the assessment of MCI and the impairment of EFs. It is necessary to include in the studies the evaluation of factors that affect EFs (e.g., depression, age, gender, socioeconomic status).

Numerous research issues concerning MCI are still unresolved and they could influence the results obtained, such as the identification of the prevalence of different subtypes (Winbland et al., 2004), the bias linked to the selection criteria of participants, the correct recognition of the conversion rates in AD and the age of the participants included in the studies (Petersen et al., 2014). Therefore, it would be desirable to carry out a more significant number of studies involving the general population to identify a possible different manifestation of the MCI. Furthermore, the implementation of systematic reviews like this can help shed some specific features of the MCI, which still today, as a few years ago (Petersen et al., 2014), is an evolving construct.



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**Table 1.** Search scripts and results.

| Task | Database | Script | # of results |
|---|---|---|---|
| *Stroop Task* | PubMed | ("Mild Cognitive Impairment") AND ("Stroop Task" OR "Stroop Test") | 512 |
| | PsycINFO, PsycARTICLES, Medline | ("Mild Cognitive Impairment") AND ("Stroop Task" OR "Stroop Test") | 666 |
| *Go/NoGo Task* | PubMed | ("Mild Cognitive Impairment") AND ("GO/NO-GO Task" OR "GO/NOGO Task") | 76 |
| | PsycINFO, PsycARTICLES, Medline | ("Mild Cognitive Impairment") AND ("GO/NO-GO Task" OR "GO/NOGO Task") | 21 |
| *Flanker Task* | PubMed | ("Mild Cognitive Impairment") AND ("Flanker Task") | 39 |
| | PsycINFO, PsycARTICLES, Medline | ("Mild Cognitive Impairment") AND ("Flanker Task") | 12 |
| *Wisconsin Card Sorting Test* | PubMed | ("Mild Cognitive Impairment") AND ("Wisconsin Card Sorting Test" OR "WCST") | 312 |
| | PsycINFO, PsycARTICLES, Medline | ("Mild Cognitive Impairment") AND ("Wisconsin Card Sorting Test" OR "WCST") | 217 |

**Table 2**. Main characteristics and results of the included studies that use Flanker Task.

| Authors | Participants | | | | | | MCI Criteria | Experimental Task | Results |
|---|---|---|---|---|---|---|---|---|---|
| | Group | N | Age (mean, SD) | Education (mean, SD) | Sex (% women) | MMSE (mean, SD) | | | |
| Wang et al., 2013 | NC | 16 | 69.3 (1.8) | 14 (0.9) | 44% | 29.3 (0.5) | Petersen et al. 1999 | Modified Eriksen Flanker Task | **MMSE**<br>AD *lower than* MCI *lower than* NC<br>**Accuracy**<br>NC *higher than* MCI *higher than* AD<br>**Response inteference**<br>AD *lower than* MCI, NC<br>MCI *equal to* NC<br>**Perceptual interference**<br>NC *equal to* MCI *equal to* AD<br>**RTs**<br>**Response interference**<br>NC *equal to* MCI *equal to* AD<br>**Perceptual interference**<br>AD *higher than* MCI, NC |
| | MCI | 15 | 72.9 (1.9) | 12.8 (0.9) | 40% | 27.0 (0.5) | | | |
| | AD | 7 | 68.6 (2.9) | 11.2 (1.4) | 57% | 21.5 (0.8) | | | |
| Wylie et al., 2007 | NC | 20 | 71.5 (8.7) | 16.0 (2.6) | 55% | 29.3 (0.8) | Clinical diagnosis of MCI | Flanker Task | **MMSE**<br>MCI *lower than* NC<br>**RTs**<br>MCI *equal to* NC<br>**Flanker effect**<br>MCI *higher than* NC<br>**Accuracy**<br>MCI *equal to* NC |
| | MCI | 20 | 73.0 (6.1) | 15.6 (2.7) | 60% | 26.0 (2.5) | | | |

Notes: MCI: Mild Cognitive Impairment; MMSE: Mini-Mental State Examination; SD: standard deviation; NC: normal controls; AD: Alzheimer's disease; RTs: reaction times.

**Table 3.** Main characteristics and results of the included studies that use Go/No-Go Task.

| Authors | Participants | | | | | | MCI Criteria | Experimental Task | Results |
|---|---|---|---|---|---|---|---|---|---|
| | Group | N | Age (mean, SD) | Education (mean, SD) | Sex (% women) | MMSE (mean, SD) | | | |
| Cid-Fernández et al., 2014 | NC | 63 | 65.9 (8.0) | 8.9 (4.8) | 65% | 28.2 (1.5) | Albert et al., 2011<br>Petersen 2004 | Go/NoGo | **RTs**<br>aMCI *higher than* NC<br>**Accuracy**<br>NC *higher than* aMCI |
| | aMCI | 30 | 69.5 (8.2) | 9.7 (4.3) | 53% | 25.9 (2.4) | | | |
| Cid-Fernández et al., 2017 | NC | 20 | 67.0 (9.8) | 9.8 (5.2) | 65% | 28.0 (1.5) | Petersen et al., 2004.<br>Albert et al., 2011. | Go/NoGo | **RTs standard conditions**<br>mdaMCI *higher than* NC<br>sdaMCI *equal to* NC<br>**RTs deviant conditions**<br>mdaMCI *higher than* NC<br>sdaMCI *higher than* NC<br>**RTs novel conditions**<br>mdaMCI *higher than* NC<br>sdaMCI *higher than* NC<br>**Go Hits standard conditions**<br>NC *higher than* mdaMCI<br>sdaMCI *higher than* mdaMCI<br>**Go Hits deviant conditions**<br>NC *higher than* mdaMCI<br>sdaMCI *equal to* NC<br>**Go Hits Novel Conditions**<br>NC *higher than* mdaMCI<br>sdaMCI *higher than* mdaMCI |
| | sdaMCI | 22 | 68.7 (10.1) | 9.0 (4.2) | 46% | 26.9 (2.0) | | | |
| | mdaMCI | 12 | 72.1 (6.9) | 9.2 (5.0) | 67% | 23.4 (1.7) | | | |
| Dwolatzky et al., 2003 | NC | 39 | 73.41 (8) | 14.95 (3.5) | 67% | 29.03 (1.1) | Petersen et al., 1999 | Go/NoGo | **MMSE**<br>MCI *lower than* NC<br>MCI *higher than* mAD<br>**Go/NoGo (Accuracy)**<br>MCI *lower than* NC<br>**General performance index**<br>MCI *lower than* NC<br>**Go/NoGo (RTs)**<br>MCI *higher than* NC |
| | MCI | 30 | 77.15 (6.43)[a;b] | 13.07 (2.86)[a,b] | 43% | 27.63 (1.5) | | | |
| | mAD | 29 | 80.55 (4.91) | 11.31 (2.85) | 55% | 24.17 (3.2) | | | |
| Mudar et al., 2016 | NC | 25 | 65.4 (7.1) | 16.6 (1.7) | 64% | 28.6 (0.5) | Petersen et al., 2001 | SiC<br>ObA | **MMSE**<br>aMCI *equal to* NC<br>**RTs**<br>aMCI *equal to* NC<br>RTs SiC *lower than* RTs ObA<br>**Accuracy No Go**<br>aMCI *lower than* NC |
| | aMCI | 25 | 68.5 (8) | 16 (1.9) | 64% | 28.4 (1.3) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **Commission errors** (false alarm/failure to inhibite during No Go trials) aMCi *higher than* NC **Omission in Go trials** aMCI *equal to* NC |
| Nguyen et al., 2017 | NC | 22 | 65.32 (6.84) | 16.59 (1.65) | 73% | 28.75 (0.5) | Albert et al., 2011 | SiC ObA | **MMSE** aMCI *equal to* NC **RTs** aMCI *equal to* NC **False alarm** aMCI *higher than* NC |
| | aMCI | 22 | 68.68 (7.69) | 16.23 (1.82) | 64% | 28.32 (1.29) | | | |
| Sung et al., 2012 | NC | 16 | 70.1 (5.1) | 8.2 (4.8) | n.r. | 26.45 (2.11) | Petersen, 2003 | Go/NoGo | **MMSE** MCI *equal to* NC **Go/NoGo (accuracy)** MCi *equal to* NC |
| | MCI | 16 | 73.3 (7.7) | 6.5 (3.4) | n.r. | 24.87 (3.40) | | | |
| Zhang et al., 2007 | NC | 32 | 73.5 (8.5) | 12.1 (3.5) | n.r. | 28.7 (1.8) | Adapted from Petersen et al., 1999 | Go/NoGo | **MMSE** MCI *lower than* NC **Go/NoGo (Accuracy)** MCI *equal to* NC **Stroop effect** MCI *equal to* NC **Word-color naming Stroop effect** MCI *equal to* NC **Negative priming** MCI *equal to* NC |
| | MCI | 32 | 73.7 (8.2) | 10.7 (2.9) | n.r. | 27.4 (2.0) | | | |
| Zihl et al., 2010 | NC | 20 | 63.4 (1) | n.r. | 55% | 28.3 (1.6) | Winblad et al., 2004 | Go/NoGo | **MMSE** MCI *lower than* NC **Go/NoGo RTs** MCI *higher than* NC **Go/NoGo Accuracy** MCI *equal to* NC **Omissions** MCI *equal to* NC |
| | MCI | 24 | 65.8 (5.8) | n.r. | 54% | 29.8 (0.4) | | | |
| Zunini et al., 2016 | NC | 17 | 72.40 (15.87) | 15.58 (3.04) | 65% | n.a. | Zunini et al., 2016 | Classic Go/NoGo | **MOCA** MCI *lower than* NC NC = 27.65 (1.62) MCI = 22.60 (2.61) **RTs** |
| | MCI | 15 | 75.60 (6.02) | 14.67 (2.79) | 53% | n.a. | | | |

| | |
|---|---|
| | MCI *equal to* NC<br>**Accuracy Go Trials**<br>NC *higher than* MCI<br>**Accuracy No Go Trials**<br>NC *higher than* MCI |

Notes: MCI: Mild Cognitive Impairment; MMSE: Mini-Mental State Examination; SD: standard deviation; NC: normal controls; mAD: mild Alzheimer's Disease; RTs: reaction times; AD: Alzheimer's disease; N.R.: not reported; WCST: Wisconsin Card Sorting Test; aMCI: amnesic MCI; N.A.: not applicable; sdaMCI: single domain aMCI; SiC: single-car task; ObA: object-animal task. [a] Significant difference between MCI and normal control ($p<.05$); [b] Significant difference between MCI and AD ($p<.05$).

**Table 4.** Main characteristics and results of the included studies that use WCST.

| Authors | Participants | | | | | | MCI Criteria | Experimental Task | Results |
|---|---|---|---|---|---|---|---|---|---|
| | Group | N | Age (mean, SD) | Education (mean, SD) | Sex (% women) | MMSE (mean, SD) | | | |
| Ballesteros et al., 2013 | NC older | 20 | 69.15 (3.15) | 13.75 (1.80) | 40% | 29.4 (0.68) | Peña Casanova et al., 1991 | WCST | **WCST**<br>**Total Errors**<br>**Perseverative errors**<br>**Non perseverative errors**<br>MCI *higher than* NC olders<br>*higher than* NC younger |
| | NC Younger | 20 | 26.25 (1.68) | 17.15 (0.98) | 40% | 29.65 (0.49) | | | |
| | MCI | 20 | 74.52 (3.94)[a] | 12 (0.81)[a] | 50% | 24.7 (1.03) | | | |
| Borkowska et al., 2009 | NC | 30 | 59.7 (7.7) | 11.6 (2.2) | 70% | 29.5 (1.9) | Borkowska et al., 2009 | WCST | **MMSE**<br>MCI *equal to* NC<br>**WCST**<br>**Non perseverative errors**<br>MCI *higher than* NC<br>**Perseverative errors**<br>MCI *higher than* NC<br>**Conceptual responses**<br>MCI *lower than* NC<br>**Categories achieved**<br>MCI *lower than* NC<br>**Trials to complete the first category**<br>MCI *higher than* NC |
| | MCI | 30 | 61.9 (5.6) | 11.7 (5.6) | 70% | 25.3 (0.9) | | | |
| Carter et al., 2012 | NC | 13 | 73.5 (4.7) | 13.2 (3.5) | 62% | 29.5 (0.52) | Petersen, 2004 | WCST | **MMSE**<br>NC *higher than* MCI *higher than* AD<br>**WCST- category shifts**<br>NC *equal to* MCI *equal to* AD |
| | MCI | 17 | 73.3 (9.7) | 11.8 (3.7) | 41% | 28.0 (1.5) | | | |
| | mAD | 15 | 77.3 (5.6) | 10.7 (2.5) | 37% | 22.3 (3.5) | | | |
| Chen et al., 2016 | NC | 25 | 70.68 (5.45) | 13.68 (2.87) | 60% | n.r. | Winblad et al., 2004 | mWCST | **mWCST**<br>**categories achieved**<br>MCI *lower than* NC |
| | MCI | 22 | 73.77 (7.7) | 12.50 (2.92) | 55% | n.r. | | | |
| Chen et al., 2009 | NC | 16 | 69 (8.4) | 10.5 (3.8) | 44% | n.a. | Petersen et al., 2001 | WCST | **WCST**<br>**Categories achieved**<br>MCI *lower than* NC<br>**Perseverative errors**<br>MCI *higher than* NC |
| | aMCI | 13 | 73.2 (9.3) | 11.4 (4.3) | 38% | n.a. | | | |
| | AD | 10 | 76.7 (8.5) | 7.8 (4.9) | 70% | n.a. | | | |
| Chiu et al., 2014 | NC | 30 | 64.4 (9.5) | 13.1 (3.03) | 57% | 28.8 (1.6) | Chiu et al., 2013 | WCST | **MMSE** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MCI | 20 | 71.2 (9.7) | 12.0 (3.1)[a;b] | 55% | 26.3 (2.7) | | | Early AD *lower than* MCI *lower than* NC<br>**WCST**<br>**(categories completed)**<br>Early AD *lower than* MCI<br>Early AD *lower than* NC |
| | EAD | 10 | 69.3 (9.4) | 7.6 (3.2) | 60% | 22.7 (3.6) | | | |
| Deiber et al., 2011 | NC | 36 | 64.7 (6.6) | 2.0 (0.8) | 67% | 29.0 (0.8) | Petersen et al., 1985-1992 | WCST | **MMSE**<br>mdaMCI *lower than* NC<br>**WCST**<br>**(n° categories completed)**<br>n.r. |
| | sdaMCI | 16 | 65.8 (5.4) | 2.4 (0.6) | 44% | 28.2 (1.5) | | | |
| | mdaMCI | 27 | 64.0 (5.3) | 1.9 (0.7) | 56% | 27.7 (1.9) | | | |
| Nagahama et al., 2003 | NC | 22 | 70.8 (9.1) | 11.1 (3.1) | n.r. | 29.1 (0.8) | Petersen et al., 2001 | Computerized mWCST | **MMSE**<br>AD *lower than* MCI *lower than* NC<br>**mWCST**<br>**Total errors**<br>AD *higher than* NC<br>MCI *equal to* NC<br>**Category achieved**<br>MCI *lower than* NC<br>**Trials to complete the first category**<br>AD *higher than* NC<br>MCI *equal to* NC<br>**Perseverative errors**<br>AD *higher than* MCI<br>AD *higher than* NC<br>MCI *equal to* NC<br>**Recurrent Perseveration**<br>MCI *higher than* NC<br>**Non perseverative errors**<br>MCI *higher than* AD<br>**Conceptual level response**<br>MCI *lower than* NC<br>**Failure to maintain set**<br>AD *equal to* MCI *equal to* NC |
| | MCI | 17 | 72.8 (5.4) | 10.9 (2.7) | n.r. | 26.4 (2.0) | | | |
| | AD | 54 | 74.2 (5.1) | 10.3 (3.3) | n.r. | 20.8 (3.3) | | | |
| Nordlund et al., 2005 | NC | 35 | 67 (5.5) | n.r. | n.r. | 29.3 (1.1) | Clinical diagnosi of MCI | WCST computer version | **MMSE**<br>MCI *lower than* NC<br>**WCST**<br>**(correct responses)**<br>MCI *equal to* NC |
| | MCI | 112 | 64 (8.2) | n.r. | n.r. | 28.5 (1.5) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nordlund et al., 2007 | NC | 60 | 66.5 (6.2) | 11.3 (2.6) | 53% | 29.3 (1.1) | Winblad et al., 2004 | WCST computer version | **MMSE**<br>NC *higher than* MCI<br>**WCST**<br>MCI-nov *lower than* NC<br>MCI-vas *lower than* NC<br>MCI-nov *equal to* MCI-nov |
| | MCI-vas | 60 | 67.0 7.3 | 11.2 (3.2) | 63% | 28.2 (1.8) | | | |
| | MCI-nov | 60 | 66.4 6.8 | 11.6 (3.7) | 53% | 28.4 (1.3) | | | |
| Rabin et al., 2006 | NC | 30 | 72.00 (5.70) | 17.03 (2.76) | 70% | 28.93 (1.17) | Petersen et al. 2001 | WCST | **MMSE**<br>NC, CC *higher than* MCI<br>**WCST**<br>**(Total categories, Perseverative errors, failure to mantain set)**<br>NC *equal to* MCI *equal to* CC |
| | MCI | 29 | 74.14 (5.55) | 16.69 (2.83) | 45% | 26.79 (1.68) | | | |
| | CC | 28 | 74.21 (6.27) | 16.71 (2.81) | 71% | 28.68 (1.68) | | | |
| Sun et al., 2016 | NC | 38 | 68.67 (5.53) | 12.42 (3.03) | 63% | 28.50 (1.06) | Petersen et al., 2001 | WCST | **MMSE**<br>aMCI *lower than* NC<br>**WCST**<br>**(perseverative errors)**<br>NC *lower than* aMCI *lower than* VCIND |
| | aMCI | 50 | 68.84 (5.88) | 12.12 (2.87) | 66% | 26.61 (1.30) | | | |
| | VCIND | 50 | 68.58 (5.26) | 12.8 (2.78) | 60% | 26.24 (1.49) | | | |
| Traykov et al., 2007 | NC | 20 | 73.3 (7.0) | 12.8 (3.3) | 30% | 29.5 (0.5) | Petersen et al., 1995 | mWCST | **MMSE**<br>MCI *lower than* NC<br>**mWCST**<br>**Categories achieved**<br>MCI *equal to* NC<br>**Perseveration**<br>MCI *higher than* NC<br>**Errors**<br>MCI *higher than* NC |
| | MCI | 20 | 73.2 (8.0) | 12.1 (3.1) | 20% | 28.95 (1.1) | | | |

Notes: MCI: Mild Cognitive Impairment; MMSE: Mini-Mental State Examination; SD: standard deviation; NC: normal controls; mAD: mild Alzheimer's Disease; RTs: reaction times; AD: Alzheimer's disease; N.R.: not reported; WCST: Wisconsin Card Sorting Test; aMCI: amnesic MCI; mdMCI: multiple domain MCI; N.A.: not applicable; CC: Cognitive Complaints; MCI-vas: MCI vascular; MCI-nov: MCI no vascular; sdaMCI: single domain aMCI; VCIND: Vascular Cognitive Impairmet-No Dementia. [a] Significant difference between MCI and normal control ($p<.05$); [b] Significant difference between MCI and AD ($p<.05$).

**Table 5.** Main characteristics and results of the included studies that use Stroop Task.

| Authors | Participants | | | | | | MCI Criteria | Experimental Task | Results |
|---|---|---|---|---|---|---|---|---|---|
| | Group | N | Age (mean, SD) | Education (mean, SD) | Sex (% women) | MMSE (mean, SD) | | | |
| Baek et al., 2012 | NC | 53 | 65.94 (7.24) | 11.81 (5.33) | 55% | 27.04 (0.44) | Petersen et al., 2011 | Korean Color-Word Stroop Test (Kang & Na, 2003) | **MMSE** NC *equal to* MCI *higher than* EAD **Stroop (Color reading)** NC *higher than* MCI *higher than* EAD |
| | MCI | 127 | 69.23 (7.48) | 11.13 (5.29) | 59% | 26.12 (0.29) | | | |
| | EAD | 72 | 73.25 (5.70) | 11.62 (9.22) | 67% | 23.10 (0.44) | | | |
| Baek et al., 2011 | NC | 53 | 70.52 (n.r.) | 11.58 (n.r.) | n.r. | 27.82 (0.36) | Petersen et al., 2001 | Korean Color-Word Stroop Test (Kang & Na, 2003) | **MMSE** NC *higher than* MCI *higher than* AD **Stroop (Color reading)** NC *higher than* MCI *higher than* AD |
| | MCI | 120 | 69.14 (n.r.) | 11.05 (n.r.) | n.r. | 26.74 (0.24) | | | |
| | AD | 97 | 73.46 (n.r.) | 11.17 (n.r) | n.r. | 22.75 (0.32) | | | |
| Belanger et al., 2010 | NC Older | 20 | 71.1 (7.5) | 13.5 (3.3) | n.r. | 28.8 (1.4) | Petersen et al., 2003 | Stroop Test | **MMSE** MCI *equal to* NC older **Stroop (incongruent trials)** RT MCI *higher than* RT NC older |
| | MCI | 20 | 72.7 (6.8) | 13.6 (4) | n.r. | 27.4 (2.1) | | | |
| | AD | 11 | 75 (6.4) | 13.5 (2.9) | n.r. | 23.4 (3.7) | | | |
| Belleville et al., 2007 | NC MCI | 25 | 66.12 (10.09) | 14.32 (3.53) | 80% | 28.88 (0.99) | Petersen, 2003 | Stroop Test, Victoria Version | **MMSE** MCI *equal to* NC MCI **Stroop (Errors on third plate)** MCI *equal to* NC MCI |
| | NC AD | n.r. | 72.42 (8.31) | 12.68 (3.96) | 15 F | 28.74 (0.93) | | | |
| | MCI | 28 | 64.76 (10.83)[b] | 14.32 (4.71)[b] | 50% | 28.36 (1.98) | | | |
| | AD | 19 | 73.42 (9.18) | 10.95 (3.84) | 53% | 24.65 (3.60) | | | |
| Carter et al., 2012 | NC | 13 | 73.5 (4.7) | 13.2 (3.5) | 62% | 29.5 (0.52) | Petersen, 2004 | Stroop (Trenerry et al., 1989) | **MMSE** NC *higher than* MCI *higher than* AD **Stroop-words** NC *higher than* AD NC *equal to* MCI MCI *equal to* AD **Stroop-colours** NC *higher than* MCI *higher than* AD **Stroop-percentage** NC *higher than* AD MCI *higher than* AD NC *equal to* MCI |
| | MCI | 17 | 73.3 (9.7) | 11.8 (3.7) | 41% | 28.0 (1.5) | | | |
| | mAD | 15 | 77.3 (5.6) | 10.7 (2.5) | 37% | 22.3 (3.5) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Chang et al., 2015 | NC | 36 | 70.67 (6.01) | 13.72 (2.95) | 58% | 29.12 (0.99) | Petersen & Morris, 2005 | Stroop (Golden, 1978) | **MMSE**<br>NC *higher than* sdaMCI, mdaMCI<br>**Stroop color naming condition**<br>NC *higher than* mdaMCI<br>sdaMCI *equal to* mdaMCI |
| | sdaMCI | 24 | 70.08 (7.83) | 12.08 (3.56) | 67% | 27.35 (1.75) | | | |
| | mdaMCI | 22 | 73.77 (8.42) | 12.18 (4.15) | 45% | 26.98 (1.68) | | | |
| Chen et al., 2013 | NC | 100 | 75.4 (7.3) | 12.5 (4.1) | 32% | 28.4 (1.7) | Adapted from Petersen et al., 1999 | Modified Stroop Test | **MMSE**<br>aMCI *lower than* NC<br>aMCI *higher than* AD<br>AD *lower than* NC<br>**Stroop test**<br>**(total score: score – reminders during the test perios of 120s)**<br>aMCI *lower than* NC<br>aMCI *higher than* AD<br>AD *lower than* NC |
| | aMCI | 120 | 78.2 (7.7)[a,b] | 11.0 (4.4)[a] | 32% | 26.6 (1.4) | | | |
| | AD | 126 | 78.9 (5.5) | 11.1 (3.8) | 30% | 20.2 (3.6) | | | |
| Chen et al., 2016 | NC | 25 | 70.68 (5.45) | 13.68 (2.87) | 60% | n.r. | Winblad et al., 2004 | Stroop Test | **Stroop Interference effect**<br>MCI *equal to* NC |
| | MCI | 22 | 73.77 (7.7) | 12.50 (2.92) | 55% | n.r. | | | |
| Duong et al., 2006 | NC | 60 | 74.38 (5.74) | 11.65 (3.09) | n.r. | 29.12 (0.97) | Adapted from Petersen et al., 2001 | Stroop Test<br><br>Stroop-Picture Naming Test | **MMSE**<br>AD *lower than* MCI *lower than* NC<br>**Stroop test**<br>**Dot baseline (color-word – dot)**<br>AD *higher than* MCI, NC<br>MCI *equal to* NC<br>**Word baseline (color-word – word)**<br>AD *higher than* MCI, NC<br>MCI *equal to* NC<br>**Stroop-Picture Naming Test**<br>**RTs**<br>**(facilitation score, inhibition different, inhibition similar)**<br>AD *equal to* MCI *equal to* NC<br>**Accuracy**<br>**Facilitation score**<br>AD *equal to* MCI *equal to* NC<br>**Inhibition different (incongruent/different-neutral)**<br>NC *lower than* MCI, AD<br>MCI *equal to* AD<br>**Inhibition similar (incongruent/similar-neutral)**<br>MCI *higher than* NC<br>MCI *lower than* AD |
| | MCI | 61 | 74.68 (6.48) | 11.03 (3.69) | n.r. | 27.20 (2.25) | | | |
| | AD | 39 | 73.62 (8.94) | 10.41 (3.53) | n.r. | 22.08 (3.76) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| H Dodge et al., 2015 | NC | 27 | 78.9 (5.5) | 16.6 (2.4) | 86% | 28.7 (1.3) | Dodge et al., 2015 | Stroop Test | **MMSE**<br>MCI *lower than* NC<br>**Stroop**<br>**(executive function/inhibition)**<br>MCI *equal to* NC |
| | MCI | 14 | 83.4 (8.8) | 14 (2.6)[a] | 63% | 26.9 (2.1) | | | |
| Johns et al., 2012 | NC | 34 | 71.8 (5.0) | 14.4 (3.2) | 59% | 28.9 (1.1) | Petersen et al., 2009; Winblad et al., 2004 | Stroop, Victoria version | **MMSE**<br>MCI *lower than* NC<br>**Interference errors**<br>MCI *higher than* NC<br>**Interference RT**<br>MCi *equal to* NC |
| | MCI | 40 | 72.4 (8.6) | 13.1 (3.1) | 55% | 28.1 (1.4) | | | |
| Kramer et al., 2006 | NC | 35 | 73.0 (5.3) | 16.6 (2.8) | n.r. | 29.5 (0.8) | Petersen et al., 1999 | Stroop | **MMSE**<br>aMCI *lower than* NC<br>AD *lower than* MCI<br>**Stroop**<br>**(interference condition**)<br>aMCI *lower than* NC<br>AD *lower than* MCI |
| | aMCI | 22 | 75.0 (6.1) | 16.5 (3.2) | n.r. | 28.5 (1.5) | | | |
| | AD | 33 | 73.4 (9.2) | 15.7 (3.3) | n.r. | 25.2 (1.3) | | | |
| Li et al., 2009 | NC | 9 | 65.2 (7.2) | 7.1 (4.6) | 56% | 28.8 (0.9) | Petersen et al. 1999 | Stroop Color Word Test | **Stroop (Accuracy)**<br>AD*lower than* MCI<br>MCI *lower than* NC<br>**Stroop (RTs)**<br>AD *higher than* MCI<br>MCI *higher than* NC |
| | MCI | 9 | 63.4 (4.6) | 7.2 (3.1) | 44% | 26.4 (4.2) | | | |
| | AD | 10 | 65.8 (6.1) | 6.8 (2.7) | 50% | 16.7 (2.6) | | | |
| Li et al., 2013 | NC | 860 | 64.1 (6.5) | 11.6 (2.9) | 64% | 28.2 (1.5) | Petersen et al., 2005 | Stroop color-word test (Guo et al., 2005) | **MMSE**<br>NC *higher than* MCI<br>sdaMCI *higher than* mdaMCI<br>mdaMCI *lower than* naMCI<br>**Stroop-time**<br>NC *lower than* MCI<br>sdaMCI *lower than* mdaMCI<br>sdaMCI *lower than* naMCI<br>**Stroop-number**<br>NC *equal to* sdaMCI *higher than* mdaMCI, naMCI |
| | sdaMCI | 65 | n.r. | n.r. | 58% | 26.97 (1.63) | | | |
| | mdaMCI | 38 | n.r. | n.r. | 55% | 26.29 (1.25) | | | |
| | naMCI | 57 | n.r. | n.r. | 70& | 26.91 (1.76) | | | |
| Lopez et al., 2006 | NC | 374 | 79.5 (3.7) | n.a. | 62% | n.r. | Lopez et al., 2003 | Stroop Test | **Stroop Interference**<br>mdMCI *higher than* NC<br>aMCI *equal to* NC |
| | aMCI | 10 | 79.9 (3.4) | n.a. | 40% | n.r. | | | |
| | mdMCI | 28 | 79.7 (5.7) | n.a. | 54% | n.r. | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Martin et al., 2016 | NC | 142 | 70.97 (8.43) | 9.48 (4.87) | 56% | 28.1 (1.82) | Winblad et al., 2004<br>Petersen, 2003 | Stroop A, B, C | **MMSE**<br>aMCI *lower than* NC<br>**Stroop A, B, C**<br>aMCI *lower than* NC |
| | aMCI | 81 | 71.51 (7.14) | 8.20 (4.16)[a] | 52% | 26.51 (2.51) | | | |
| Nordlund et al., 2005 | NC | 35 | 67 (5.5) | n.r. | n.r. | 29.3 (1.1) | Clinical diagnosi of MCI | Stroop Test, Victoria Version | **MMSE**<br>MCI *lower than* NC<br>**Stroop**<br>MCI *higher than* NC |
| | MCI | 112 | 64 (8.2) | n.r. | n.r. | 28.5 (1.5) | | | |
| Nordlund et al., 2007 | NC | 60 | 66.5 (6.2) | 11.3 (2.6) | 53% | 29.3 (1.1) | Winblad et al., 2004 | Stroop, Victoria version | **MMSE**<br>NC *higher than* MCI<br>**Stroop**<br>MCI-vas, MCI-nov *higher than* NC<br>MCI-vas *equal to* MCI-nov |
| | MCI-vas | 60 | 67.0 7.3 | 11.2 (3.2) | 63% | 28.2 (1.8) | | | |
| | MCI-nov | 60 | 66.4 6.8 | 11.6 (3.7) | 53% | 28.4 (1.3) | | | |
| Nyström et al., 2015 | NC | 40 | 66.7 (7.5) | 12.7 (3.2) | 60% | 29.5 (0.6) | Clinical diagnosis of MCI | Stroop Test, Victoria Version (Strauss et al., 2006) | **Stroop**<br>NC *lower than* MCI-nov *lower than* MCI-vas |
| | MCI-nov | 38 | 62.4 (8.6)[c] | 12.9 (3.1)[c] | 61% | 28.5 (2.1) | | | |
| | MCI-vas | 32 | 69.2 (8.8) | 10.7 (2.4) | 53% | 27.7 (1.6) | | | |
| Puente et al., 2014 | NC | 26 | 74 (5.5) | 17 (2.3) | 62% | 28.0 (2) | Puente et al., 2014 | m-Stroop Task | **MMSE**<br>MCI *lower than* NC<br>**Stroop (RTs congruent, incongruent, neutral trials)**<br>MCI *equal to* NC<br>**Stroop effect**<br>MCI *equal to* NC |
| | MCI | 17 | 75 (6.3) | 14.4 (3.4)[a] | 59% | 25.9 (2.4) | | | |
| Ramos Goicoa et al., 2016 | NC | 45 | 65.4 (9.2) | 10.1 (5.3) | 62% | 28.5 (1.3) | Albert et al., 2011<br>Petersen 2004 | Stroop Color-Word Task | **MMSE**<br>NC *higher than* aMCI<br>**Stroop (RTs)**<br>aMCI *equal to* NC<br>**Stroop (accuracy)**<br>aMCI *equal to* NC |
| | aMCI | 39 | 70.7 (9.1)[a] | 9.9 (5.2) | 54% | 25.2 (2.5) | | | |
| Sánchez-Benavides et al., 2014 | NC | 356 | 64.9 (9.3) | 10.4 (5.4) | 60% | 28.7 (1.5) | Sánchez-Benavides et al., 2014 | Stroop Word, Stroop Color, Stroop Color-Word | **MMSE**<br>NC *higher than* MCI *higher than* AD<br>**Stroop**<br>NC *higher than* MCI *higher than* AD |
| | MCI | 79 | 72.8 (6.5)[a] | 8 (4.7)[a] | 57% | 25.7 (2.2) | | | |
| | AD | 100 | 74.4 (7.5) | 7.6 (4.6) | 65% | 20.2 (4.0) | | | |
| Seo et al., 2016 | NC | 180 | 71.94 (4.19) | 9.69 (4.30) | 67% | 27.92 (1.52) | Petersen et al., 1999 | Stroop Test | **MMSE**<br>Pre-MCI *lower than* NC |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-MCI | 77 | 72.64 (4.67) | 9.64 (4.64) | 75% | 27.30 (1.97) | | | **Stroop**<br>Pre-MCI *lower than* NC |
| Traykov et al., 2007 | NC | 20 | 73.3 (7.0) | 12.8 (3.3) | 30% | 29.5 (0.5) | Petersen et al., 1995 | Stroop Color Interference Test | **MMSE**<br>MCI *lower than* NC<br>**Stroop test (interference)**<br>MCI *lower than* NC |
| | MCI | 20 | 73.2 (8.0) | 12.1 (3.1) | 20% | 28.95 (1.1) | | | |
| Van der Meulen et al., 2012 | NC | 15 | 68.1 (7.2) | 14.3 (2.6) | 60% | 29.5 (0.8) | Petersen et al., 2001 | Stroop Test classic version | **MMSE**<br>aMCI *lower than* NC<br>**Stroop**<br>aMCI *equal to* NC |
| | aMCI | 13 | 69.2 (8.2) | 13.0 (2.3) | 69% | 26.7 (2.3) | | | |
| Wang et al., 2012 | NC | 122 | 63.63 (8.05) | 12.52 (3.22) | ≈57% | 28.24 (1.74) | Petersen, 2004 | Stroop Color Word Test | **MMSE**<br>aMCI *lower than* NC<br>naMCI *lower than* NC<br>aMCI *equal to* naMCI<br>**Stroop (accuracy)**<br>aMCI *lower than* NC<br>naMCI *lower than* NC<br>aMCI *equal to* naMCI<br>**Stroop (RT)**<br>aMCI *lower than* NC<br>naMCI *lower than* NC<br>aMCI *equal to* naMCI |
| | aMCI | 133 | 65.51 (8.34)[a] | 12.62 (2.98)[a] | 53% | 27.30 (1.80) | | | |
| | naMCI | 72 | 63.28 (9.35)[a] | 12.01 (2.90)[a] | 56% | 27.49 (1.88) | | | |
| Ye at al., 2012 | NC | 958 | n.r. | n.r. | n.r. | 27.5 (0.1) | Petersen, 2004 | Stroop Color Reading Test | **MMSE**<br>EOaMCI *lower than* NC<br>LOaMCI *lower than* NC<br>EOaMCI *equal to* LOaMCI<br>**Stroop**<br>NC *higher than* EOaMCI *higher than* LOaMCI |
| | EOaMCI | 124 | <65 years | n.r. | 60% | 25.3 (0.3) | | | |
| | LOaMCI | 301 | >65 years | n.r. | 60% | 20.5 (0.2) | | | |
| Ye et al., 2014 | NC | 147 | 67.2 (7.7) | 11.4 (4.9) | 69% | 28.7 (1.4) | Ye et al., 2013 | Stroop Test Word and Colour Reading | **MMSE**<br>NC *higher than* EOaMCI *higher than* LOaMCI<br>**Stroop (accuracy)**<br>EOaMCI *lower than* NC<br>LOaMCI *lower than* NC |
| | EOaMCI | 73 | 68.1 (7.3) | 10.4 (5.6) | 60% | 27.2 (2.8) | | | |
| | LOaMCI | 117 | 67.8 (7.5) | 10.4 (4.8) | 67% | 26.0 (2.6) | | | |
| Zhang et al., 2007 | NC | 32 | 73.5 (8.5) | 12.1 (3.5) | n.r. | 28.7 (1.8) | Adapted from Petersen et al., 1999 | Stroop Color Word Test<br><br>Stroop version negative priming | **MMSE**<br>MCI *lower than* NC<br>**Stroop effect**<br>MCI *equal to* NC<br>**Word-color naming** |
| | MCI | 32 | 73.7 (8.2) | 10.7 (2.9) | n.r. | 27.4 (2.0) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **Stroop effect**<br>MCI *equal to* NC<br>**Negative priming**<br>MCI *equal to* NC |
| Zheng et al., 2012 | NC | 36 | 67.4 (5.0) | 11.1 (3.3) | 59% | 29.5 (0.7) | Petersen, 2004 | Modified Stroop Task | **MMSE**<br>aMCI *lower than* NC<br>**Stroop**<br>aMCI *equal to* NC |
| | aMCI | 34 | 67.9 (6.7) | 10.0 (2.9) | 50% | 28.3 (1.5) | | | |

Notes: MCI: Mild Cognitive Impairment; MMSE: Mini-Mental State Examination ; SD: standard deviation; NC: normal controls; mAD: mild Alzheimer's Disease; RTs: reaction times; AD: Alzheimer's disease; N.R.: not reported; WCST: Wisconsin Card Sorting Test; aMCI: amnesic MCI; mdMCI: multiple domain MCI; N.A.: not applicable; MCI-vas: MCI vascular; MCI-nov: MCI no vascular; sdaMCI: single domain aMCI; EAD: early AD; EOaMCI: Early onset aMCI; LOaMCI: late onset aMCI; naMCI: non amnesic MCI. [a] Significant difference between MCI and normal control ($p<.05$); [b] Significant difference between MCI and AD ($p<.05$); [c] Significant difference between MCI groups ($p<.05$).

**Figure 1**. Classification of Mild Cognitive Impairment (adapted from Petersen et al., 2004).

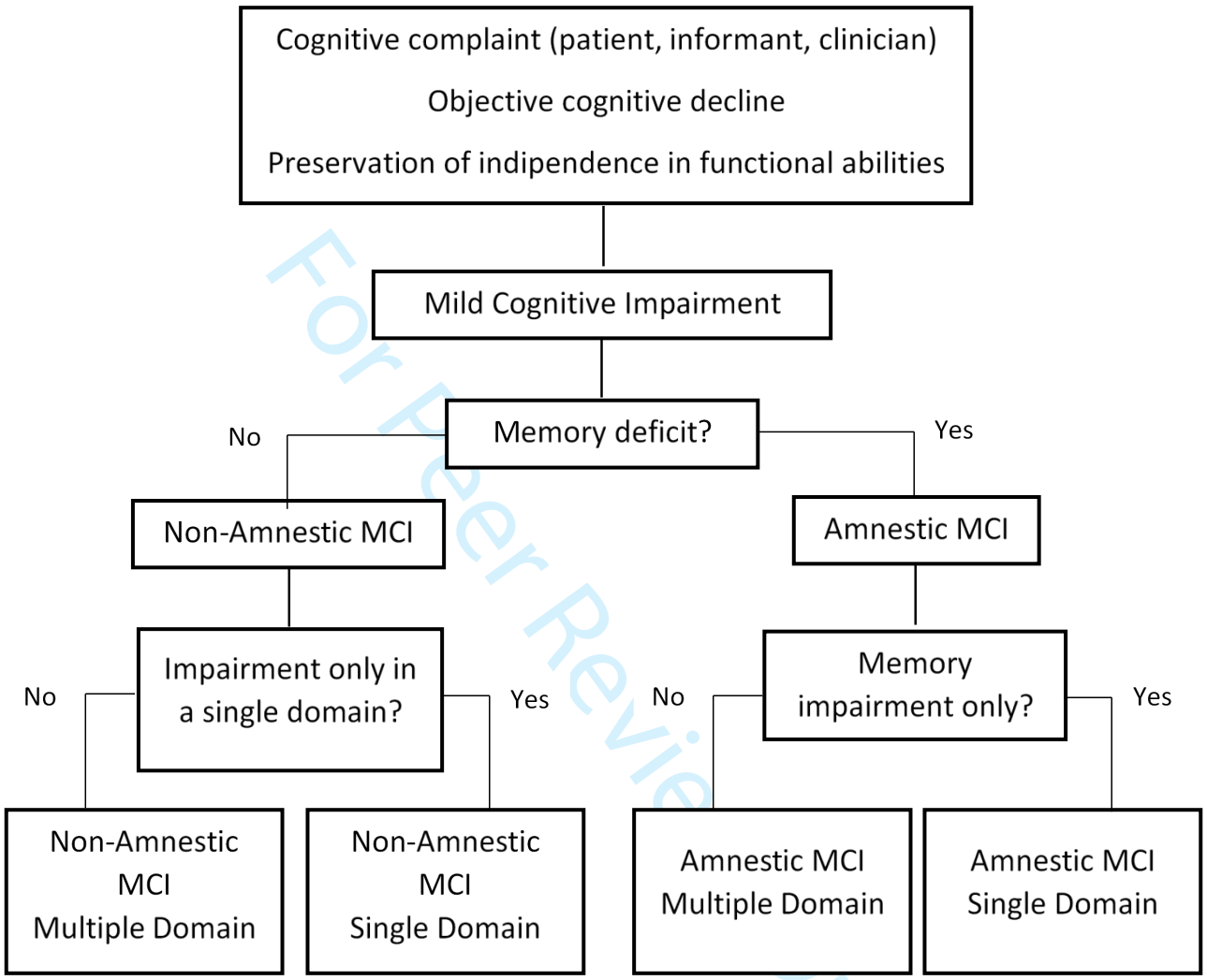

**Figure 2.** Selection of the studies included in the review.