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Social Cognition in Normal Aging, Subjective Cognitive Decline and Mild Cognitive Impairment: A Systematic Review and Meta-Analysis

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I. List of abbreviations

AAN	American Academy of Neurology
AD	Alzheimer's disease
aMCI	amnestic Mild Cognitive Impairment
ATN – scheme	amyloid/tau/neurodegeneration – scheme
CI	Confidence Interval
CSF	Cerebrospinal fluid
DRS	Dementia Rating Scale
FER	Facial Emotion Recognition
IWG	International Working Group
MCI	Mild Cognitive Impairment
MMSE	Mini-Mental-Status-Examination
MoCA	Montreal Cognitive Assessment
non-aMCI	non-amnestic Mild Cognitive Impairment
RMET	Reading the Mind in the Eyes Test
SCD	Subjective Cognitive Decline
SDM	Social Decision Making
SLUMS	Saint Louis University Mental State Examination
SMD	Standard Mean Difference
ToM	Theory of Mind
VPT	Visual Perspective Taking
WHO	World Health Organization

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1. Introduction

Humans are social beings that live in communities and depend on interacting with others. An integral part of human interaction is the ability to perceive, understand and react towards our social environment. It is the result of a number of conscious and subconscious processes that occur simultaneously throughout our daily life (Kemp et al., 2012). Social cognition is an umbrella term that is defined as the ability to interpret and predict other people's behavior with regards to thoughts, intentions, desires and beliefs, as well as to interact in intimate relationships and complex social environments and to emphasize with other's mental states (Baron-Cohen et al., 2000). Here, a variety of socio-cognitive processes have been described that are relevant for human social interactions, including facial emotion recognition (FER), social decision making (SDM), visual perspective taking (VPT) and theory of mind (ToM). Intact social cognition is associated with improved quality of life, emotional well-being and social functioning throughout the entire lifespan (Bodden et al., 2010; Bora et al., 2006; Fulford et al., 2014; Slaughter et al., 2015; Yogarajah et al., 2019). In contrast, impairment in social cognition is associated with poor communication skills, reduced social competence, social isolation and loneliness, which has been observed in people suffering from neurodevelopmental, neuropsychiatric and neurodegenerative disorders (Feldman et al., 1991; Holwerda et al., 2014; Layden et al., 2017). As of 2019, 33.6% of the European population was older than 55 years of age, this number is projected to increase to 49.6% by 2050 (WHO). An extensive body of research has demonstrated a decline in cognitive functions among the elderly population, as aging is the most important risk factor for cognitive decline (Chehrehnegar et al., 2020). In light of the demographic change and the known development in cognitive functions, it is necessary to determine whether changes in social cognition also occur with advancing age (Murman, 2015). Along with the increased percentage of older people in populations worldwide, the prevalence of neurodegenerative diseases, such as dementia, is projected to rise as well (Irwin et al., 2018). Studies have shown that people suffering from Alzheimer's disease (AD), the most common form of dementia, have impaired cognition and social cognition, resulting in a decrease of life satisfaction and high demand for special care (Bediou et al., 2009; Bertrand et al., 2016; Verdon et al., 2007). AD imposes a strain on the public health as caring for those affected requires the utility of financial and labor resources (Alzheimer's disease facts and figures, 2020). Therefore, substantial effort has been devoted to identifying functional deficits in preclinical stages of AD and other types of dementias, in order to develop preventive strategies. Subjective cognitive decline (SCD) and mild cognitive impairment (MCI) are conditions characterized by subjective/self-perceived (SCD) or objective (MCI) cognitive deficits to varying degrees and an increased risk for developing dementia, AD, in particular.

A sizeable number of studies has been carried out in order to investigate social cognition in healthy aging, due to conflicting data surrounding this topic. Several systematic reviews and meta-analyses concluded that different aspects of social cognition can be impaired even in healthy older people (Henry et al., 2013; Kemp et al., 2012; Ruffman et al., 2008). However, a substantial amount of studies has

emerged following the most recent analysis, it is therefore reasonable to perform an updated review that includes more current findings. Active research is also being conducted in the field of social cognition with particular interest in SCD and MCI. As scientific research in SCD is sprouting, it is yet to be determined whether social cognition is compromised in people affected by SCD. Additionally, several meta-analyses revealed a significant decline in ToM and emotion recognition in people affected by MCI (Bora et al., 2017; McCade et al., 2011). The aim of this thesis is to shed light on the socio-cognitive changes in healthy and pathological aging, i.e., SCD and MCI, in an attempt to lay a foundation for the development of preventive and treatment measures with the goal of providing a better perspective for people affected by impairment in social cognition. Therefore, a systematic review and meta-analysis was conducted investigating socio-cognitive abilities in healthy young and old adults, as well as in adults with SCD and MCI to provide a comprehensive overview of the potential progression of socio-cognitive impairment.

In the following pages, a brief overview of the most relevant social cognitive constructs will be provided, including the definition, development, assessment, and neurological findings. The introduction will close with the research questions and a brief methodological overview of the present work. It will be then supplemented by the most recent data regarding cognitive changes in healthy aging, as well as a presentation of the disorders, SCD and MCI. Further, the methodology and results of the meta-analyses, including the graphical depiction of the findings, will be presented and explained. Finally, the discussion will critically scrutinize the findings and provide explanations based on recent scientific evidence, as well as highlight the strengths and weaknesses of this thesis. A conclusion will provide a summary and outlook for future research.

1.1. Social cognition: Theory of Mind

Theory of Mind is one of the key constructs of social cognition. It describes the ability to attribute mental states such as emotions, thoughts, beliefs and intentions to others and oneself and make inferences about these (Baron-Cohen, 2000). In social environments, human beings are constantly confronted with the mental states of others. ToM enables us to anticipate other people's behavior and reflect on it. Premack and Woodruff coined the term "Theory of Mind" in 1978 during their research on metacognition in chimpanzees and explained that "an individual has theory of mind if he imputes mental states to himself and others" (Premack et al., 1978). Over the past decades, other terms were used interchangeably with ToM, such as "mentalizing". Mentalizing, however, refers solely to the "reflection of affective mental states", whereas ToM includes affective and epistemic states, such as beliefs and intentions (Wyl, 2014). Generally, we discriminate between two types of ToM: the affective component, which involves attribution of emotional mental states such as feelings and the cognitive component, which refers to attribution of cognitive states such as beliefs, intentions and desires (Shamay-Tsoory et al., 2010). Research has shown that separate neural correlates are involved in processing of cognitive and affective

ToM, showing that these two subtypes function independently from one another (Ruitenberg et al., 2020; Sebastian et al., 2012). Apart from differentiating between affective and cognitive ToM, first and second order false-belief reasoning can be distinguished. The false-belief reasoning is based on the notion that a subject's belief and thoughts may differ from reality. A first order false-belief task assesses a subject's ability to consider another subject's perspective, whereas the second order false-belief task assesses the ability of a subject to attribute a mental state to another subject who in turn is attributing another mental state to someone else (Wimmer et al., 1983). There is a number of tasks that enables us to assess the different aspects of ToM, affective and cognitive, a selection of these can be found in the Appendix – Supplementary Tables 1 and 2.

ToM precursor skills develop in infancy and the most notable change in the emergence of ToM occurs at around 18-24 months, where children grasp the concept of pretend play (Leslie, 1987). Apart from that, Repacholi and Gopnik found out that at 18 months, children are able to understand that others have preferences that differ from their own (Repacholi et al., 1997). At around two years of age, children predict others behavior in terms of "desires", ascribing predicted emotions rather than projecting their own (Wellman et al., 1990). At the age of three to four, children develop the first order false-belief reasoning, displaying an understanding that other people may hold a false belief of an event (Gopnik et al., 1988; Wimmer et al., 1983). The second order false-belief reasoning manifests itself at the age of six to seven years, children learn that others are able to infer mental states of someone else (Miller, 2009; Perner et al., 1985). Between the ages of nine to eleven, children develop an understanding of complex mental states such as faux-pas, irony and sarcasm (Baron-Cohen et al., 1999; Glenwright et al., 2010).

It becomes evident that ToM is a multidimensional entity and involves many cognitive processes, such as language, memory, vision and so forth. Due to its complex nature, it is still not possible to point out the exact neuronal networks that are activated in association with ToM and this topic therefore still is subject of research. So far, there has been an agreement on the presence of a core network that is involved in ToM processing; areas involved are the median prefrontal cingulum and the temporo-parietal junction (Frith et al., 2006; Gallagher et al., 2003; Schurz et al., 2014). Further, functional imaging studies found task-related activation of other brain areas such as the precuneus, inferior frontal gyri and the temporal lobes (Schurz et al., 2014).

1.2. Social cognition: Facial Emotion Recognition

Facial emotion recognition is a fundamental part of social interaction. It plays a key role in non-verbal communication, next to emotional prosody and body language (Lambrecht et al., 2012). Faces carry information about a person's mental state, therefore the ability to recognize, infer and react upon an emotional state appropriately, is a crucial skill to establish and maintain social competence (Ekman, 1997; Horstmann, 2003). Failure to interpret a counterparts' emotional state correctly may have a negative impact on social skills and relationships (Greve et al., 1994). Consequently, this leads to a

reduced social acceptance and is associated with reduced life satisfaction (Ciarrochi et al., 2000). Studies have shown that infants already are able to categorize certain emotions, but the ability to correctly recognize them develops throughout childhood and adolescence (Kujawa et al., 2014; Leppanen et al., 2006). Extensive research has been conducted on the subject of universality of emotions. Charles Darwin's seminal work laid the foundations for this field of research as he postulated that humans express some emotions in a similar manner regardless of their cultural background (Darwin, 1872). While to this day opponents of this theory exist, the universality theory has found acceptance in the scientific world and through a series of studies conducted by Paul Ekman, amongst others, six basic emotions could be distinguished: fear, happiness, anger, disgust, surprise and sadness (Ekman et al., 1969). These constitute the most commonly used FER cognition tests available. Supplementary Table 3 summarizes the different modalities that are currently in use for the assessment of FER. Many neural systems participate in the process of FER, including visual and emotional processing areas. Emotional processing areas are thought to be the superior temporal sulcus, fusiform gyri, the amygdala and the frontal lobes, which include the orbitofrontal, medial and prefrontal subdivisions and the cingulate area (McCade et al., 2013a). It should be noted that other brain areas engage in emotion recognition processing but to a lesser degree.

1.3. Social cognition: Social Decision Making

Social decision making involves two main consecutive processes: First, a social inference about a situation or a mental state and second, a choice from multiple alternatives i.e., decision making (Lee et al., 2013; Rilling et al., 2011). A large proportion of research on SDM stems from economics studies. Previously, standard economic decision models, such as the utility theory, anticipated participants to base their decisions strictly on rational thinking with regard to the highest reward, the influence of emotions on people's choices has been largely disregarded (Sanfey et al., 2003). The process of SDM, however, is far more complex: social decisions also depend on choices of others and are additionally formed based on self and other-regarding behavior with consequences for oneself and others (Fehr et al., 2007; Sanfey, 2007). The field of neuroeconomics concentrates on the social and cognitive aspects of SDM using tasks developed for research in economic studies, e.g., Ultimatum Game. Variants of this game have been used in preschool children and shown that children at that age begin to understand fairness and prosociality, while strategic thinking develops at school age (Allgaier et al., 2020). An overview of a selection of these tasks can be seen in Supplementary Table 4. The numerous processes underlying SDM are still not well understood. It is assumed that brain networks involved in decision making and social cognition are the ones processing SDM (Lee et al., 2013). Will and Güroglu summarized the relevant findings from functional imaging studies that support the idea of a collaboration between these neural circuits as follows (Will et al., 2016):

Three distinct neuronal networks interact with one another in SDM: Basic affective network, the ToM network and the cognitive regulatory network (Rilling et al., 2011). The basic affective neuronal network includes the anterior insula, ventral striatum and the amygdala (Haruno et al., 2010; Sanfey et al., 2003; Tabibnia et al., 2008). This network is believed to be involved in processing positive and negative affects (Will et al., 2016). Further, it cooperates with the neuronal circuit responsible for cognition, it is constituted of the dorsal anterior cingulate cortex and areas of the prefrontal cortex, in particular the ventrolateral prefrontal cortex and the dorsolateral prefrontal cortex (Rilling et al., 2011). Both these networks then interact with the brain areas regulating inferences about other people's mental states, which are the bilateral temporo-parietal junction, superior temporal sulci, the ventral and dorsal regions of the medial prefrontal cortex (Frith et al., 2010; Saxe et al., 2004).

1.4. Social cognition: Visual Perspective Taking

Visual perspective taking is the ability to view the world from a perspective other than one's own (Flavell, 1977). It ranges from spatial thinking, such as navigation and spatial problem solving, to understanding other people's minds during a social interaction (Michelon et al., 2006). A prerequisite to solve this task is the presence of spatial and social information (Pearson et al., 2013). Two levels of VPT can be distinguished: Level 1 and Level 2. Level 1 refers to the ability to predict what someone can and cannot see (Michelon et al., 2006; Pearson et al., 2013). This ability develops as early as two years of age (Lempers et al., 1977). Level 2 refers to the ability to understand that two people can see an object differently, this skill develops at around four or five years of age (Gzesh et al., 1985; Michelon et al., 2006). Level 2 perspective taking is more difficult to master as it is more demanding on cognitive resources (Apperly et al., 2009). VPT and ToM are sometimes considered the same construct and although they are very similar, they are not the same (Harwood et al., 2006). In ToM, mental states are attributed, whereas VPT requires a mental rotation to understand another point of view. Also, brain imaging studies looking for overlapping VPT and ToM processing areas did not find any overlap activation in the core ToM network but only in less important regions (Arora et al., 2017). Research on the neuronal processes and involved brain regions is still sparse, a recent meta-analysis revealed a number of brain areas that participate in VPT, these are the following: the dorsolateral prefrontal cortex, temporo-parietal junction, posterior middle frontal gyrus, inferior frontal gyrus, posterior dorsal precuneus, intraparietal sulcus, the superior cerebellum and the inferior posterior temporal sulcus (Bukowski, 2018). Supplementary Table 5 provides a more detailed overview of the tasks.

1.5. Cognitive changes in normal aging

Aging is associated with emerging frailty and behavioral changes (Fried et al., 2004). While physical changes are the most apparent, cognitive changes, whether physiological or pathological, require

attention as well. During the aging process, a number of cognitive changes takes place that differ in time of onset and intensity. Cognitive abilities can be divided into six broad domains: processing speed, memory, language, visuospatial abilities, executive functions and attention, many of which decline during the aging process (Harada et al., 2013). Further, research suggests that some cognitive domains are related to social cognition (Wade et al., 2018). This relation has been the focus of many investigations in healthy people as well as people who are affected by various diseases and disorders.

While the discussion is still not settled, a growing body of evidence supports the notion of a link between social cognition and cognitive abilities. In particular, executive functions seem to be associated with different domains of social cognition. Executive functions constitute a set of higher order cognitive skills that regulate our goal-directed behavior. They include a variety of processes such as decision-making, inhibition control, working memory, problem-solving and many more (Lezak, 2012). An interrelation between executive functions and ToM has been found in several studies including children and adults of different ages (Bull et al., 2008; Charlton et al., 2009; Perner et al., 1999). Apart from that, other domains of social cognition, such as FER and VPT are believed to be supported by mechanisms underlying executive functions and other cognitive processes such as fluid cognitive abilities, processing speed and memory (Fizke et al., 2014; Frick et al., 2017; Horning et al., 2012; Qureshi et al., 2018; Virtanen et al., 2017).

Brain imaging studies provide support for the relation between social cognition and cognitive processes, however, it is yet to be determined as to how these mechanisms work (Wade et al., 2018). Considering these findings and the fact that cognitive abilities decline with advancing age, it becomes natural to ask the question whether social cognition is also affected similarly later in life. Likewise, it is not clear what effects SCD and MCI have on the different domains of social cognition. Studies are available that also point towards a decline in different cognitive functions, such as executive functions and memory, as well as towards an impairment in social cognition itself (Bora et al., 2017; Guarino et al., 2020; Valech et al., 2018). In the following chapters the conditions SCD and MCI will be introduced based on current research data that is available.

1.6. Subjective Cognitive Decline

The term ‘Subjective Cognitive Decline’ describes a self-reported deterioration in cognitive capacities while maintaining average scores on standard cognitive tests adjusted for age, sex and education (Jessen et al., 2020). It was first coined in 2014 by the Subjective Cognitive Decline Initiative (SCD-I) but has been subject of research since the 1980s (Jessen et al., 2014). As of now, it is considered an early manifestation of dementia, in particular AD (Studart et al., 2016). Taking into account the cognitive state, individuals with SCD are less impaired than people with MCI or AD and can only be distinguished from cognitively healthy individuals by the presence of subjective complaints. According to a recent study that combined data from 16 cohorts across the globe, the cumulative prevalence in individuals

older than 60 years of age is estimated to be approximately 25% (Röhr et al., 2020). Prevalence, however, varied largely among studies, presumably due to a lack of standardized assessment and a consentaneous terminology in the pre-SCD-I era. The study also asserted that prevalence is higher in men, lower educated individuals, in economically weak countries, Asians and African black people and more recent studies (Röhr et al., 2020). It is noteworthy that the prevalence is higher in individuals with SCD in research settings than in community-based cohorts (Slot et al., 2019). Based on the underlying cause, SCD can take three different courses. Reversible SCD can be the result of depression, sleep-disturbances or a side-effect of medication, that will go into full remission once the cause is treated. Stable, non-reversible SCD will not remit nor will it progress to objective cognitive impairment, a possible cause is the normal aging process. Lastly, progressive SCD will eventually develop into dementia, the cause of it is neurodegenerative disease (Jessen et al., 2020). Annual progression rates from SCD to dementia and MCI are estimated to be 2.3% and 6.6%, respectively (Mitchell et al., 2014). Diagnosis of SCD is largely based on the subjective feeling of altered cognition and subsequent consultation of a physician. As cognitive decline is not objective and affected individuals are otherwise healthy, no neuropsychological test nor cutoff score exist to distinguish a healthy person from SCD clinically. In order to overcome this problem, a cutoff for the standard deviation has been proposed, where, depending on the number of domains being examined, scores of >1.0->1.5 below the normal values indicate presence of SCD (Molinuevo et al., 2017). A recent multicenter study reported an overall reduced SD of 0.3, whereas MCI and AD-dementia participants had scores of -2.37 and -5.24, in comparison with healthy participants, respectively (Wolfsgruber et al., 2020).

A number of tools, mainly in form of questionnaires, exist as a means to estimate the severity of cognitive decline, but again, there is no cut-off that allows differentiation between a healthy and a patient experiencing SCD. According to a South Korean nationwide study published in 2020, which included over half a million participants, individuals who scored worse on a screening questionnaire that determined the extent of subjective cognitive impairment, had an increased risk of progression to dementia (Lee et al., 2020).

To determine whether SCD and AD are related, great emphasis has been put on biomarker research and indeed, several studies were able to establish a connection. A recent study used the ATN-scheme[1], which is normally used in Alzheimer's research, and successfully detected biomarker profiles that were at higher risk of progression to dementia, this again, supports the notion of SCD being a preclinical form of dementia (Ebenau et al., 2020). Another study found reduced volumes of specific brain regions associated with AD in individuals with primarily subjective memory complaints in comparison with individuals without any memory complaints (Dauphinot et al., 2020). Abnormal biomarker values in cerebrospinal fluid (CSF) were present in individuals with SCD within a German cohort, the study also observed a progression rate of 12.2% to AD and 22% to MCI within 3 years (Wolfsgruber et al., 2017).

1 The ATN-scheme is a biomarker-based classification (amyloid, tau and neurodegeneration), which will be described in more detail in the section 'Mild Cognitive Impairment'.

However, biomarker testing in individuals with SCD is not common practice yet and is limited to research only.

Ideally, causal therapy is the treatment of choice in cases where the etiology is known e.g., therapy of depression, change of medication, etc. In cases where the underlying cause is unknown, treatment poses a great challenge, especially when it comes to pharmacologic intervention. Alternatively, cognitive interventions have been investigated in a number of studies, however, their effect has been found to be small (Smart et al., 2017). There are currently not enough studies available that investigated lifestyle changes in individuals with SCD to draw conclusions on their effectiveness.

To date, only few studies have investigated social cognition in individuals diagnosed with SCD, mainly focusing on ToM and FER and resulting in contradictory findings (Pietschnig et al., 2016; Yildirim et al., 2020b). One study did not find any differences between healthy individuals and subjects affected by SCD, while the other detected a slightly worse performance in the SCD group. This could mean that SCD is impaired in some domains of social cognition but not others. However, taking together the low amount of research and the results at hand, this demonstrates that social cognition in SCD is an uncharted territory in the scientific world and more research is required to answer questions regarding socio-cognitive impairment, its intensity and domains affected.

1.7. Mild Cognitive Impairment

Mild Cognitive Impairment refers to a syndrome characterized by loss of cognitive capacities greater than expected for an individual's age and education level without causing any significant impediment to their every day's life and not meeting the criteria for dementia (Gauthier et al., 2006). Initially, the main focus of MCI diagnosis was the chief complaint of memory loss (Petersen et al., 1999). Over time, other cognitive deficits were recognized and added to MCI, so the definition nowadays shows the heterogeneity and complexity of this condition.

Today, MCI is classified according to memory deficit involvement (amnestic or non-amnestic subtype) and is followed by the number of cognitive domains affected (single or multiple domains) (Petersen et al., 2005). Amnestic MCI (aMCI) refers to sole impairment in memory retrieval and is also the most common type, which occurs twice as often as non-amnestic MCI (Petersen et al., 2001; Sanford, 2017). In non-amnestic MCI (non-aMCI) memory is spared but other cognitive domains are affected (Petersen et al., 2008). Those domains that potentially could be affected are language, learning, social functioning, complex attention and executive functioning (Sachdev et al., 2014). Typically, in individuals with aMCI involving multiple domains these are only marginally impaired (Tangalos et al., 2018).

According to the 'Report of the Guideline Development, Dissemination and Implementation Subcommittee of the American Academy of Neurology' (AAN) published in 2018, the prevalence of MCI ranges from 6.7-25.7 % among 60-84-year-old individuals (Petersen et al., 2018). Differences in prevalence can be due to a number of reasons. For example, various definitions are used for MCI in

studies included in the report, further, there is a lack of consensus as to what cut off score to use in neuropsychological testing to diagnose MCI (Pandya et al., 2016). Differences in demographics of studied populations also account for varying results. Many risk factors have been identified so far. Increasing age, male sex, presence of the apolipoprotein E4 allele, family history of cognitive impairment and vascular risk factors increase the risk of MCI development (Caselli et al., 2009; Ng et al., 2016; Petersen et al., 2018)

It is widely accepted that MCI is an intermitted state between cognitive changes in normal aging and different forms of dementia, most commonly AD (Bora et al., 2017). Studies show that amnestic MCI most likely progresses into AD, whereas non-aMCI progresses into other forms of dementia (Ferman et al., 2013; Grundman et al., 2004). According to a meta-analysis from 2018, the incidence for the development of dementia in patients suffering from MCI aging 65 or older was 14.9% after 2 years (Petersen et al., 2018). It is important to mention that MCI is not only caused by neurodegeneration, but it can also develop secondary to extrinsic factors as well as diseases, disorders and deficiencies (Petersen et al., 2018). To exemplify, polypharmacy, the use of several medications, may promote MCI, due to drug interaction (Moore et al., 1999). Moreover, anticholinergic drugs have shown to have a negative effect on cognitive functions in older adults (Campbell et al., 2009).

Considering MCI on a scale of cognitive function, with normal cognition on one end and dementia on the other, individuals suffering from MCI lie somewhere in between and may remain in that position or move up and down the scale, which means MCI does not always progress towards dementia but can also revert to normal cognition (Sanford, 2017). The simplest way to illustrate reversion is to consider medications or vitamin deficiencies, once the medication is changed or a deficiency is replenished, individuals suffering from MCI are expected to regain their cognitive function (Bonetti et al., 2015; Campbell et al., 2009). As etiological factors and development of MCI are still subject to current research, reversion without presence of a known reversible cause is still not well understood. It has been observed that individuals with better performances on cognitive tests or who were diagnosed with non-aMCI or did not have the apolipoprotein E4 allele had greater chances to revert to normal cognition (Koepsell et al., 2012).

Reversion rates differ greatly among studies, ranging from 14.4-38%. It should be stressed that those patients who reverted to normal cognitive function remain at a higher risk of developing MCI again or even progress to dementia (Petersen et al., 2018). Several sets of diagnostic criteria have been developed in order to diagnose MCI, one of the most frequently used in literature were established by Petersen (Fig. 1).

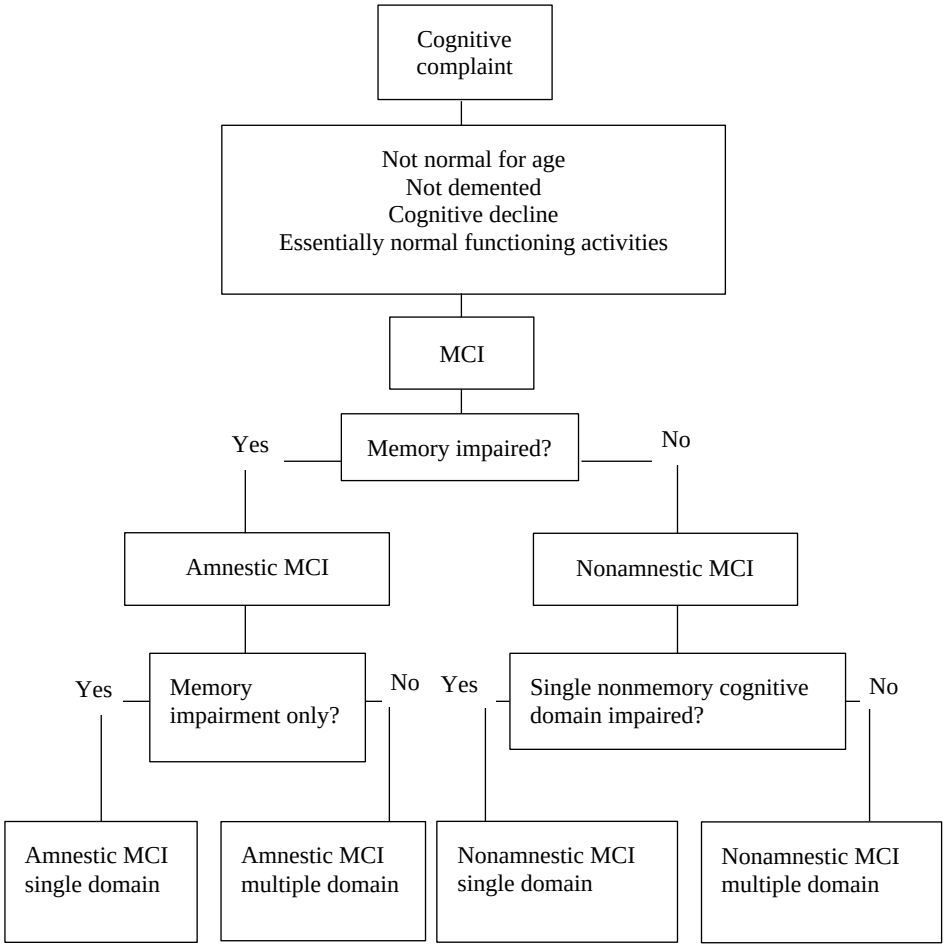

Figure 1. Current diagnostic algorithm for diagnosing and subtyping MCI (Petersen, 2004).

Diagnosis of MCI should be approached in several steps. Often, affected individuals or care givers express concerns regarding cognitive function decline, such as increasing forgetfulness of recent events or difficulties with multitasking. After medical history is obtained and vascular, traumatic or medical causes are excluded, a cognitive screening test should be administered. The wide range of cognitive tests available makes it difficult to choose the appropriate test, especially since there are currently no universal guidelines available for MCI diagnosis. Tests such as the Mini-Mental-State-Examination (MMSE), the Saint Louis University Mental State Examination (SLUMS), Dementia Rating Scale (DRS) and Montreal Cognitive Assessment (MoCA) have been administered before, however, a meta-analysis concluded that the MoCA with a cutoff point of 24/25 was more accurate in detecting MCI than the MMSE with a cut-off of 27/28 (Ciesielska et al., 2016). Another study has shown that the SLUMS test is also superior to MMSE, however, MMSE still remains the most commonly used cognitive test in MCI (Szcześniak et al., 2016).

The diagnosis of MCI largely relies on clinical presentation, which does not provide information about the possible etiology and therefore limits treatment possibilities. Biomarker-testing on the other hand can be helpful in gaining information about cerebral structural and functional abnormalities, as well as

presence of certain peptides and proteins in the CSF that are associated with dementia, in particular AD. In 2011, the National Institute on Aging and Alzheimer's Association introduced preclinical core diagnostic markers for AD that can also be identified in patients with MCI developing due to Alzheimer's. At that time two biomarkers were suggested, the extracellular deposits of amyloid-beta proteins in the brain or CSF (A) as well as the presence of neurodegeneration (N) (Albert et al., 2011). Based on this classification, a framework for the likelihood of MCI development due to AD was established, it included the core clinical criteria and presence of biomarkers. Further research has led to a revision of the recommendations published in 2011 and introduced a new biomarker-based scheme. Known as the A/T/N- classification, it explores three groups of biomarkers, each containing a CSF and an imaging biomarker in a binary fashion, indicating their presence or absence (Jack et al., 2016). As in the 2011 recommendations, "A" and "N"-marker, stand for amyloid-beta and neurodegeneration, respectively. A marker labelled "T" was added to the scheme and refers to intracellular depositions of tau protein in the brain as well as its detection in cerebrospinal fluid. Testing for biomarkers could play a significant role in early detection of AD as it allows for interventive measures to take place early before disease onset and potentially change the course of the disease.

A recent study compared four different predictive models of dementia development from MCI, the ATN-scheme being one of them. It was shown that amongst all different models, the ATN-scheme had the precisest prognostic performance (van Maurik et al., 2019). Another study has shown that biomarker testing added a prognostic value in a portion of the tested MCI patients, and is therefore a recommended tool (van Maurik et al., 2020).

Next to diagnosis, treatment and prevention of progression to dementia, especially from amnestic MCI to AD, has been the focus of research for many years. Thus far, no pharmacological treatment has proven to be effective, although multiple trials have been conducted. Much hope was set on cholinesterase inhibitors as they are already used in the management of mild to moderate AD, however, the results have not shown any significant improvements in cognition (Cooper et al., 2013). Many other treatment approaches have been targeted, including anti-inflammatory medication, vitamins and supplements, without any promising results. Recent meta-analyses investigated the effects of cognitive training and physical exercise, they concluded that both types of interventions seem to improve cognition in MCI (Nuzum et al., 2020; Sherman et al., 2020).

A growing body of research shows that social cognition is more impaired in patients with MCI compared to healthy older individuals. A recent meta-analysis that investigated ToM and FER in MCI showed that both socio-cognitive domains were significantly impaired among individuals affected by MCI compared to their healthy counterparts (Bora et al., 2017). However, impairment among individual basic emotions was not consistent, meaning that recognition of some emotions remained unaffected by cognitive decline. Because up to the present moment studies investigating SDM and VPT are lacking, it is unknown if those domains are also affected in MCI, which leaves a large research gap in this field.

1.8. The aim of the thesis

Social cognition is an essential component of human interactions, which enables us to negotiate our way around our social environment and ensures social functioning. Therefore, it is not surprising that deficits in social cognition have a negative impact on our emotional well-being and quality of life (Bodden et al., 2010; Bora et al., 2006; Fulford et al., 2014; Slaughter et al., 2015; Yogarajah et al., 2019). Such deficits have been observed among the elderly part of society as well as among people affected by neurodegenerative disorders such as AD and its precursors (Bora et al., 2017; Henry et al., 2009; Kemp et al., 2012; Ruffman et al., 2008).

The objective of this thesis is to combine data of all available studies examining four types of socio-cognitive domains (ToM, FER, VPT and SDM) in healthy young adults, healthy elderly adults, individuals affected by SCD and MCI and perform a qualitative and quantitative analysis in order to explore possible changes in social cognition.

The following research questions will be investigated in this review:

i. Do socio-cognitive abilities, in particular, ToM, FER, SDM and VPT, decline in healthy older individuals and in individuals with SCD and MCI?
ii. If so, how significant are the changes between the individual groups?
iii. Are all domains equally affected or are some domains affected more than others, are some domains left unaffected at all?

2. Methods

Prior to the commencement of the study, a detailed protocol was developed and agreed upon by the review team (M.R., J.B., S.R., A.M., A.F., M.M.). The study has been registered at the PROSPERO database with the registration number: CRD42020191607, the review protocol can be acquired from www.crd.york.ac.uk/PROSPERO/. The current systematic review and meta-analysis conformed to the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009b). The “PRISMA for Abstracts Checklist” and the “PRISMA checklist for systematic reviews” can be found in the Appendix, Supplementary Tables 6 and 7.

2.1. Study design

The foundation of this systematic review and meta-analysis is a systematic selection of published articles that investigated social cognition in healthy young individuals vs. older individuals, healthy older individuals vs. patients diagnosed with MCI and individuals with SCD vs. patients with MCI. The

focused question was: “Does social cognition differ in healthy young and older adults, people with SCD and patients with MCI?”, and it was elaborated using the PICO format. Healthy older individuals, individuals with SCD and patients with MCI were considered the population (P) and compared to younger individuals, patients with MCI and older people, respectively (C). This study did not include any interventional studies, hence only prospective observational studies were included. Several outcomes were considered, which will be discussed in detail below. The primary outcome (O) was ‘Theory of Mind’, secondary outcomes were: ‘Facial Emotion Recognition’, ‘Social Decision Making’ and ‘Visual Perspective Taking’.

2.2. Search and study selection

The search process was initiated through an unsystematic explorative literature search in databases such as Pubmed/MEDLINE and Google Scholar in order to gain an overview over the current body of evidence. This search revealed that substantial literature related to social cognition in healthy and pathological aging was available. This has led to the establishment of a systematic search strategy.
A comprehensive search of electronic databases without time restrictions in the past literature for articles written in English or German was undertaken until the 15th June 2020. The following databases were searched: Pubmed/MEDLINE, Web of Science Core Collection, Cochrane Central Register of Controlled Trials (CENTRAL), PsycINFO & PsycArticles. Below, the search strategy used in Pubmed/MEDLINE is illustrated:

((((((Social Cognition) OR (Theory of Mind)) OR (Emotion Recognition)) OR (Visual perspective taking)) OR (social decision making) AND ((((mild cognitive impairment) OR (subjective cognitive decline)) OR (healthy aging)) OR (healthy older adults)) NOT ((psychosis) OR (schizophrenia) OR (depression) OR (parkinson)).

For a detailed overview of our search strategy for the remaining data bases, see Appendix, Figure 1 to 3. This procedure was supplemented by a manual search of bibliographies found in relevant review articles for further literature. In addition, authors of relevant studies, and study groups that are known to be active in the field of social cognition were contacted for unpublished material or further information on ongoing studies. Also, in cases of missing or unclear data, authors were contacted for clarification. When a response was not received after 14 days or the data was judged to not fitting for the review, the study was excluded.
Owing to the large volume of literature yielded from the extensive search process, a two stage-screening was carried out in accordance with the eligibility criteria, independently by two researchers (J.B. and M.R.) to increase precision by using the Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia) screening and data extraction tool. The first stage comprised

of screening the titles and abstracts. It was followed by the second stage, the screening of the full-text articles. Inclusion or exclusion of individual studies, as well as reasons for exclusions, were documented in Supplementary Table 7. At each stage, any disagreement was resolved by discussion.

2.3. Eligibility criteria

a. Study participants

Three groups of participants were investigated separately (healthy older individuals, individuals with SCD, and individuals with MCI). The first group was comprised of healthy older female and male participants over the age of 50. Participants had to be cognitively healthy, have no history of neurological nor psychiatric disorders and be in good general health.

Young-to-middle aged healthy individuals (aged between 18 and 49 years) served as comparisons for healthy older individuals, they had to be free of any psychiatric or neurological illnesses and be cognitively healthy. In studies presenting data of more than one age group, the average age was calculated, when possible. The second groups comprised of individuals with SCD. Individuals experiencing SCD had to fulfill the SCD-I criteria, as defined by Jessen et al. in 2014, which are currently the only diagnostic criteria available. The third group investigated individuals with MCI. Individuals exhibiting MCI had to be diagnosed conforming to validated neuropsychological criteria (e.g. Petersen, International Working Group (IWG), or others). These also included subtypes of MCI, such as amnestic and non-aMCI and further classified according to the number of domains impaired, affecting one cognitive domain (single domain) or several cognitive domains (multiple domains). Both groups had to be otherwise healthy from the neurological and psychiatric point of view.

b. Types of studies

This review included only prospective observational cohort studies with a research design that compared at least two of our groups of interest. Multi-arm studies containing relevant information on the study question were also considered. Studies needed to provide full study reports. Conference abstracts and studies of lower quality within the hierarchy of scientific evidence, such as case studies, theses and book chapters, were excluded.

c. Outcome measures

Social cognition is constituted of various components, however, we limited our research to ToM, FER, SDM and VPT. Only standardized tests were considered, no self-reports were accepted. Studies had to report on at least one outcome in order to be included.

i. Primary outcome

The primary outcome was 'Theory of Mind', as it is the most frequently investigated socio-cognitive construct (Kemp et al., 2012). As mentioned earlier, ToM can be divided into affective ToM, which means the ability to infer someone's feelings or emotions, and cognitive ToM, which is defined as the ability to infer a person's thoughts, beliefs and intentions (Healey et al., 2018). Many tests exist to assess ToM and an overview of the most common ToM tasks and their characteristics is provided in Supplementary Tables 1 and 2. In order to prevent loss of valuable information, a mixed category was introduced, as several ToM tasks contained both cognitive and affective components without any information regarding their ratio (affective:cognitive) within the same tasks.

ii. Secondary outcomes

We considered 'Facial Emotion Recognition', 'Social Decision Making' and 'Visual Perspective Taking' as secondary outcomes. FER is the ability to infer an emotion from people's facial expressions. There is a number of facial expression databases currently available to test recognition of basic emotions, the variety in databases might underly cultural and ethnical differences (Jack et al., 2012). To test recognition of complex emotions, the Reading the Mind in the Eyes Test (RMET) (Baron-Cohen et al., 2001) is widely used. However, there were no restrictions on specific tests. Hence, all facial expression databases and tests were accepted. Examples and characteristics of the most common FER tasks can be seen in Supplementary Table 3. In order to examine SDM, the ability to make decisions in a social context, many tests were available and were all accepted for this review. Supplementary Table 4 summarizes the most common tasks and their characteristics. All tasks available to test VPT were accepted in this review. As with previous outcomes, Supplementary Table 5 provides an overview over the most common tests and their characteristics.

2.4. Data extraction

For studies that fulfilled the inclusion criteria, a standardized data extraction form was used, and data was collected by two independent reviewers (J.B. and M.R.). When data of individual studies were missing, authors were contacted for additional information and were asked to provide this information within a 14-day time frame. For each individual study we extracted general study information (authors and publication year), sample characteristics (condition, sample size, diagnostic criteria, age, gender ratio, education), cognitive findings (cognitive tasks, social cognition task, characteristics, outcomes, result evaluation) and an overview on the ToM domains that were investigated (affective, cognitive or mixed). Table 1 contains a list and descriptions of the key characteristics relevant for the systematic

review. The information obtained during the data extraction process was summarized in Supplementary Table 8.

Table 1. Description of key characteristics.

Sample total	Sample size might be an indicator for representativeness of a study meaning that studies with more participants often lead to more precise results (Borenstein, 2009).
Diagnostic criteria	Only necessary for the studies including people suffering from SCD and MCI. It is important for between group comparisons and subgroup analysis.
Mean age	Information on the participant's age discloses whether the participants were matched prior to the study and might explain potential differences in their performance.
Gender ratio	Details on gender ratios provides information about potential gender differences and allows a subgroup analysis if necessary.
Education	In order to determine if education is somehow associated with cognitive decline, information about years of education is of interest and provides a basis for subgroup analysis.
Cognitive task	Testing the participants' cognition before study begin is crucial in order to exclude patients who might be cognitively impaired and are likely to perform worse on the social cognition tasks.
Social cognition task	The main focus of the study is social cognition, and it is therefore necessary to have an overview of the tasks performed. This overview aids in pooling of the data during meta-analysis.
Characteristics	Characteristics are related to cognitive tasks and their results e.g., results of the cognitive tasks such as MMSE.
Outcome	A brief summary of the study results related to the social cognition task that was performed.
Result evaluation	Gives additional information on how to evaluate the present result.

2.5. Risk of bias assessment

In order to detect possible bias, the risk of bias assessment was executed by using a modified version of the 'Cochrane Collaboration Tool to Assess the Risk of Bias in Cohort Studies' (Higgins et al., 2011). A modification of the tool was necessary as the original was not applicable to our study design. The adaption was discussed and agreed upon by the review authors. The risk of bias assessment tool used for this review can be found in Supplementary Table 9. Each study was assessed regarding selection bias, measurement of the outcome and missing outcome data. There were eight signaling questions in total. Response options for the signaling questions were the following: Yes, probably yes, no, probably

no, and no information. For the overall risk of bias judgement, we used the "Revised Cochrane risk-of-bias tool for randomized trials (RoB 2)" (Higgins et al., 2020), because the "Tool to Assess the Risk of Bias in Cohort Studies" did not contain any guidelines for the overall evaluation. The RoB 2.0 Tool suggested the following classification:

- Low risk of bias, when all domains were judged to be at low risk of bias.
- Some concerns, when at least one domain was judged to raise some concerns in at least one domain but not to be at high risk of bias in any domain.
- High risk of bias, when the study is judged to be at high risk of bias in at least one domain or to have some concerns for multiple domains.

The answers as well as overall risk assessment were color coded, which can be seen in Supplementary Table 9. The assessment was conducted by three reviewers (J.B., S.R., M.R.) in two stages, independently.

2.6. Meta-analysis: Included outcomes and methodological aspects

Meta-analyses were performed for observative studies providing sufficient data for 'Theory of Mind tasks' as the primary outcome and 'Facial Emotion Recognition' as secondary outcome. Due to an insufficient amount of data, studies reporting on SDM and VPT were not included in the meta-analysis. Data were extracted by one reviewer (J.B.) and checked for accuracy by a second reviewer (M.R.). Separate analyses were conducted for different ToM domains: affective, cognitive and mixed, as well as basic emotions and a total for FER tasks. Subgroup analyses were calculated where deemed necessary.

The software used for the meta-analyses was R, Version 1.3.1073 for Macintosh (R Core Team, 2020), the analyses were carried out using the "meta" package. Data extracted for each study included the mean outcome, the mean standard deviation and the number of participants in the sample and control groups. Both fixed and random effects models were computed in the meta-analyses, however, the latter was prioritised for interpretation. The random effects model (DerSimonian, 1986) in its calculation of the overall effect size, accounts for differences in variances within and in between studies and was therefore the method of choice. In contrast, the fixed effects model accounts for differences within studies only, however, it was used as a reference for the results obtained from the random effects model. Further, weighting of the studies occurred by the inverse variance method where larger studies with more precise results were assigned more weight than smaller studies with less precision (Higgins et al., 2020). The standard mean difference (SMD) was used in order to measure the effect size with 95% confidence intervals (CI). It was interpreted as follows: effects from 0.2 to under 0.5 were considered as small, effects from 0.5 to under 0.8 as moderate, and effects of 0.8 or higher as large (Cohen, 1988). When required, the Hedge's g correction was performed (Hedges et al., 1985). The confidence intervals were calculated using the Jackson method (Jackson, 2013). The significance level was set at alpha = 0.05.

The heterogeneity was examined with I^2 and interpreted as follows: 0% to 40%: low heterogeneity; 30% to 60%: moderate heterogeneity; 50% to 90%: substantial heterogeneity; 75% to 100%: considerable heterogeneity.

Due to the large number of studies, data was not always available in the form required for the analyses and was subject to the following adjustments:

1. When standard errors were given for each group instead of standard deviations, the standard deviation was calculated using the formula SD = SE x √N, as suggested in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2020).
2. In cases where data for more than one age group were present, means and standard deviations were pooled, whenever possible. If it was not possible, it was discussed which group to include in the meta-analysis (Calso et al., 2019; Giovagnoli, 2019; Kessels et al., 2014; Williams et al., 2009).
3. When several tests were conducted in order to test one outcome in a study, only the test method which was more often found in other studies was used in order to decrease heterogeneity (Phillips et al., 2011).
4. When a study contained several experiments using different social cognition tasks and different populations, only the experiment describing the social cognition task, which was more frequently used in the other studies was included in the meta-analysis in order to aim for more homogeneity (Calder et al., 2003).
5. In cases where statistical data was only presented graphically, Digitize Plot to Data V2.2.2 for Windows was used to obtain the necessary means and standard deviations (Smirnov, 2013). It is a tool that allows us, upon uploading an image of the e.g., diagram, and adjusting parameters, to read the required information (Bailey & Henry, 2008; Beadle et al., 2012; Beadle et al., 2015; Calder et al., 2003; Gaudreau et al., 2013; Girardi et al., 2018; Halberstadt et al., 2011; Harle et al., 2012; Henry et al., 2012; Hot et al., 2013; Jarvis et al., 2017; Keightley et al., 2006; Mattan et al., 2017; McKinnon et al., 2007; Phillips et al., 2011; Richard-Mornas et al., 2012; Roalf et al., 2012; Smith et al., 2018).
6. When statistical data was unclear or studies were incomplete, authors of the studies were contacted and asked to provide the data within the following two weeks. Five authors were contacted (Mattan et al., 2017; Poletti et al., 2013; Sarabia-Cobo et al., 2015; Sullivan et al., 2004b; Suzuki et al., 2007) and only two responded (Mattan et al., 2017; Sullivan et al., 2004b). As a consequence, incomplete studies were not included in the meta-analysis.

3. Results

The systematic search yielded 9,481 research papers, of these 1,216 duplicates were excluded and 7,805 studies were excluded after title and abstract screening. One hundred seventeen full articles were assessed for eligibility. After screening the 114 full texts of selected papers, six could not be accessed and 40 were excluded for various reasons, which are presented in Supplementary Table 7. Ultimately, 69 studies met the inclusion criteria. Additionally, three systematic reviews were searched for further studies and 16 studies were found. A manual search produced three more studies. In the end, 86 studies were included in this systematic review and meta-analysis. Out of the 86 papers that included 88 comparisons, 58 studies investigated social cognition in healthy young and healthy older individuals, two compared social cognition in people with SCD and MCI and 28 compared people with MCI and healthy older individuals. Out of these, 47 studies contained enough information to perform a quantitative synthesis i.e., meta-analysis (Fig. 2). The screening was carried out by two review authors (J.B. and M.R.). All studies were published in English. A detailed description of the study characteristics is summarized in Supplementary Table 8.

3.1. Systematic review: Description of included studies

3.1.1. Study design

All included studies were observational studies with a one-time point of measurement. Two studies contained several comparisons relevant for this meta-analysis and therefore appear more than once (Maki et al., 2013; Pietschnig et al., 2016).

3.1.2. Study participants

In total, 8,252 subjects participated in 86 studies and 88 comparisons (see Figure 2 for details). The comparison between younger and older adults included 6,349 individuals, followed by 200 subjects in the comparison between patients with SCD and MCI and lastly, 2,013 subjects were included in the group comparing healthy older adults and individuals with MCI[2]. Out of a total of 6,349 participants in the first comparison group, 3,036 were older individuals. Overall sample sizes ranged from 20 – 1128 (Cook et al., 2007; Holland et al., 2019). A great variety could be observed in the age range of healthy young and older participants, namely 19.00 to 31.83 years (García-Rodríguez et al., 2009; Maylor et al., 2002) and 59.20 to 80.60. (Maylor et al., 2002; Yildirim et al., 2020a), respectively. Only about half of the studies provided information about the average number of years of education.

[2] Two studies, Pietschnig et al. 2016 and Maki et al. 2013, investigated multiple subgroups relevant for this meta-analysis, which resulted in certain subgroups being used for comparison several times, however, the individuals were counted once per each comparison per subgroup.

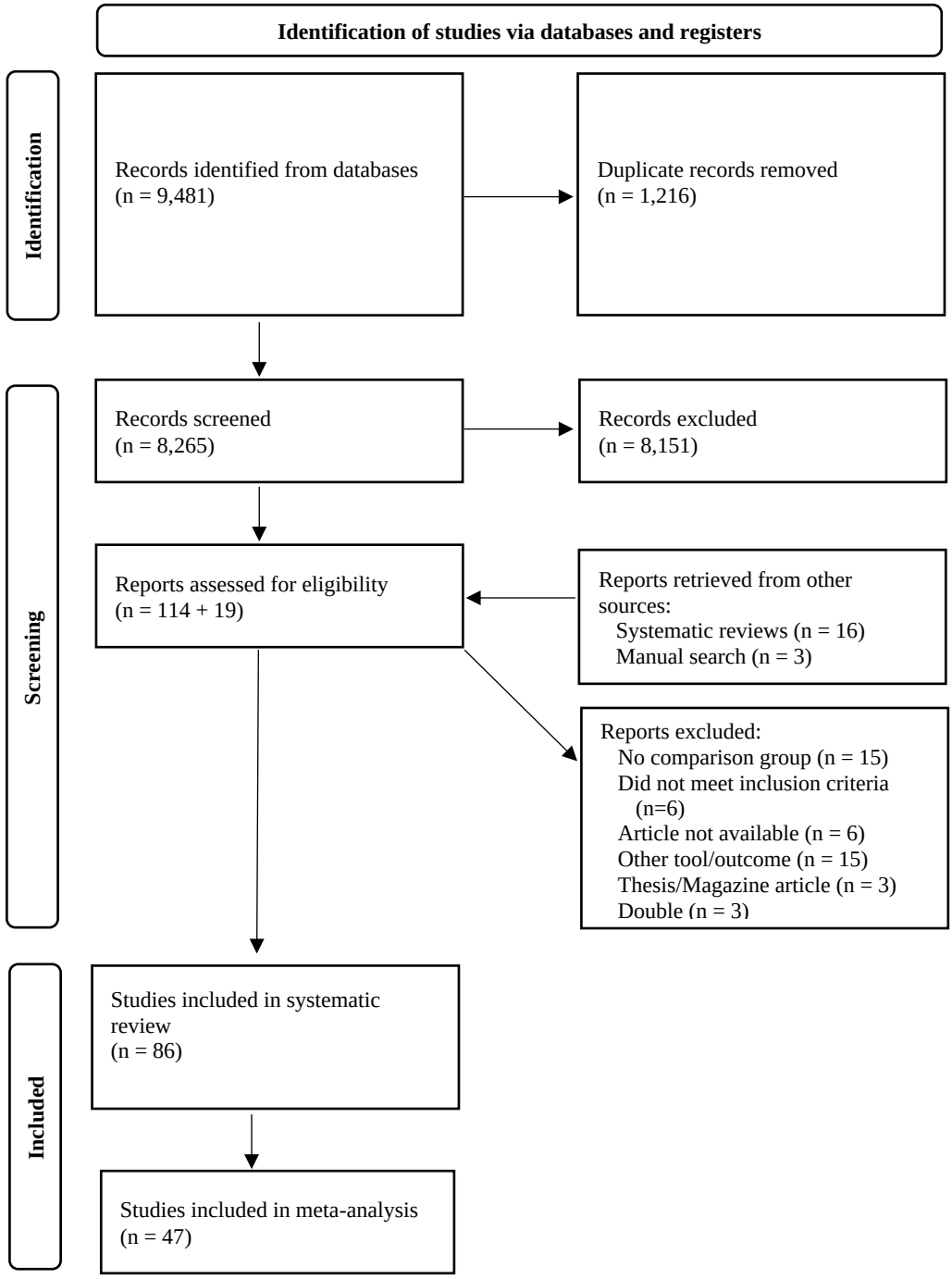

Figure 2. Flow diagram of the study selection progress.

Cognitive tests were performed in 36 out of 58 studies and the majority relied on the MMSE, which was conducted in 28 studies. Eight studies used other tests to measure cognitive functions (Bailey & Henry, 2008; Baksh et al., 2018; Baksh et al., 2020; Calder et al., 2003; Duval et al., 2011; German et al., 2006; Girardi et al., 2018; Mattan et al., 2017), while the remaining ones did not use any tests but relied on a variety of parameters that might be indicative of cognitive health, such as psychological and

neurological assessment by a physician. However, some studies did not disclose such information. Patients with SCD and MCI comprised a group of 200 individuals, with sample sizes of 137 and 63 individuals (Pietschnig et al., 2016; Yildirim et al., 2020b). Both studies used the same diagnostic criteria in order to diagnose their participants, for SCD diagnostic criteria established by Jessen in 2014 were used and MCI patients were diagnosed according to Petersen criteria (Jessen et al., 2014; Petersen et al., 2005). The age range was similar in both groups, ranging from 64.52 to 71.66 years of age (Yildirim et al., 2020b). Both groups used the MMSE to measure cognitive functions. The last comparison group contained 2013 individuals, 1057 of whom were healthy older individuals and 956 were patients diagnosed with MCI. The vast majority was diagnosed in accordance with the Petersen criteria, six were diagnosed according to the IWG criteria (Dodich et al., 2016; Garcia-Casal et al., 2019; Henry et al., 2012; Maki et al., 2013; McCade et al., 2018; Michaelian et al., 2019), one according to DMS 5 (Rossetto et al., 2018) and another according to Albert's criteria (Gaudreau et al., 2015). The sample size varied between 20 and 166 participants (Bediou et al., 2009; Michaelian et al., 2019). The age range among healthy older individuals varied between 62.20 to 77.40 (Henry et al., 2012; Michaelian et al., 2019) and among individuals diagnosed with MCI between 63.40 to 78.70 (Henry et al., 2012; Michaelian et al., 2019). Amongst other tests measuring cognition, MMSE was administered in all studies except two (Gaudreau et al., 2013; Gaudreau et al., 2015). The MMSE scores among healthy old patients ranged from 27.91 to 30.00 (Bediou et al., 2009; Park et al., 2017) and among patients affected by MCI they ranged from 23.08 to 28.21(Rossetto et al., 2018; Sarabia-Cobo et al., 2015).

3.1.3. Outcomes

Different methods of social cognition assessment were applied across the studies. The primary outcome was defined as ToM, and further divided into affective, cognitive and mixed ToM. The division into affective or cognitive ToM was based either on explicit mentioning of domain assessment or on inference of mentioned key words that indicated what type of ToM was assessed in the study e.g., belief-desire reasoning tasks were classified as cognitive ToM, unless indicated otherwise. Further, assessment of cognitive and affective ToM was termed "mixed ToM", if assessment of both domains was either mentioned in the study or could be inferred from the information provided in the study protocol. Other outcomes were FER, SDM and VPT.

In 15 studies focusing on social cognition in healthy young and older individuals, affective and cognitive ToM tests were conducted (Baksh et al., 2020; Bottiroli et al., 2016; Calso et al., 2019; Castelli et al., 2010; Duval et al., 2011; Happe et al., 1998; Jarvis et al., 2017; Keightley et al., 2006; MacPherson et al., 2002; Maki et al., 2013; Maylor et al., 2002; McKinnon et al., 2007; Nazlidou et al., 2015; Rakoczy et al., 2012; Sullivan et al., 2004b). For understanding purposes, it was called "mixed" ToM. Seven studies examined the affective aspects of ToM (Baksh et al., 2018; Baksh et al., 2020; Bottiroli et al., 2016; Duclos et al., 2018; Giovagnoli, 2019; Girardi et al., 2018; Jarvis et al., 2017), and 16 studies

presented data on cognitive ToM, separately (Bailey & Henry, 2008; Baksh et al., 2018; Baksh et al., 2020; Bottiroli et al., 2016; Calso et al., 2019; Castelli et al., 2010; Duval et al., 2011; German et al., 2006; Giovagnoli, 2019; Girardi et al., 2018; Halberstadt et al., 2011; Jarvis et al., 2017; Keightley et al., 2006; Kovalchik et al., 2005; Nazlidou et al., 2015; Phillips et al., 2011; Verdon et al., 2007). Out of these studies, ToM stories were used in eleven studies, which was the most common ToM task in this comparison group. Due to the large diversity in clinical ToM tasks, many other tasks were used. The most common domain of social cognition to be measured was FER, which was examined in 37 studies (Akturk et al., 2020; Bailey & Henry, 2008; Bailey, Henry, et al., 2008; Baksh et al., 2018; Calder et al., 2003; Calso et al., 2019; Castelli et al., 2010; Chaby et al., 2015; Cook et al., 2007; de Souza et al., 2018; Dodich et al., 2014; Duclos et al., 2018; Duval et al., 2011; Garcia-Casal et al., 2019; Halberstadt et al., 2011; Holland et al., 2019; Hot et al., 2013; Hunter et al., 2010; Keightley et al., 2006; Kessels et al., 2014; Kiffel et al., 2005; Lambrecht et al., 2012; MacPherson et al., 2002; Martin et al., 2019; Nazlidou et al., 2015; Phillips et al., 2002; Rakoczy et al., 2012; Richoz et al., 2018; Ruffman et al., 2006; Smith et al., 2018; Sullivan et al., 2004a, 2004b; Suzuki et al., 2007; Werheid et al., 2010; Yildirim et al., 2020a). For that, a variation of the Ekman photograph set (Ekman et al., 1976; Matsumoto et al., 1989) was used in 13 studies, followed by the RMET (Baron-Cohen et al., 2001), which was used in nine studies. SDM was measured in seven studies, the ultimatum game being the most frequently used in four studies (Beadle et al., 2012; Girardi et al., 2018; Harle et al., 2012; Roalf et al., 2012). Next to that, the dictator game was used in two studies (Beadle et al., 2015; Roalf et al., 2012), followed by the gambling task (MacPherson et al., 2002) and the trust game (Sutter et al., 2007) in one study each. Only three studies focused on VPT (Baksh et al., 2020; Martin et al., 2019; Mattan et al., 2017).

Two studies were included in the comparison group between patients with SCD and patients with MCI. In both groups, social cognition was measured by means of FER, one group using the Vienna Emotion Recognition Task (Pietschnig et al., 2016) and the other RMET (Yildirim et al., 2020a). In addition, the faux-pas task was used in the latter study (see Supplementary Table 1 and 2).

A total of 28 studies met the inclusion criteria of the last comparison group, which investigated social cognition in healthy older individuals and patients with MCI. The most often measured outcome was FER, it was examined in 22 studies (Bediou et al., 2009; Fujie et al., 2008; Garcia-Casal et al., 2019; Henry et al., 2012; Henry et al., 2009; McCade et al., 2018; McCade et al., 2013a, 2013b; Michaelian et al., 2019; Park et al., 2017; Pernigo et al., 2015; Pietschnig et al., 2016; Poletti et al., 2013; Richard-Mornas et al., 2012; Rossetto et al., 2018; Sarabia-Cobo et al., 2015; Sheardova et al., 2014; Spoletini et al., 2008; Teng et al., 2007; Varjassyova et al., 2013; Weiss et al., 2008; Yang et al., 2015). A variation of the “Pictures of Facial Affect” by Paul Ekman was used in nine studies (Fujie et al., 2008; Henry et al., 2012; Henry et al., 2009; McCade et al., 2018; McCade et al., 2013a, 2013b; Pernigo et al., 2015; Sheardova et al., 2014; Varjassyova et al., 2013) and the RMET in three (Michaelian et al., 2019; Poletti et al., 2013; Rossetto et al., 2018). In the remaining studies, no other measurement instrument occurred more than twice. Mixed ToM was assessed in seven studies, however, the heterogeneity of the test

methods was large (Baglio et al., 2012; Dodich et al., 2016; Gaudreau et al., 2013; Gaudreau et al., 2015; Maki et al., 2013; Moreau et al., 2015; Rossetto et al., 2018). There were no studies measuring SDM or VPT in this comparison group.

3.2. Risk of bias

The results of the risk of bias assessment are shown in Supplementary Table 9. The majority of the studies did not describe the methodology in sufficient detail, so the overall judgement of 38 included studies was rated 'unclear'. Further, 12 studies provided such limited data that these studies contained a high risk of bias. The 38 remaining studies were judged to be of low risk of bias. The most obscurity was observed in regards to group matching for variables associated with the outcome or adjustment of study results for population characteristics, as in 44 studies it was considered at the least "unclear" if it was carried out. Additionally, some studies did not disclose if cognitive functions were measured before the actual assessment of social cognition. As a consequence, inadequate reporting of information may have biased the results.

3.3. Meta-analysis

3.3.1. Social cognition in healthy young and older individuals

i. Affective Theory of Mind

For the overall evaluation of the effects on affective ToM in healthy young individuals in comparison with healthy older individuals, we included 4 studies in total, resulting in 115 young healthy individuals and 138 healthy old individuals. No studies were excluded. The overall effect size, the SMD, was moderate (SMD = 0.76, 95% CI: 0.26 - 1.26). This was a statistically significant finding (p = 0.0029), showing that healthy young individuals performed better on affective ToM tasks in comparison with healthy old individuals. The heterogeneity (I^2 = 71.3%, 95% CI: 18.1% - 89.9%) was high. Results can be seen in Figure 3.

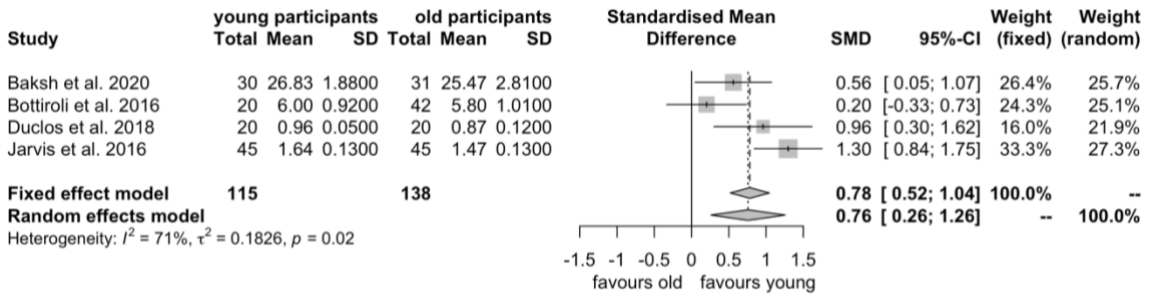

Figure 3. Forest plot of comparison between young and old individuals, outcome = Affective ToM.

ii. Cognitive Theory of Mind

For the overall evaluation of the effects on cognitive ToM in healthy young subjects in comparison with healthy older subjects, we included 11 studies in total, resulting in 327 healthy young subjects and 344 healthy older subjects. No studies were excluded. The overall effect size, the SMD, was 0.78 (95% CI: 0.49 – 1.07), hence, a large effect size. This was a statistically significant finding ($p = 0.0001$), indicating that younger subjects outperformed older subjects at cognitive ToM tasks. The heterogeneity (I^2 = 68.9%, 95% CI: 41.8% - 83.4%) was high. Results can be seen in Figure 4.

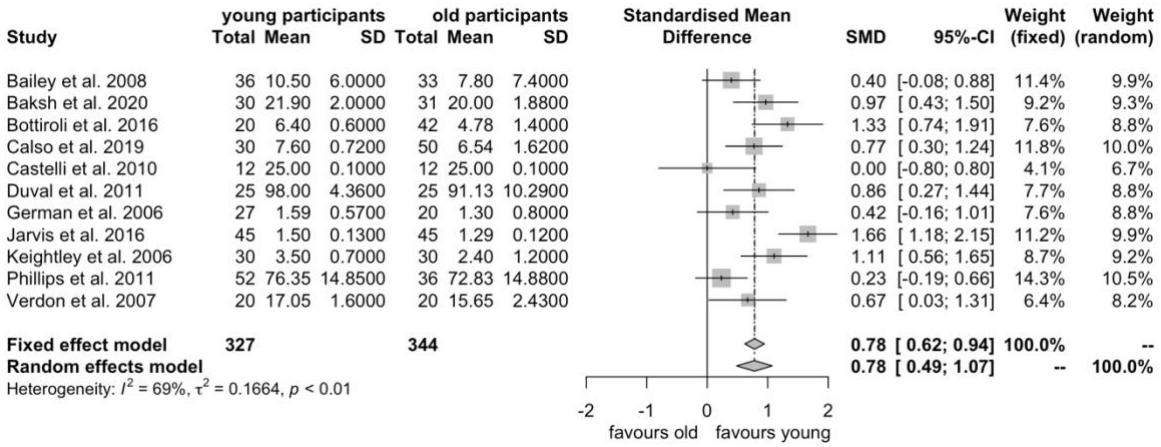

Figure 4. Forest plot of comparison between young and old subjects, outcome = Cognitive ToM.

iii. Mixed Theory of Mind

For the overall evaluation of the effects on mixed ToM (cognitive and affective ToM combined) in healthy young individuals in comparison with healthy older individuals, we included 13 studies in total, resulting in 401 healthy young individuals and 462 healthy older individuals. No studies were excluded. The overall effect size, the SMD, was 0.72 (95% CI: 0.33 – 1.10), hence, a large effect size. This was a statistically significant finding ($p = 0.0002$), indicating that younger individuals outperformed older individuals at cognitive and affective ToM tasks. The heterogeneity (I^2 = 84.9%, 95% CI: 75.7% - 90.6%) was considerable. Results can be seen in Figure 5.

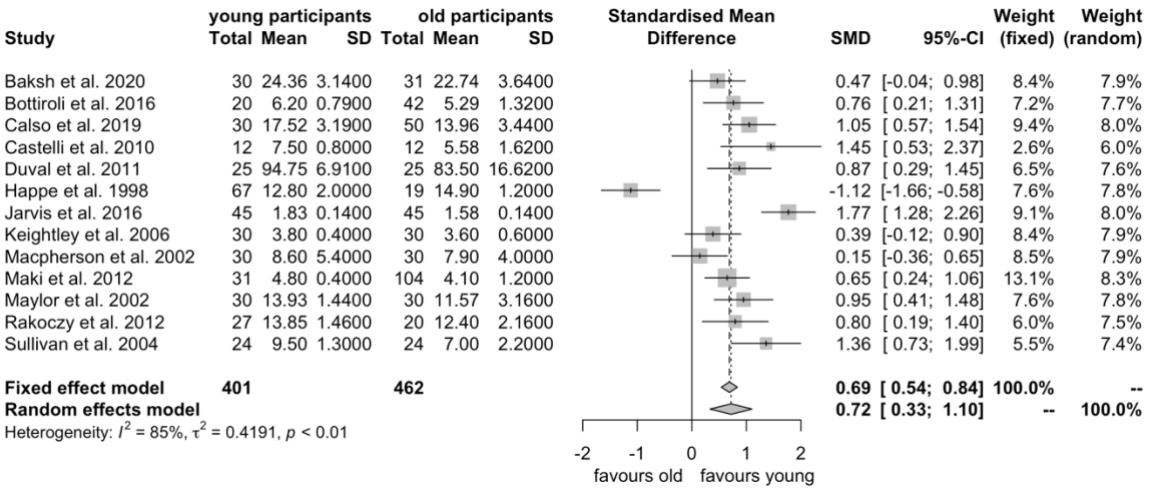

Figure 5. Forest plot of subgroup analysis between young and old individuals, outcome = Mixed ToM.

iv. Facial Emotion Recognition: Total

For the overall evaluation of the effects on FER (the process of detecting all possible human emotions) in healthy young subjects in comparison with healthy older subjects, we included 16 studies in total, resulting in 996 healthy young subjects and 926 healthy older subjects. No studies were excluded. The overall effect size, the SMD, was moderate with SMD = 0.66 (95% CI: 0.34 – 0.98), indicating that younger subjects were more effective in recognizing overall emotions compared to older subjects. This was a statistically significant finding (p = 0.0001). The heterogeneity (I^2 = 88.3%, 95% CI: 82.6% - 92.1%) was high. Results can be seen in Figure 6.

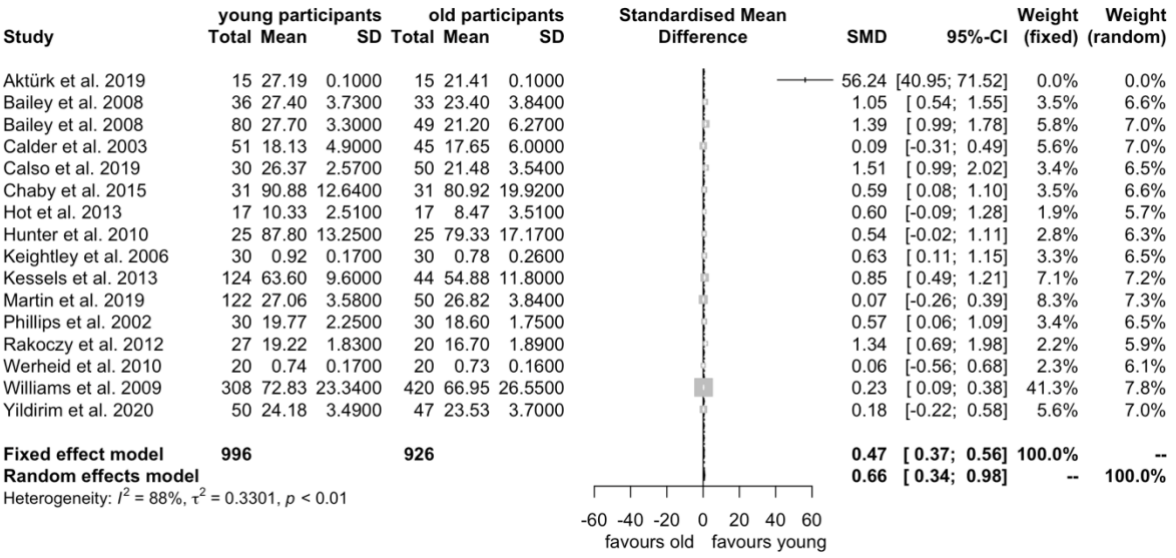

Figure 6. Forest plot of comparison between young and old subjects, outcome = FER, total.

v. Facial Emotion Recognition: Happiness

For the overall evaluation of the effects on FER of happy faces in healthy young individuals in comparison with healthy old individuals, we included 10 studies in total, resulting in 621 healthy younger individuals and 647 healthy older individuals. No studies were excluded. The SMD was 0.34 (95% CI: 0.08 - 0.61), which was a small effect indicating that healthy younger individuals were more successful at identifying happy faces than healthy older individuals. However, this was a statistically significant finding (p = 0.0117). The heterogeneity (I^2 = 69.9 %, 95% CI: 40.0% - 84.9%) was high. Results can be seen in Figure 7.

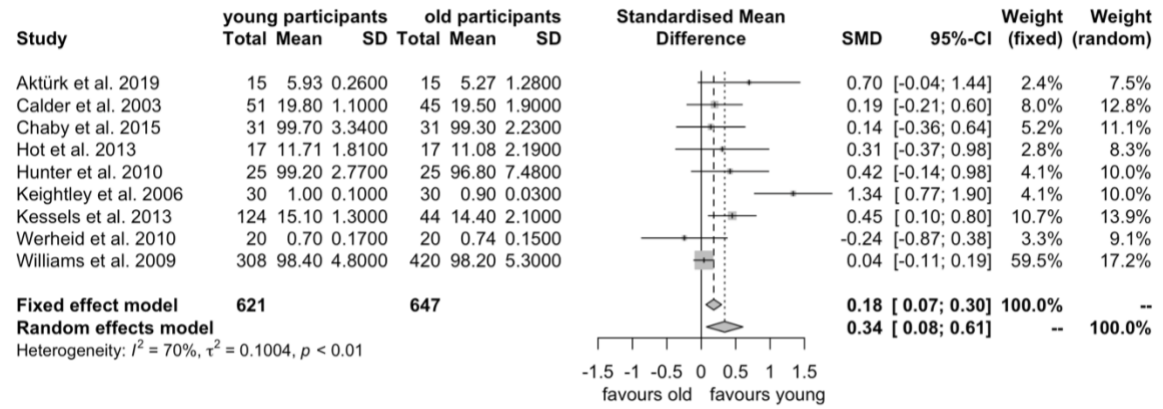

Figure 7. Forest plot of comparison between young and old individuals, outcome = FER, happy faces.

vi. Facial Emotion Recognition: Anger

For the overall evaluation of the effects on FER of angry faces in healthy young subjects in comparison with healthy old subjects, we included 9 studies in total, resulting in 621 healthy younger subjects and 647 healthy older subjects. No studies were excluded. The SMD was 0.63 (95% CI: 0.42 – 0.85), which was a large effect. This shows that healthy younger subjects achieved better results than healthy older subjects at identifying angry faces. This was a statistically significant finding (p = 0.0001). The heterogeneity (I^2 = 51.2% 95% CI: 0.0% - 77.2%) was high. Results can be seen in Figure 8.

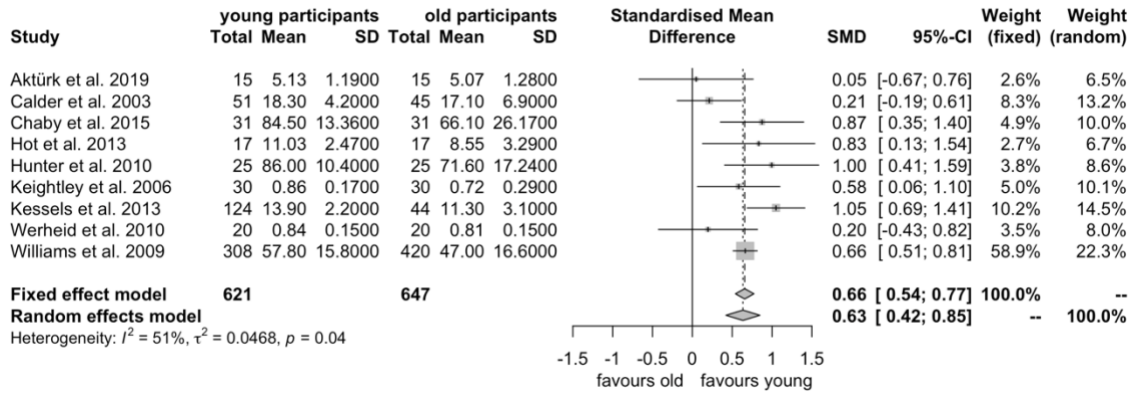

Figure 8. Forest plot of comparison between young and old subjects, outcome = FER, angry faces.

vii. Facial Emotion Recognition: Fear

For the overall evaluation of the effects on FER of fearful faces in healthy young individuals in comparison with healthy old individuals, we included 8 studies in total, resulting in 601 healthy younger individuals and 627 healthy older individuals. No studies were excluded. The SMD was 0.58 (95% CI: 0.46 – 0.70), which was a large effect showing that healthy younger individuals were better at identifying fearful faces than healthy older individuals. This was statistically significant (p = 0.0001). There was no statistical heterogeneity (I^2 = 0.0%, 95% CI: 0.0% - 58.2%). Results can be seen in Figure 9.

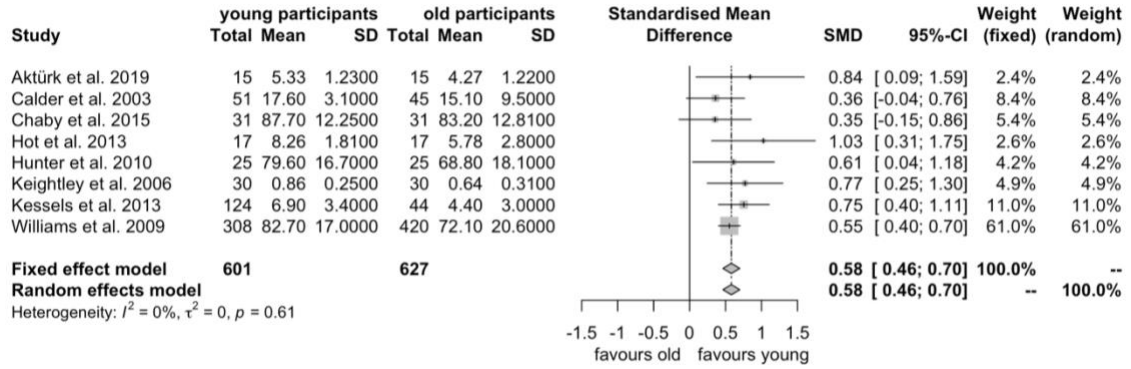

Figure 9. Forest plot of comparison between young and old individuals, outcome = FER, fearful faces.

viii. Facial Emotion Recognition: Sadness

For the overall evaluation of the effects on FER of sad faces in healthy young individuals in comparison with healthy old individuals, we included 7 studies in total, resulting in 584 healthy younger individuals and 610 healthy older individuals. No studies were excluded. The SMD was 0.72 (95% CI: 0.34 – 1.09), which was a large effect. This shows that younger people were more effective in identifying sad faces than older individuals. This finding was statistically significant (p = 0.0002). The heterogeneity (I^2 = 83.7%, 95% CI: 67.9% - 91.7%) was substantial. Results can be seen in Figure 10.

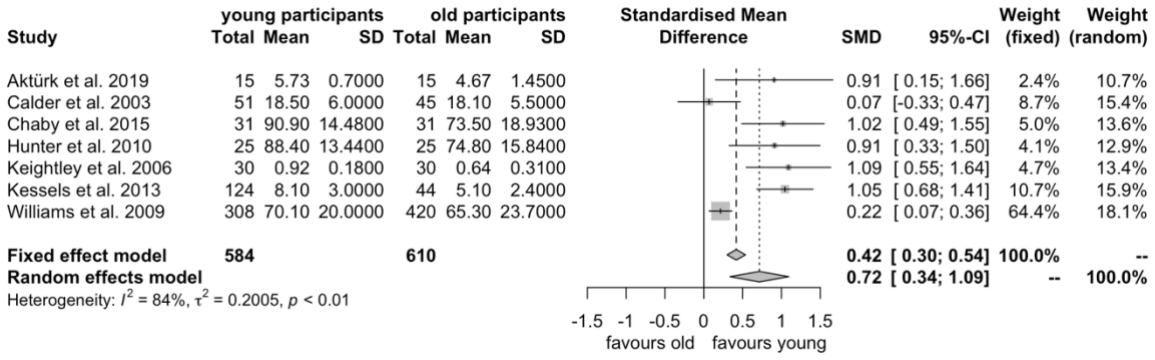

Figure 10. Forest plot of comparison between young and old individuals, outcome = FER, sad faces.

ix. Facial Emotion Recognition: Disgust

For the overall evaluation of the effects on FER of faces with an expression of disgust in healthy younger subjects in comparison with older subjects, we included 6 studies in total, resulting in 569 healthy younger subjects and 595 older subjects. No studies were excluded. The overall effect size, the SMD, was 0.28 (95% CI: -0.07 – 0.63), which was a small effect, showing that younger subjects were more successful at detecting facial expressions of disgust than older psubjects. This was a statistically not significant finding (p = 0.1182). The heterogeneity (I^2 = 81.3%, 95% CI: 60.0%; 91.3%) was substantial. Results can be seen in Figure 11.

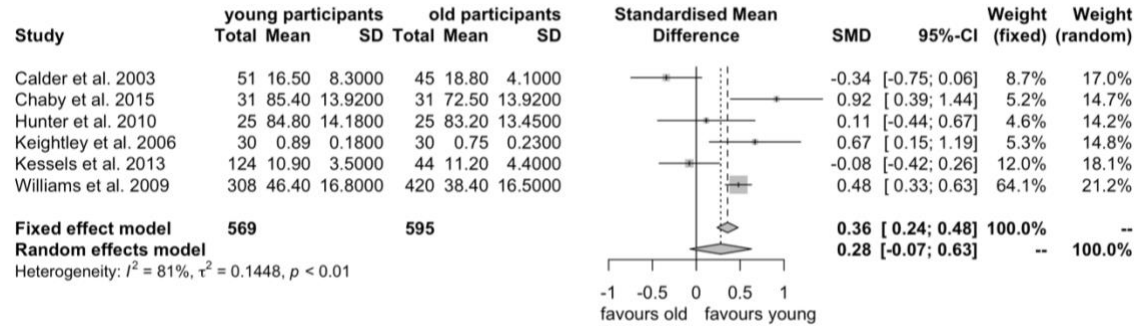

Figure 11. Forest plot of comparison between young and old subjects, outcome = FER, expression of disgust.

x. Facial Emotion Recognition: Surprise

For the overall evaluation of the effects on FER of surprised faces in healthy young individuals in comparison with healthy old individuals, we included 4 studies in total, resulting in 230 healthy younger individuals and 144 healthy older individuals. No studies were excluded. The SMD was 0.27 (95% CI: 0.03 – 0.51), which was a small effect indicating that younger individuals were more effective in detecting surprised faces than older individuals. This was statistically significant (p = 0.0281). The heterogeneity (I^2 = 15.8 %, 95% CI: 0.0% - 87.1%) was low. Results can be seen in Figure 12.

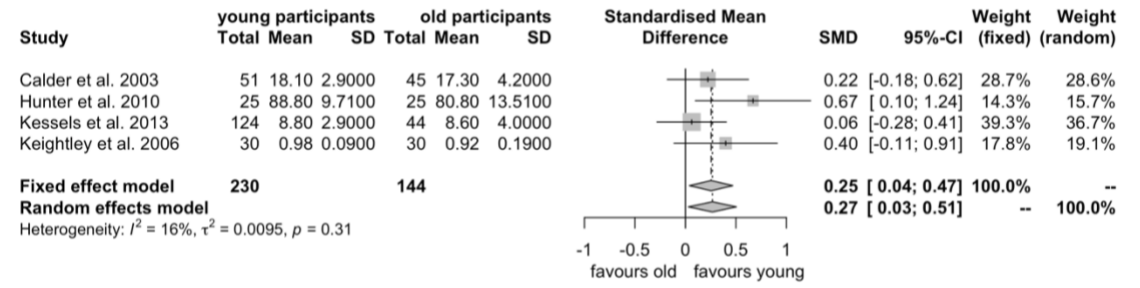

Figure 12. Forest plot of comparison between young and old individuals, outcome = FER, surprised faces.

xi. Facial Emotion Recognition: Neutral

For the overall evaluation of the effects on FER of neutral facial expressions in healthy young subjects in comparison with healthy old subjects, we included 5 studies in total, resulting in 404 healthy younger subjects and 516 healthy older subjects. No studies were excluded. The overall effect size, the SMD, was 0.56 (95% CI: 0.09 - 1.03). Hence, a large effect size. This was a statistically significant finding (p = 0.0204), showing that the recognition of neutral facial expressions was more successful among younger healthy subjects compared with healthy older subjects. The heterogeneity (I^2 = 80.4%, 95% CI: 54.0%; 91.7%) was substantial. Results can be seen in Figure 13.

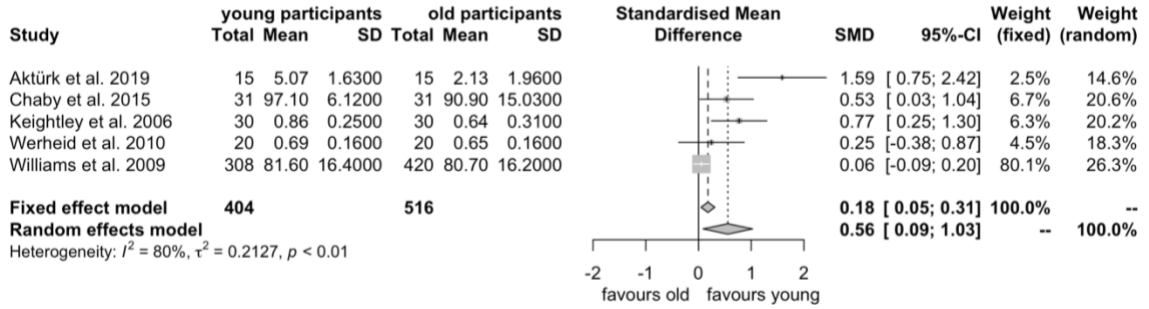

Figure 13. Forest plot of comparison between young and old subjects, outcome = FER, neutral faces.

3.3.2. Social cognition in healthy individuals and in individuals with MCI

i. Theory of Mind

For the overall evaluation of the effects on ToM in healthy older individuals in comparison with older individuals with MCI, we included 4 studies in total, resulting in 214 healthy older and 103 individuals with MCI. No studies were excluded. The overall effect size, the SMD, was small with SMD = 0.45 (95% CI: 0.20 - 0.69). This shows that healthy older individuals performed better at ToM tasks than individuals with MCI. This was a statistically significant finding (p = 0.0004). There was no statistical heterogeneity (I^2 = 0%, 95% CI: 0.0% - 47.2%). Results can be seen in Figure 14.

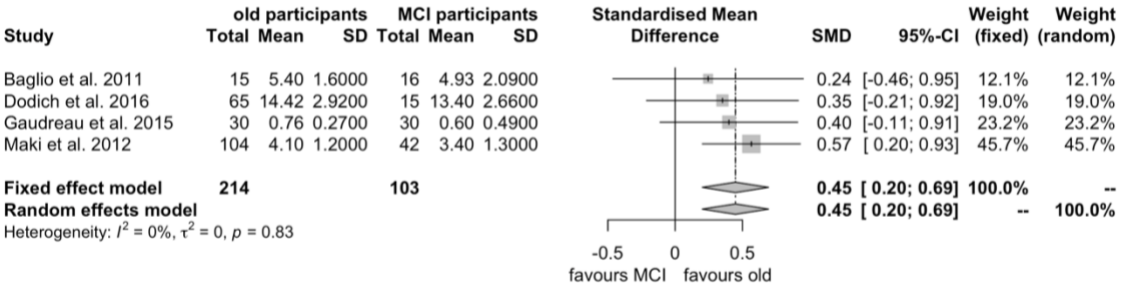

Figure 14. Forest plot of comparison between old and MCI individuals, outcome = ToM.

ii. Facial Emotion Recognition: Total

For the overall evaluation of the effects on FER (the process of detecting all possible human emotions) in healthy older subjects in comparison with older subjects with MCI, we included 13 studies in total, resulting in 493 healthy older subjects and 488 participants with MCI. No studies were excluded. The overall effect size, the SMD, was moderate with SMD = 0.63 (95% CI: 0.44 - 0.81), indicating that older subjects were more effective in recognizing overall emotions compared to subjects with MCI. This was a statistically significant finding (p = 0.05). The heterogeneity (I^2 = 43.7%, 95% CI: 0.0% - 70.6%) was moderate. Results can be seen in Figure 15.

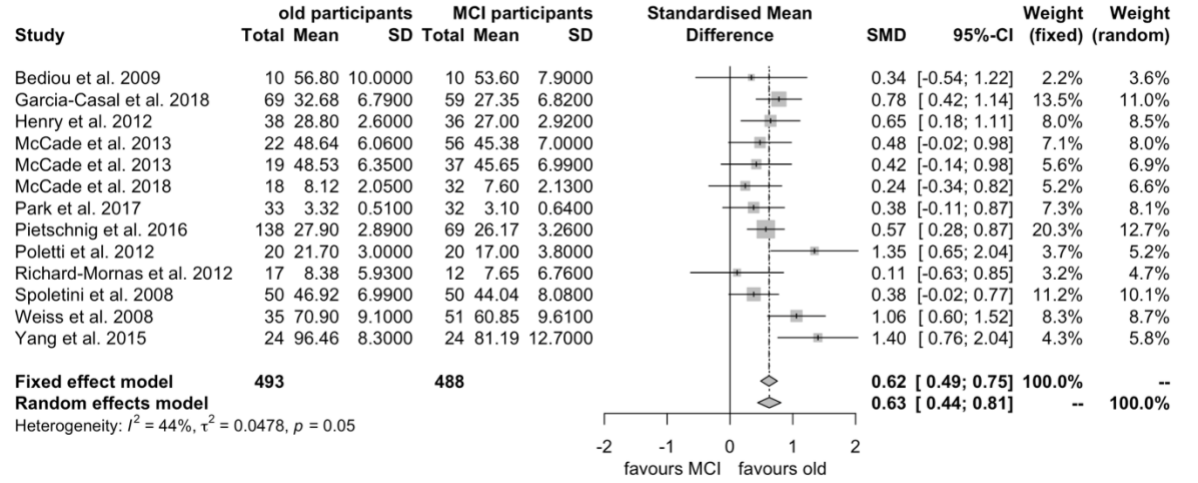

Figure 15. Forest plot of comparison between old subjects and subjects with MCI, outcome = FER, total.

iii. Facial Emotion Recognition: Happiness

For the overall evaluation of the effects on FER of happy faces in healthy older individuals in comparison with older individuals with MCI, we included 11 studies in total, resulting in 335 healthy older individuals and 399 individuals in the MCI group. No studies were excluded. The SMD was 0.15 (95% CI: 0.00 - 0.30), which was a small effect showing that older individuals were more effective in identifying happy faces than individuals with MCI. This was a statistically significant finding (p = 0.0437). There was no statistically significant heterogeneity (I^2 = 0%, 95% CI: 0% - 0%). Results can be seen in Figure 16.

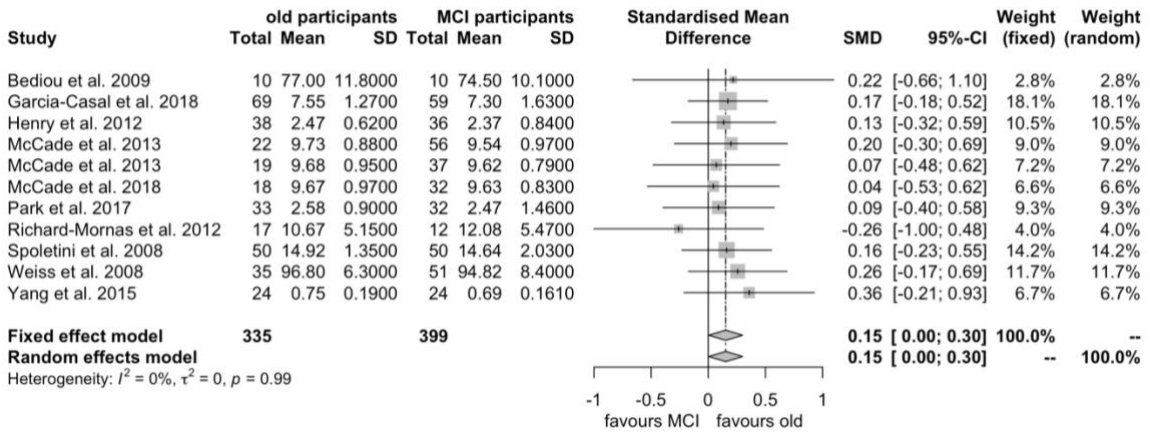

Figure 16. Forest plot of comparison between old individuals and individuals with MCI, outcome = FER, happy faces.

iv. Facial Emotion Recognition: Anger

For the overall evaluation of the effects on FER of angry faces in healthy older subjects in comparison with older subjects with MCI, we included 11 studies in total, resulting in 335 healthy older subjects and 399 subjects with MCI. No studies were excluded. The overall effect size was small; SMD = 0.31 (95% CI: 0.17- 0.46). This result shows that older subjects were more likely to correctly identify angry faces than subjects with MCI. This was a statistically significant finding (p = 0.0001 The heterogeneity (I^2 = 0%, 95% CI: 0% - 55.8%) was moderate. Results can be seen in Figure 17.

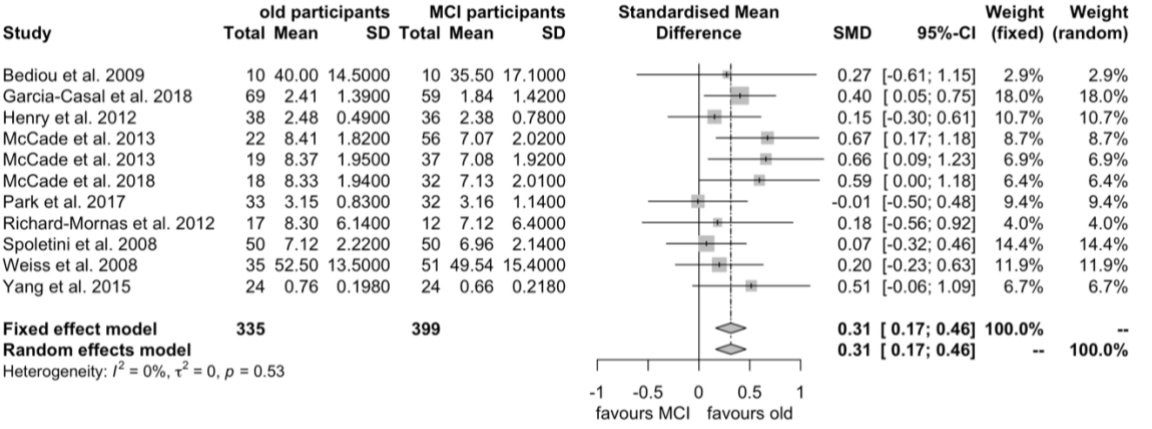

Figure 17. Forest plot of comparison between old subjects and subjects with MCI, outcome = FER, angry faces.

v. Facial Emotion Recognition: Fear

For the overall evaluation of the effects on FER of fearful faces in healthy older individuals in comparison with older individuals with MCI, we included 10 studies in total, resulting in 311 healthy older individuals and 375 individuals with MCI. No studies were excluded. The overall effect size, the

SMD, was 0.29 (95% CI: 0.14 - 0.45). Thus, the effect size was small. This was a statistically significant finding (p = 0.0002), showing that older individuals were more likely to correctly identify fearful faces in comparison with individuals with MCI. There was no statistical heterogeneity (I^2 = 0%, 95% CI: 0% - 57.3%). Results can be seen in Figure 18.

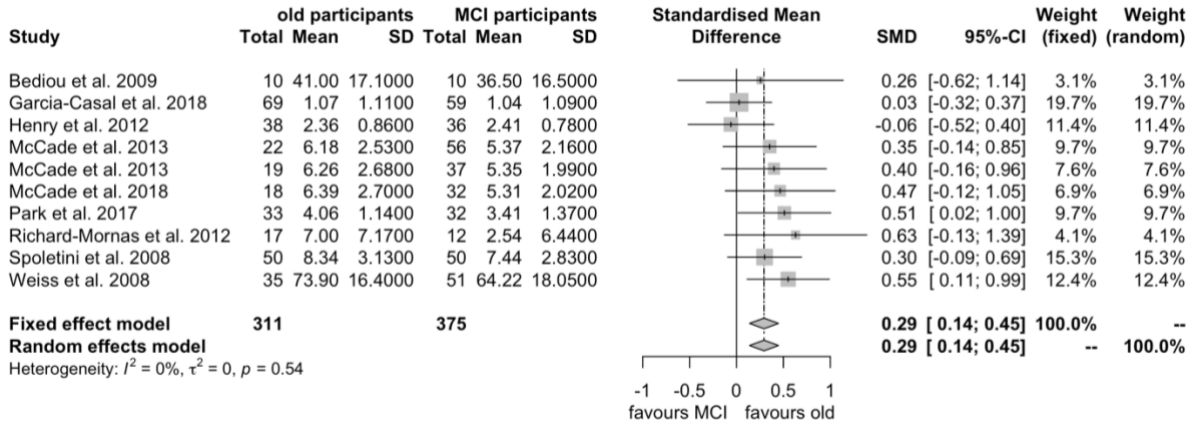

Figure 18. Forest plot of comparison between old individuals and individuals with MCI, outcome = FER, fearful faces.

vi. Facial Emotion Recognition: Sadness

For the overall evaluation of the effects on FER of sad faces in healthy older subjects in comparison with older subjects with MCI, we included 8 studies in total, resulting in 284 healthy older subjects and 353 participants in the MCI group. No studies were excluded. The overall effect size was 0.26 (95% CI: 0.10 - 0.42), which was small. This was a statistically significant finding (p = 0.0013), showing that older individuals were more effective in recognizing sad faces compared to patients with MCI. There was no statistical heterogeneity (I^2 = 0%, 95% CI: 0.0% - 60.3%). Results can be seen in Figure 19.

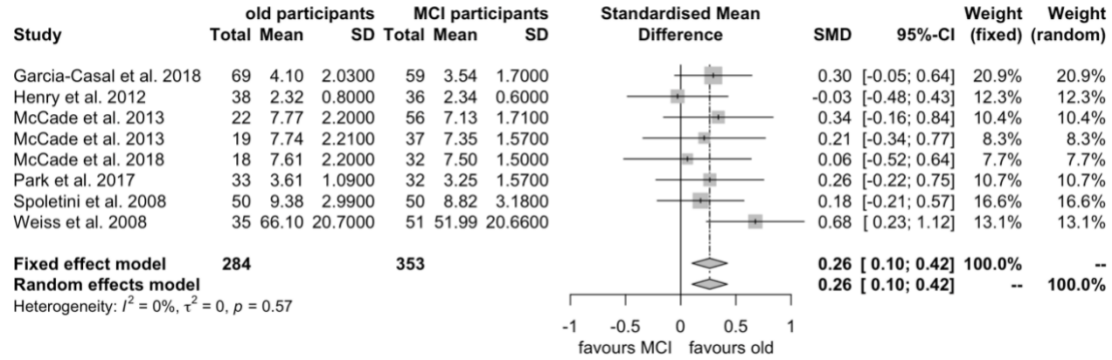

Figure 19. Forest plot of comparison between old subjects and subjects with MCI, outcome = FER, sad faces.

vii. Facial Emotion Recognition: Disgust

For the overall evaluation of the effects on FER of faces with an expression of disgust in healthy older individuals in comparison with older individuals with MCI, we included 7 studies in total, resulting in 221 healthy older individuals and 276 individuals with MCI. No studies were excluded. The overall effect size, the SMD, was 0.24 (95% CI: 0.06 - 0.42), which was a small effect showing that older individuals were more successful in detecting facial expressions of disgust than individuals with MCI. This was a statistically significant finding (p = 0.0086). The heterogeneity (I^2 = 0%, 95% CI: 0.0%; 45.9%) was low. Results can be seen in Figure 20.

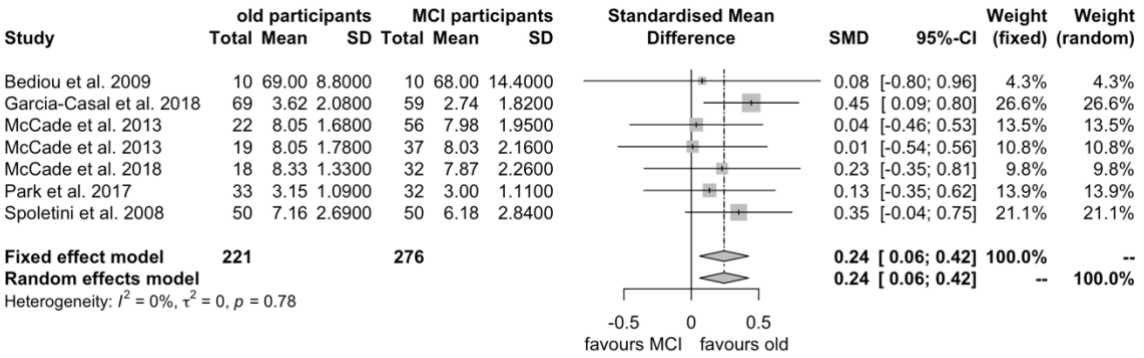

Figure 20. Forest plot of comparison between old individuals and individuals with MCI, outcome = FER, disgusted facial expression.

viii. Facial Emotion Recognition: Surprise

For the overall evaluation of the effects on FER of surprised faces in healthy older subjects in comparison with older subjects with MCI, we included 5 studies in total, resulting in 161 healthy older subjects and 216 subjects with MCI. No studies were excluded. The overall effect size was small (SMD = 0.27, 95% CI: -0.03 - 0.57), indicating that older subjects performed slightly better at identifying surprised faces than subjects with MCI. This was a statistically not significant finding (p = 0.0810). The heterogeneity (I^2 = 49.1%, 95% CI: 0.0%; 81.3%) was moderate. Results can be seen in Figure 21.

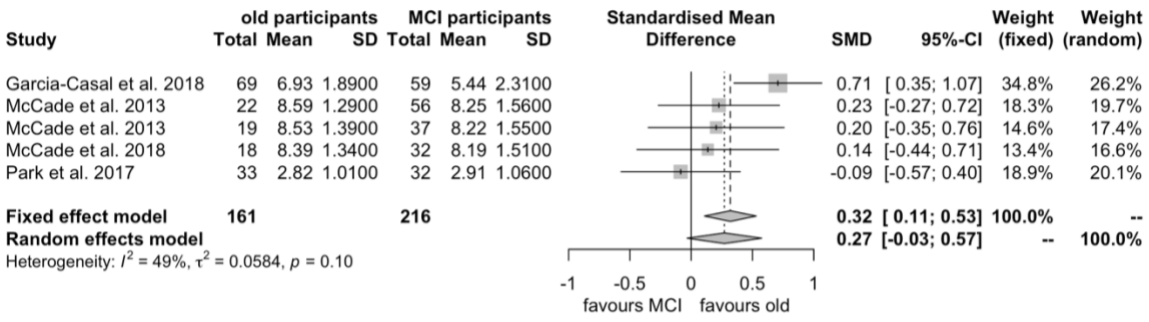

Figure 21. Forest plot of comparison between old subjects and subjects with MCI, outcome = FER, surprised faces.

ix. Facial Emotion Recognition: Neutral

For the overall evaluation of the effects on FER of neutral facial expressions in healthy older individuals in comparison with older individuals with MCI, we included 5 studies in total, resulting in 178 healthy older individuals and 178 individuals with MCI. No studies were excluded. The overall effect size, the SMD, was 0.41 (95% CI: 0.05 - 0.78). Hence, a small effect size. This was a statistically significant finding (p = 0.0261), showing that the recognition of neutral facial expressions was more successful among older healthy individuals compared with individuals with MCI. The heterogeneity (I^2 = 62.3%, 95% CI: 0.00%; 85.8%) was substantial. Results can be seen in Figure 22.

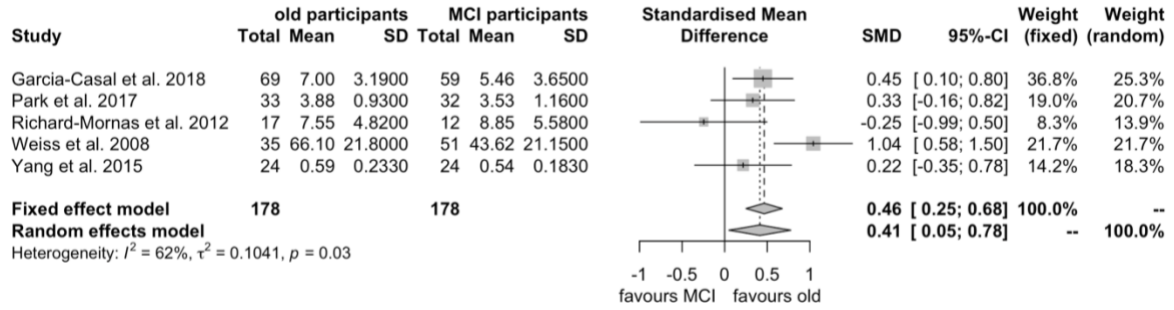

Figure 22. Forest plot of comparison between old individuals and individuals with MCI, outcome = FER, neutral faces.

4. Discussion

The primary goal of the present thesis was to determine whether social cognition, more precisely, ToM, FER, SDM and VPT declines with advancing age among healthy individuals and individuals affected by SCD and MCI. Further goals were to investigate the significance of the decline as well as the domains affected. This was accomplished by conducting a systematic review of available literature and a meta-analysis of its data. As a result, 86 studies and 88 comparisons were included in the qualitative analysis, of which 47 were eligible for quantitative analyses. Our overall results show that older subjects were at a greater disadvantage at picking up on social cues, such as ToM and FER, in comparison to their younger counterparts. They did, however, perform better than individuals affected by MCI. Due to the lack of sufficient data, a quantitative analysis comparing individuals affected by SCD to either group could not be performed. The results of the studies showed no difference between healthy subjects and individuals with SCD with regards to ToM, but a subtle decline in FER in comparison to healthy subjects and a better performance compared to individuals with MCI was found. To the author's best knowledge, the present thesis was the first to investigate several components of social cognition in healthy aging and dementia precursors and was able to show a gradual progression of social cognition decline in these patient populations. In the following, the main findings will be reviewed and discussed in more detail

as well as their relevance in the present state of research. Further, limitations and strengths as well as implications for future research and practice will be outlined and followed by a conclusion.

4.1. Theory of Mind

The assessment of ToM was most frequent in the comparison between young and elderly individuals, this might be in part due to the large abundance of research investigating social cognition particularly in these two age groups. It was assessed in 25 studies relevant for this thesis, of which 19 were eligible for quantitative analysis.

Ultimately, 13 studies that combined affective and cognitive tasks in their study designs were included in a meta-analysis, its results showed that young individuals performed better at these tasks with an effect size of 0.72, which is a large effect (Fig. 4). Similar effects were observed for affective and cognitive ToM, namely 0.76 and 0.78, respectively, albeit with fewer eligible studies, i.e., four studies investigating affective ToM and 11 studies investigating cognitive ToM. These findings are in line with previous research for all ToM domains, which is not surprising, since the majority of studies that were included in the previous meta-analysis (Henry et al., 2013) constitute a large part of this quantitative analysis (i.e., five new studies). However, when considering studies that emerged since 2013, especially studies investigating affective ToM, it becomes apparent that their results coherently show a poorer performance among the elderly group of individuals, varying only in their effect size. It should be noted that affective ToM in the previously mentioned meta-analysis was assessed using the RMET mostly, which in this thesis was classified as a measure of emotion recognition, because in a recent study it was discovered that RMET heavily relies on emotion recognition rather than ToM, and therefore appears to be an inappropriate tool to assess affective ToM (Oakley et al., 2016). Therefore, this is the first meta-analysis that shows an impairment of both, cognitive and, more importantly, affective ToM among the elderly when an appropriate methodological approach is used.

A growing body of evidence suggests a link between ToM abilities and executive functions, which constitute a critical part of cognition and are known to decline with advancing age (Bull et al., 2008; Charlton et al., 2009; Cho et al., 2019; Perner et al., 1999). Processes like inhibitory control, updating working memory, cognitive self-shifting and word fluency have been associated with ToM (Bottiroli et al., 2016). Studies have shown that different ToM tasks draw on different processes of executive functions (Cavallini et al., 2013), further, involvement of specific types of executive functions also depend on ToM domains (i.e. affective or cognitive) (Bottiroli et al., 2016). This implies that underlying mechanisms responsible for cognitive decline also play a part in the decrease of socio-cognitive abilities (Henry et al., 2013). In addition, neuroimaging studies have identified task-unrelated activation of a ToM core network, consisting of the prefrontal medial cortex and temporoparietal junction and further task-related activation of other brain areas (Schurz et al., 2014). The prefrontal medial cortex is known to decline in function with age and in numerous neurodegenerative diseases, such as MCI and AD (Pardo

et al., 2007). While our findings cannot establish the missing link between executive functions and ToM, a decline in ToM might be in part explained by progressive loss in executive functions. It should be noted that prior studies have concluded that cognitive ToM imposes higher executive demands compared to affective ToM, which would consequently mean a greater decline in cognitive rather than affective ToM abilities. However, our findings cannot corroborate this notion, as both components of ToM obtained similar results. This could be explained by affective ToM being more cognitively demanding than previously assumed, or by the use of inappropriate tasks to assess affective ToM, i.e., RMET, which indeed, might be cognitively less demanding.

A variety of tasks and modalities was used to assess affective and cognitive ToM, in the latter case most commonly though, false-belief tasks. This finding could pose a problem: The fact that different tasks were used to assess cognitive and affective ToM makes it difficult to judge whether one domain is more compromised in a population than the other. In order to overcome this problem, tasks that tackle affective and cognitive ToM through domain-appropriate questions could be used, examples of such tasks could be the faux-pas test or the false-belief task that include questions regarding the intent and affect (see Supplementary Table 1 and 2). In addition, it is not clear how the presentation modalities (e.g., verbal, visual, static, videos) used affect the performance of study subjects and if there are modalities that should be preferred in the assessment of ToM, therefore, research in this field is required. So far, only one meta-analysis investigated presentation modalities (visual vs. verbal) and their influence on performance in young and older individuals and it was concluded that performance did not suffer from modality used (Henry 2013), however, as mentioned before, more research is needed to address and investigate other presentation modalities, too.

The heterogeneity was high among the studies of these three comparisons, ranging between 69-85%. This can be explained by the diverse nature of ToM assessment on the one hand and the versatility in study design on the other. For instance, while an attempt was made to compare similar tasks in order to increase homogeneity, some studies included ToM tasks that were more demanding than others in their test batteries, which could have led to poorer performances (Jarvis et al., 2017). To exemplify, according to a study conducted by McKinnon et al., elderly subjects perform significantly worse on second-order belief tasks compared to first-order belief tasks than their younger counterparts (McKinnon et al., 2007). First-order belief is the understanding that one can hold a false belief about real events and second-order belief is the understanding that the belief about another person's belief can be false (Wimmer et al., 1983). A similar observation was made in a study performed by Duval et al., which was also included in this meta-analysis (Duval et al., 2011). Further, studies included in these meta-analyses varied in their mean age, some included subjects higher in age and by that raising the average age, which according to research, is negatively correlated with task performance (Bottiroli et al., 2016; Calso et al., 2019). The age effect was particularly evident in a cohort that included subjects within the age-span of 50-89 years, showing a progressive decline in ToM scores with increasing age (Charlton et al., 2009). Another factor that heterogeneity might be ascribed to is the difference in rating scales. Heterogeneity is an important

aspect of meta-analyses, as it determines the interpretability of the overall results, as such high heterogeneity is a limiting factor, whereas low heterogeneity allows the generalisation of results.

Since SCD is a rather novel entity and research in this field is still in its infancy (Jessen et al., 2020), only one study regarding ToM was found (Yildirim et al., 2020b). In that study, the faux-pas task was used in order to explore possible differences in ToM among individuals affected by SCD and MCI as well as AD. There was no statistical difference between SCD and MCI, but subjects with AD performed significantly worse. These findings imply that ToM, or at least faux-pas reasoning, starts to decline when a significant cognitive impairment is present. These findings are not in line with previous research, which has shown a decline in faux-pas recognition among individuals affected by MCI (Bora et al., 2017; Yi et al., 2020). It should be noted that while the results were similar among both groups, the SCD group did perform slightly better without reaching significance and because of that, the slight difference was likely dismissed by the authors. However, more research is needed, for example, with more study subjects and different tasks that also assess both, the affective and cognitive ToM, especially in the comparison to healthy aging.

Research on ToM in patients affected by MCI in comparison to healthy elderly individuals was rather sparse, resulting in seven studies being eligible for qualitative analysis. For the assessment of ToM, most frequently, false-belief tasks were used, followed by strange stories and others. Collectively, study results pointed towards an impairment in individuals affected by MCI, which was later confirmed through meta-analysis of four studies.

The results were unanimously in favour of the elderly subjects, with an effect size of 0.45, which was a moderate effect. There was no heterogeneity among the studies. Due to the small number of included studies, the possibilities to explore the effects of ToM tasks and MCI subtypes were limited. For example, two studies used various ToM tasks in their test batteries and concluded that patients affected by MCI are only significantly impaired in the second-order belief task, which is similar to the findings of studies that investigated ToM in young and elderly individuals, indicating that patients affected by MCI struggle with complex ToM tasks (Baglio et al., 2012; Gaudreau et al., 2015). However, other studies that investigated first-order belief tasks were also able to show significant deficits in patients affected by MCI (Dodich et al., 2016; Kessels et al., 2021). As mentioned previously, various studies that investigated ToM in aging and neurodegenerative diseases such as AD suggest that ToM is taxing certain executive functions (Sandoz et al., 2014). Research specifically investigating ToM and executive functions in MCI is currently limited, but more pronounced cognitive impairment possibly contributes to progression of ToM impairment compared to healthy older individuals.

Granted that executive functions are impaired in patients with MCI, as shown by multiple studies, ToM impairment could be explained by executive dysfunction (Brandt et al., 2009; Reinvang et al., 2012; Traykov et al., 2007). Apart from that, it is also suspected that neurodegeneration and functional changes in certain brain areas, such as the prefrontal medial cortex are responsible for changes in ToM abilities (Pardo et al., 2007).

All studies explored ToM within the amnestic subtype of MCI, only two studies included participants with additional cognitive deficits (Gaudreau et al., 2013; Gaudreau et al., 2015). Therefore, these findings are limited to the amnestic subtype. ToM in other subtypes of MCI has been neglected so far, hence, more research is needed to investigate the effect increased cognitive impairment (i.e., multiple domain MCI) has on ToM.

In sum, a progressive decline in ToM from young individuals to individuals affected by MCI was observed, albeit the heterogeneity among the studies in healthy aging was high. The underlying factors contributing to this decline have yet to be identified. The observed progression of ToM decline from healthy aging to MCI warrants assessments of these functions even in healthy elderly individuals to allow for early diagnosis and intervention. However, a consensus is needed in order to establish a standardised approach in the assessment of ToM, which would improve the comparability of results. Future research should use said approach in order to set up homogenous studies that would yield comparable and representative study results.

4.2. Facial Emotion Recognition

FER was the most commonly used task in order to investigate social cognition across all age groups and pathological states in this systematic review and meta-analysis. Hence, a large number of studies was included in the qualitative analysis and revealed a great variability in assessment tools for FER. While it is a visual task, it was assessed using different static photograph sets including sets with emotions portrayed by different ethnicities, as no geographical restrictions were set, and dynamic stimuli such as videos and animations (for an overview of different sets see Supplementary Table 8). In more than half of the studies the results showed impairment in at least one emotion among the elderly individuals, while the remaining studies reported no statistical difference between the two populations or even improvement in single emotions. The discrepancy on a descriptive level therefore calls for a quantitative analysis.

Overall, young individuals outperformed their elderly counterparts in the recognition of basic and complex emotions in the qualitative analysis. The general ability to recognise any possible facial emotion, here called “total”, included 16 studies and, with an effect size of 0.66, which was a moderate effect, showed that young adults were better at recognising emotions than older adults (Fig. 4). These results support the findings of previous meta-analyses (Goncalves et al., 2018; Hayes et al., 2020; Ruffman et al., 2008). However, heterogeneity among the studies was at 88%, which is high, and as mentioned in the context of ToM, sets a limit in terms of interpretability of the results. However, heterogeneity becomes evident when the effect sizes of individual studies are considered. These vary greatly, ranging from small to large effects but remain all in favour of young individuals. This can be explained as follows: The versatility of assessment protocols and modalities employed in the studies ranged from the use of RMET in order to assess basic and complex emotions to different data sets to

assess basic emotions and neutral facial expressions. As mentioned previously, RMET was traditionally considered a tool to assess affective ToM, however, a recent study showed that in fact RMET indexes emotion recognition rather than ToM, and was therefore included in this comparison rather than ToM (Oakley et al., 2016). Further, FER was assessed using different types of photograph sets as well as video material. This is relevant because according to a recent meta-analysis different task characteristics, whether it be variance in photograph sets or modalities used (e.g. videos), lead to different effects in single emotions, however, no overall effects were calculated in that study and no modality has been superior to the others (Hayes et al., 2020) and therefore more research is required.

When considering individual emotions, older adults struggled with the recognition of angry, fearful, sad, and neutral facial expressions the most, with effect sizes varying between 0.56 and 0.72, which were large effects and lesser with surprised and happy facial expressions, there the effect sizes were 0.27 and 0.34, respectively, which were small effects. The expression of disgust, similarly to previous findings, was recognised by young subjects only slightly better, as shown by the effect size of 0.28, however, this effect was not significant and points towards the preservation of disgust recognition with age.

Interestingly, emotion recognition does not decline following a uniform pattern across all emotions, rather, it appears do so in almost a random fashion. However, extensive research has been conducted in order to explain general decline of emotion recognition and its pattern as well as recognition of individual emotions. Some studies have proposed the "positivity effect", an ability to retain and recognise positive information rather than negative, which can be observed among the elderly, as a possible explanation for their superior performance at recognising positive stimuli such as facial expressions (Di Domenico et al., 2015; Isaacowitz et al., 2011). Judging by the effect sizes, older adults did not perform better than younger adults, but they had less difficulties with recognition of happy and surprised faces in comparison to other emotions. Also, it can be argued that the expression of surprise can be considered positive and negative. Taken together, these arguments dismiss the "positivity effect"-theory.

Other studies were able to demonstrate a connection between general cognitive decline associated with the aging process and deficits in emotion recognition in general and identifying specific emotions (Suzuki et al., 2013; Virtanen et al., 2017). For example, Suzuki showed that age-related deficits in recognising expressions of happiness, surprise, sadness and fear were correlated with cognitive decline as measured by processing speed and fluid intelligence (Suzuki et al., 2013). In contrast, a recent study investigated a possible correlation between working memory, fluid intelligence, processing speed, and FER in young and elderly adults, it revealed a subtle correlation between general and social cognition, therefore the authors suggest involvement of other processes to explain age-related difficulties in FER, such as structural and functional changes in the brain, which in turn might also explain decline in cognitive abilities (Qiuyi et al., 2022). In fact, Ruffman and colleagues have provided several substantiated explanations for these arising difficulties. According to their review, several brain regions that are known to partake in recognition of fear, anger, and sadness decline with advancing age, those

are amygdala, the cingulate and orbitofrontal cortex, respectively (Ruffman et al., 2008). Less research and consensus can be found regarding brain regions involved in the recognition of the remaining emotions. Facial emotions expressing surprise are processed in the parahippocampal gyrus, a brain region which is known to process novelty detection and is subject to age-related and pathology-related decline in activity as well as volume (Duan et al., 2010; Echavarri et al., 2011; Iidaka et al., 2002; Schroeder et al., 2004). The insula plays a major role in processing of facial expressions of disgust, though, it is unclear if and how the insula changes with increasing age, as study results are contradictory (Foundas et al., 1998; Long et al., 2012; Wicker et al., 2003). However, strong evidence exists showing that insular atrophy occurs in neurodegenerative diseases and is associated with a decreased ability to correctly identify facial expressions of disgust (Verstaen et al., 2016; Woolley et al., 2015). According to research, multiple brain areas are involved in processing happy faces, the most commonly areas are the ventromedial prefrontal cortex, possibly in connection with the amygdala as well as the cingulate cortex (Ebner et al., 2012). While the amygdala and cingulate cortex seem to decline in aging, function of the ventromedial prefrontal cortex appears to remain steady over the years (Lighthall et al., 2014; Nashiro et al., 2012). Neutral facial expressions elicit activity in different areas of the brain. A study has found that neutral faces possess structural similarities to emotional expressions, therefore viewing of neutral faces can cause trait inferences and activate brain areas that are associated with said traits (Said et al., 2009). Due to the complexity of its matter, it should be noted that processing of specific emotions cannot be traced back to a single brain region. Similarly, a study investigating brain activity in FER showed that different activation patterns can be seen in young and older adults (Keightley et al., 2007).

A different explanation for the pattern of FER decline in aging could lie in the strategies used to process faces: Studies have shown that young and older individuals process faces differently, namely, while older individuals focus more on the mouth region, their younger counterparts tend to scan the entire face (Mather, 2016). Happiness and disgust are easier to recognise from the lower part of the face, which explains why older individuals perform better at recognising these emotions, in contrast, anger, fear and sadness are more recognisable from the upper region of the face, while surprise can be recognised from the upper and lower facial region (Calder et al., 2000).

Lastly, it has been suggested by several authors that activation of neural circuits as opposed to brain areas and gaze patterns are the mechanism behind emotion recognition (Goncalves et al., 2018; Ruffman et al., 2008). More studies are needed to investigate this area of research.

In conclusion, an age-related effect is present for emotion recognition in general and most of the basic emotions. As of now it is not possible to pinpoint the exact mechanism behind the decline of emotion recognition in aging. It is possible that multiple processes are involved, e.g. neurodegeneration leading to cognitive impairment, this is, however, beyond the scope of this thesis and should be the focus of future research.

Only two studies explored FER in individuals with SCD, one study used an emotion recognition test battery and compared their performance to healthy subjects and individuals with MCI (Pietschnig et al.,

2016). The other study used the RMET in individuals with SCD, MCI and AD (Yildirim et al., 2020b). While the amount of data was not sufficient to perform a meta-analysis, the results allow for a preliminary conclusion. Individuals with SCD performed slightly worse on the FER task than healthy adults, which was statistically not significant, but performed better than individuals with MCI. During the RMET, subjects with SCD outperformed individuals with MCI and AD. These findings support the expectation that even slight cognitive deficits will be reflected in the FER task performance, as brain scans of objectively healthy older adults with subjective cognitive complaints revealed incipient loss in white and grey matter volume and other changes associated with neurodegeneration (Cedres et al., 2021; Schwarz et al., 2021; Valech et al., 2019). On top of that, another peculiarity is that individuals with SCD usually fly under the radar with regards to neurocognitive tests, to which FER might be an exception, however, more studies are needed to confirm these observations.

The ability to correctly identify facial emotions in individuals diagnosed with MCI in comparison to healthy elderly individuals was investigated in 22 studies (Supplementary Table 8), with the majority of studies reporting about impairment in at least one emotion among the individuals with MCI. The meta-analysis, which included 14 studies, confirmed that older subjects performed better than subjects affected by MCI, the effect was within the medium range, with an effect size of 0.63, and a moderate heterogeneity (43.7%). This comparison yielded a similar result as the meta-analysis performed by Bora et al. in 2017, which was foreseeable, because the majority of studies used in both analyses were the same (Bora et al., 2017). Therefore, this meta-analysis provides an update with research that has been published since and included RMET (Poletti et al., 2013) next to FER protocols involving full faces and with it might have contributed to the heterogeneity (Garcia-Casal et al., 2019; McCade et al., 2018; Park et al., 2017). Studies that were published after the last meta-analysis, unanimously showed an impairment in FER among individuals affected by MCI. Most of the studies included in the meta-analysis investigated the amnestic subtype of MCI, only a few explored the effects of other single- and multiple-domain types on FER. Those that did, provided data which supported the notion that severity of MCI directly translates into task performance, meaning that individuals with the amnestic subtype perform worse than those with the non-amnestic subtype (McCade et al., 2018; McCade et al., 2013a, 2013b; Michaelian et al., 2019; Pietschnig et al., 2016) and further, subjects with amnestic single-domain perform better than the amnestic multiple-domain type (Sheardova et al., 2014; Teng et al., 2007; Varjassyova et al., 2013; Weiss et al., 2008). Therefore, these findings suggest a link between emotion recognition and general cognitive abilities.

Regarding the six basic emotions and neutral facial expression individually, it becomes apparent that subjects with MCI struggle with recognition of all emotions, with the exception of surprise, as compared to healthy individuals. These findings are partially in line with those of previous research, that has revealed impairment in recognition of fear, sadness, and anger but not in the other emotions, presumably because the effects of their results failed to reach significance due to the small amount of data available at that time (Bora et al., 2017).

For all facial emotions, except surprise and neutrality, the effects were small, ranging from 0.15 - 0.31, also there was no heterogeneity among the studies. Results of surprised faces were in favour of healthy adults, with a small effect of 0.27, however, it was not significant. Neutral faces were recognised by healthy adults with higher accuracy and the effect was moderate with an effect size of 0.41 and a substantial heterogeneity of 62.3%.

Various studies support the previously mentioned idea that FER deficits in MCI are likely secondary to cognitive impairment, which was corroborated by the fact that increased disease severity results in worse performance on FER tasks (Bora et al., 2017; Moreira et al., 2022; Schild et al., 2021). However, individuals with MCI are also affected by structural and functional changes in brain areas associated with processing of FER, those changes are even more pronounced in patients with increased disease progression, which could also explain these findings but do also lead to cognitive impairment (Brambati et al., 2009; Ries et al., 2008; Whitwell et al., 2007). Therefore, while a decline in FER abilities in MCI has been demonstrated in this thesis, future research should focus on the reasons behind the decline.

Overall, a progressive decline in FER from healthy to pathological aging has been observed. These findings also demonstrate that FER is a reliable measure to assess social cognition in healthy individuals and those, who are suspected of MCI. However, a standardised approach needs to be established in the assessment of FER, which could then be incorporated in conventional cognitive test batteries as an additional diagnostic tool and used to initiate targeted intervention to help affected individuals to overcome social difficulties and improve their quality of life. Further, more research is needed to investigate whether these findings are generally representative of individuals affected by SCD.

4.3. Social Decision Making and Visual Perspective Taking

According to this review, SDM and VPT were the least researched socio-cognitive domains studied and were limited to comparisons between healthy young and older adults. Only four studies investigated SDM and were eligible for meta-analysis, which, unfortunately, did not yield any meaningful results. The studies varied in their task design and results. Overall, there was a tendency of older individuals to display more prosociality in terms of acceptance of unfair monetary offers, equally splitting funds and accepting unfair offers as opposed to young individuals (Beadle et al., 2015; Girardi et al., 2018; Roalf et al., 2012). These findings were contradicted by a different study that has observed consistent behavioural patterns among both groups and less acceptance of moderate unfair offers among the elderly (Harle et al., 2012). Statistically speaking, the results failed to reach significance and were accompanied by a high heterogeneity (95.3%). Therefore, the informative value of this analysis is low and as such should be considered with caution. For this reason, social behavioural patterns of the elderly population are still not well understood. This is problematic since it begs the question if the elderly are capable of making the best possible choices in different social situations, for example, regarding their own or their partner's health, the timing of moving to a nursing facility or trusting others.

Three studies exploring VPT were considered for meta-analysis, which failed to provide any meaningful results due to the high heterogeneity in task design and incomparable results. However, it appears that some studies are in agreement that older adults are more impaired in alternate point of views, while performing well on self-perspective tasks (Martin et al., 2019; Mattan et al., 2017). Another study did not find any differences between the different point of views but a general impairment in the elderly subjects (Baksh et al., 2020). According to these results, older individuals are at least impaired in understanding other people's perspective, which, in a practical sense, could mean difficulties in conversing with others or participating in traffic.

Overall, the above mentioned discrepancies in study results demonstrate inconclusiveness and the need for more sufficient research in order to close the research gap in this field. Therefore, the question whether assessment of SDM and VPT are eligible for early detection of socio-cognitive deficits in healthy and pathological aging remains unanswered for the time being but should be addressed in future studies.

4.4. Strengths and limitations

This thesis is the first systematic review and meta-analysis to investigate social cognition, more precisely, ToM, FER, SDM and VPT in four populations, namely, healthy young and old individuals, individuals affected by SCD and MCI. It is also the first to show a progressive decline in specific socio-cognitive abilities, i.e. FER and ToM, from young adults to individuals with MCI. These findings demonstrate that affected individuals struggle not only with taking part in social interactions due to poor communication skills but also with understanding social interactions and situations as observers. These deficits can have major consequences for their lives such as confusion, reduced social well-being and social isolation, which, according to the results of this thesis, worsen with the severity of cognitive impairment (Bailey, Henry, et al., 2008; Byom et al., 2013; Pinquart et al., 2000).

These findings are based on a substantial amount of data that validates the inclusion of certain socio-cognitive tasks in neurocognitive test batteries in order to diagnose those who are impaired in social cognition, especially ToM and FER, and also provides grounds for development of preventive and therapeutic measures to improve people's socio-cognitive skills and essentially quality of life. Previous reviews focused on two populations and two constructs at the most, while in this thesis, more populations and constructs were investigated, although a quantitative analysis for two constructs could not be performed. On top of that, this is the first systematic review and meta-analysis to show the research gap regarding socio-cognitive changes in individuals with SCD as well as SDM and VPT in all populations. Further, this systematic review and meta-analysis followed the PRISMA guidelines and was pre-registered at www.crd.york.ac.uk/PROSPERO, where the study protocol can be accessed (Moher et al., 2009a).

This systematic review and meta-analysis also contained some limitations. Just as with other meta-analyses, this meta-analysis was limited by availability of specific data, to exemplify, only about half the studies included in this systematic review contained data for quantitative analysis. With respect to the inclusion criteria for healthy individuals, data on social cognition of individuals from the upper and lower age spectrum of adulthood was included, hence this thesis did not investigate social cognition in the middle age and only few studies provided information in that specific age group (Calder et al., 2003; Duval et al., 2011; Kessels et al., 2014; Phillips et al., 2011). In addition, due to the lack of studies in this field, it was impossible to explore socio-cognitive abilities among MCI subtypes and domains, except for the amnestic subtype, which, as previously stated, was the most commonly investigated MCI subtype among included studies. In regard to the constructs, the results of the meta-analyses were very high in heterogeneity in the healthy aging group for ToM, which can be ascribed to the diversity of tasks included. It was not possible to divide the studies according to different ToM tasks and perform an analysis to reduce heterogeneity, as this would have drastically reduced the amount of data. Further, the limited number of studies exploring ToM in MCI subjects did not allow for analyses of changes in affective and cognitive ToM, separately. Additionally, available data from SDM and VPT studies was sparse. Therefore, in order to maintain a high standard in this thesis, a meta-analysis of that data was omitted and merely a preliminary estimation was undertaken. Similarly, with only two studies available for ToM and FER in SCD subjects, the informative value was low. In contrast to other recently published meta-analyses investigating FER, it was not possible to identify influencing factors that might have had an impact on these results (Goncalves et al., 2018; Hayes et al., 2020). Further, with these findings it was not possible to determine what cognitive deficits underlay which socio-cognitive ones and how they interacted with one another. However, it should be noted that this thesis focused on several populations and multiple constructs, hence, providing a plethora of data, therefore, it was beyond the scope of this investigation, to perform these kind of analyses, too.

The aforementioned shortcomings however, also present an opportunity for areas of future research. To sum up, the results of this systematic review and meta-analysis provide valuable findings that can be used for diagnosis and development of preventive and treatment protocols.

4.5. Implications for future practice and research

This systematic review and meta-analysis demonstrates that ToM and FER is impaired in healthy aging and MCI. It also points to a possible impairment of emotion recognition in SCD, however, research in that area is limited. In a practical setting, assessment of social cognition in these population groups can be recommended and hence included in neurocognitive test batteries. Information gained from the assessment can be used in order to introduce targeted interventions in those in need with the aim to improve their quality of life. One could also go one step further and implement preventive measures in seemingly cognitively healthy individuals to preclude a decline from happening. In a research setting,

this information can be used in order to develop interventional studies, preventive as well as therapeutic. With regards to ToM, interventions should aim to improve the face-to-face communication in affected individuals, as well as communication via technology, such as mobiles phones (e.g. communication with friends and relatives via messengers). Further, such interventions may be suited to help affected individuals understand social interactions as observers or bystanders, for example, while watching the news or while walking around the neighborhood. Similarly, interventions for improvement of FER may result in better communication skills by recognizing emotions and deciding how to respond appropriately, which essentially leads to SDM.

The results of a recent meta-analysis have shown improvement in socio-cognitive abilities through interventional studies, especially in healthy older individuals (Roheger et al., 2022). Also, the same meta-analysis was able to identify only few intervention studies in that age group, showing that more research in this field is needed. There is also a drastic need for interventional studies in MCI, as no studies have been published so far.

Further implications can be drawn from the results of the present systematic review and meta-analysis. For the sake of completeness and in order to understand the dynamic of social cognition throughout the entire lifespan, research investigating middle age is necessary.

The results of the meta-analysis regarding ToM in healthy individuals were weakened by the heterogeneity among the studies, therefore more clinical trials are needed to reproduce these findings with more homogenous study-designs. Furthermore, future research should clearly differentiate between affective and cognitive ToM to generate more data and determine if individuals are affected in one domain or the other, as those tap into different socio-cognitive processes and may require other cognitive processes to different extents. As mentioned previously, those tasks should be chosen, which can challenge epistemic and affective understanding simultaneously without the need to employ several tasks, such as the faux-pas task or false-belief task, and by that reducing the possibility of inaccurate results. This accounts for all study populations. In addition, it would be interesting to investigate how task modalities influence the performance in the assessment of ToM and also what modality is best to use. Also, research investigating ToM in MCI was sparse and therefore more studies in consideration of the aforementioned suggestions are needed.

So far, FER was investigated mainly with the help of static photograph sets, often in black and white. However, recent research suggests the use of dynamic and colored stimuli as they appear more realistic (Isaacowitz et al., 2011). A recent meta-analysis revealed that the modality used in the assessment of FER impacts the performance of older individuals, reducing the age-effect with video tasks in comparison to static stimuli (Hayes et al., 2020). Given the fact that in reality emotion recognition occurs not from pictures, the above-mentioned suggestion to use dynamic stimuli appears to be reasonable and should be considered in future research (Isaacowitz et al., 2011). As mentioned earlier, this thesis revealed a lack of research regarding SDM and VPT. This finding is astounding, because it shows knowledge deficits in essential behavioral patterns in the elderly and cognitively impaired individuals,

especially as they constitute a large part of our society. Although the debate regarding SDM in aging is still not settled, some studies point to a reduced ability to make appropriate decisions in healthy aging. Interventive studies need to be developed so that affected individuals can make better choices in their everyday life regarding, for example, their finances, undergoing risky medical procedures or trusting strangers.

Some studies showed that healthy older individuals tend to struggle with understanding other people's perspective, in a direct and figurative sense. VPT interventions should aim to improve spatial thinking e.g. when giving directions to a person on the street or figuratively, enable affected individuals to take another person's perspective during an argument for a better outcome.

Also mentioned previously was the paucity of research in subjective cognitive decline. Further research on social cognition is crucial because subjective cognitive decline is considered the mildest form of cognitive impairment and upon diagnosis could provide an appropriate time frame for intervention and therefore prevention of further decline (Studart et al., 2016). One of the major tasks of future research is, however, to determine what specific cognitive deficits are related to the impairment of social cognition and how these processes interact with one another.

To summarize, findings of this thesis, including the results of the quantitative analyses and the lack of research in certain relevant areas, provide a fertile ground for development of high-quality studies that can advance research and, most importantly, help individuals improve their socio-cognitive abilities.

Table 2. Summary of recommendations for future research.

Recommendations for…	
Future studies in the field of social cognition	*Social cognition in subjective cognitive decline* (future studies may explore ToM, FER, SDM, VPT in that population) *Assessment of theory of mind in MCI* (see suggestions for study design below) *Assessment of further socio-cognitive domains in all populations* (SDM and VPT) *Assessment of all socio-cognitive domains over the lifespa*n (future studies may also investigate socio-cognitive abilities in middle-aged adults) *Interventional studies in all populations* (future studies should develop socio-cognitive interventions for deficits in ToM, FER, SDM and VPT) *Evaluation of used modalities (*future studies should explore and determine the best possible modality in the assessment of ToM)
Study design and documentation in cohort studies	*Clear definitions of constructs and task design* (future studies should make a point of clear definitions of domains and subdomains , e.g. affective/cognitive/mixed ToM) *Reduce heterogeneity in task design* (future studies should employ tasks for different subdomains that are similar e.g. faux-pas with questions assessing affective and cognitive ToM instead two different tasks)

4.6. Conclusion

The present thesis is the first to show a progressive decline in ToM and FER in healthy and pathological aging, i.e. from young and late adulthood to MCI. Individual studies suggest a decline in socio-cognitive abilities among individuals with SCD, too. Thereby demonstrating that affected individuals experience constraints in their social abilities on a daily base, which has major consequences for their emotional well-being and quality of life. It is therefore highly important to assess social cognition in individuals suspected of cognitive decline and introduce interventive measures where needed. Further, ToM and FER have shown to be reliable tools in the assessment of social cognition that can be incorporated in neurocognitive test batteries. This thesis also identified some major research gaps in the field of social cognition, including domains such as SDM and VPT, as well as populations such as SCD and others, that need to be filled in future.

In sum, the findings of this thesis substantially contribute to the field of social cognition, not only by providing a comprehensive description of the current state of social cognition research in healthy aging and pathological aging conditions, but also by providing grounds for development of new research that aims to improve lives of those who suffer from socio-cognitive decline.

5. Summary

Background: Intact socio-cognitive abilities, such as theory of mind (ToM), facial emotion recognition (FER), social decision making (SDM) and visual perspective taking (VPT), are essential for human well-being and quality of life. Impairment in social cognition can have major implications for health in affected individuals and society as a whole. Evidence for changes in social cognition in healthy and pathological aging processes, such as subjective cognitive decline (SCD) and mild cognitive impairment (MCI), is currently either sparse or inconclusive. It is important to determine how social cognition changes in healthy and pathological aging and provide grounds for targeted and early assessment and intervention. The aims of this thesis were to investigate social cognition across four domains, in particular, ToM, FER, SDM and VPT, in healthy young and older individuals, as well as in individuals with cognitive deficits, such as SCD and MCI. In the case of a decline, further goals were to investigate the degree of impairment and the domains affected.

Methods: A systematic literature search was conducted in four major academic databases, MEDLINE, Web of Science Core Collection, CENTRAL, and PsycInfo, for studies investigating social cognition in healthy young and old individuals as well as individuals affected by SCD and MCI which met the inclusion criteria. The primary outcome was ToM and secondary outcomes were FER, SDM and VPT. After a systematic review was performed, studies eligible for meta-analysis were divided according to comparison groups and outcomes. Random-effects meta-analyses were conducted using standardized mean differences (SMD). Risk of Bias was assessed using the "Tool to assess risk of bias in cohort studies" modified for the present study design.

Results: After a thorough systematic literature search, 86 studies containing 88 comparisons were included in the systematic review, of which 47 were eligible for quantitative analysis. The meta-analysis revealed a progressive decline in ToM and FER abilities from young adulthood to MCI. Varying effect sizes demonstrated different trajectories of change for specific domains. Due to a lack of research, data investigating SDM and VPT, as well as SCD were insufficient for quantitative analysis.

Conclusion: ToM and FER decline gradually from healthy to pathological aging. Therefore, assessment of social cognition is important and should be incorporated in routine neurocognitive testing, so that targeted interventions can be introduced when needed. With this information in mind, future research should focus on the development of new assessment tools, as well as preventive and treatment strategies. This review also identified research gaps in certain populations (e.g. SCD, middle age, MCI-subtypes) as well as domains (VPT and SDM) that need to be addressed in the future.

6. Zusammenfassung

Hintergrund: Sozio-kognitive Fähigkeiten, wie Theory of Mind (ToM), Emotionserkennung (FER), soziale Entscheidungsfindung (SDM) und Visual Perspective Taking (VPT), sind essenzielle Bestandteile der sozialen Interaktion und tragen erheblich zu unserem Wohlbefinden bei. Einschränkungen in der sozialen Kognition können erhebliche Konsequenzen für den Alltag der Betroffenen haben. Veränderungen in der sozialen Kognition im gesunden, wie auch im pathologischen Alterungsprozess, z.B. bei der subjektiven kognitiven Verschlechterung (SCD) und leichter kognitiver Beeinträchtigung (MCI), sind wissenschaftlich noch nicht endgültig geklärt. Es ist daher wichtig zu ermitteln, wie sich die soziale Kognition in den vorher erwähnten Populationen verändert und eine Basis für neue Forschungsansätze schaffen, die sich mit präventiven und therapeutischen Maßnahmen befasst. Ziel dieser These waren es ToM, FER, SDM und VPT in jungen und älteren Erwachsenen, wie auch Menschen, die unter SCD und MCI leiden, zu untersuchen. Im Falle einer Verschlechterung, waren die weiteren Ziele, den Verschlechterungsgrad und die betroffenen Domänen genauer zu untersuchen.

Methoden: Die Literatursuche wurde in den Datenbanken MEDLINE, Web of Science Core Collection, CENTRAL und PsychInfo durchgeführt. Gesucht wurde nach Studien, die ToM, FER, SDM und VPT in gesunden jungen und älteren Erwachsenen und Menschen, die von SCD und MCI betroffen sind, untersuchten. Studien, die für die systematische Übersichtsarbeit geeignet waren, wurden auf Daten geprüft, die in die Meta-Analyse eingeschlossen werden können. Diese wurden nach Domänen und Vergleichsgruppen sortiert und einer Meta-Analyse unterzogen, dabei wurde das Random-Effects-Modell genutzt und das SMD als Effektmaß verwendet. Das Verzerrungsrisiko wurde anhand des „Tool to assess risk of bias in cohort studies“, welches an das Studiendesign angepasst war, bestimmt.

Ergebnisse: Es konnten 86 Studien mit 88 Vergleichen der systematischen Übersichtsarbeit herangezogen werden, während 47 Studien in die Meta-Analyse eingeschlossen werden konnten. Die Meta-Analyse zeigte eine progressive Abnahme der ToM und FER mit zunehmender kognitiver Beeinträchtigung, d.h. von jungen Erwachsenen bis zur MCI. Unterschiede in den Effektstärken zeigten die unterschiedlichen Entwicklungen der einzelnen Domänen. Aufgrund mangelnder Studien konnte eine quantitative Analyse von SDM, VPT und SCD nicht durchgeführt werden.

Fazit: ToM und FER nehmen bei zunehmender kognitiver Beeinträchtigung ab. Deshalb ist die Bewertung der sozialen Kognition wichtig und sollte bei neurokognitiven Tests miteingeschlossen werden, um rechtzeitig adäquate Interventionen einzuleiten. In der Forschung kann diese Information der Entwicklung neuer therapeutischer Strategien dienen. Diese Übersichtsarbeit identifizierte auch Forschungslücken, beispielsweise in bestimmten Populationen (SCD, mittleres Alter, MCI-Subtypen) und in bestimmten Domänen, u.A. VPT und SDM, diese müssen in Zukunft geschlossen werden.

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8. Appendix

8.1. Constructs

Table 1. Construct of Affective Theory of Mind: The ability to infer an agent's feelings or emotions. (Healey, 2018)

Task	Typical Task Requirements	Modality	Sample Item	Control Item
Stories	Understanding of a character's behaviour by implementing a mental state (experimental condition) or by logical reasoning about a physical event.	Verbal modality, although can be accompanied by visual-static images.	One day Aunt Jane came to visit Peter. Now Peter loves his aunt very much, but today she is wearing a new hat; a new hat which Peter thinks is very ugly indeed. Peter thinks his aunt looks silly in it, and much nicer in her old hat. But when Aunt Jane asks Peter, ‘‘How do you like my new hat?’’ Peter says, ‘‘Oh, it’s very nice’’. 1. Was it true what Peter said? 2. Why did he say it?	3. Is Peter visiting his aunt? 4. Did Aunt Jane buy a new purse?
Videos	Identification of emotional states or physical characteristics (control condition) from video clips.	Visual-dynamic.	The videos task consisted of 16 silent 5-s color videoclips that portrayed characters interacting. Participants were instructed to choose the word that best described the thoughts or feelings of the person in the video. It was clear from the angle of filming which character participants were to judge. Each clip was surrounded by four possible options describing mental state such as frustrated, excited, annoyed, and bored.	A control videos task using the same stimuli was also administered where participants chose the option that best described the age and gender of the key character (e.g., Male 40–50, Female 40–50, Female 50–60, Male 50–60).
Faux Pas	Identification of socially inappropriate behaviour or utterance (experimental task). Control tasks include identification of socially appropriate behaviour and understanding of the physical event.	Verbal modality, although can be accompanied by visual-static images.	Sally has short blonde hair. She was at her Aunt Carol’s house. The doorbell rang. It was Mary, a neighbor. Mary said “Hello,” then looked at Sally and said “Oh, I don’t think I’ve met this little boy. What’s your name?” Aunt Carol said “Who’d like a cup of tea?.” 1. Whose house was Sally at? 2. Did Mary know that Sally was a little girl? (Baron-Cohen, 1999)	Jill has short brown hair. She was at her Uncle Ted’s house. The doorbell rang. It was Mrs. Smith, a neighbor. Mrs. Smith said “Hello,” then looked at Jill and said “Oh, I don’t think I’ve met this little girl. What’s your name?” Uncle Ted said “Who’d like some tea?”. 1. Whose house was Jill at? 2. Did Mrs. Smith know that Jill was a little girl? (Baron-Cohen, 1999)
False Belief	Understanding of a character’s false belief and mental state. Control tasks include questions about the physical event.	Verbal modality, although can be accompanied by visual-static images.	Joe and Anna are setting the table for a festive dinner at the dining room. Anna pours Joe a glass of water, but some water spills on his new shirt. Joe says: “It’s nothing, I will change the shirt later”. Anna puts the glass on the table and goes to look for a paper towel to dry Joe’s shirt. When she leaves the dining room, Joe gets furious about the wet shirt and kicks the table. Anna peeks into the dining room, sees what Joe is doing and feels guilty. Anna comes back to the dining room. 1. What does Joe think that Anna feels about the wet shirt, when she returns? 2. What does Anna think Joe feels about the wet shirt? 3. How does Joe feel? (Shamay-Tsoory, 2007)	4. What were Joe and Anna preparing for? (Shamay-Tsoory, 2007)

Table 2. Construct of Cognitive Theory of Mind: The ability to infer an agent's thoughts, beliefs or intentions. (Healey, 2018)

	Typical Task Requirements	**Modality**	**Sample Item**	**Control Item**
Stories	Understanding of a character's behaviour by implementing beliefs or intentions (experimental condition) or by logical reasoning about a physical event.	Verbal modality, although can be accompanied by visual-static images.	Joe went into the bank manager's office and couldn't find anywhere to sit down because all the chairs were occupied with documents and folders. An unorganized pile of letters and documents were randomly set on the table. Joe said to the bank manager: ''Your office is so tidy!'' 1. Why did Joe say that? 2. Did Joe think the office was tidy?	3. Was the office tidy? 4. Which office did Joe go to?
False Belief	Understanding of a character's false belief. Control tasks include questions about the physical event.	Verbal modality, although can be accompanied by visual-static images.	Joe and Anna are setting the table for a festive dinner at the dining room. Anna pours Joe a glass of water, but some water spills on his new shirt. Joe says: "It's nothing, I will change the shirt later". Anna puts the glass on the table and goes to look for a paper towel to dry Joe's shirt. When she leaves the dining room, Joe takes his handkerchief and dries the shirt and the table. Anna peeks into the dining room, sees what Joe is doing, and so she doesn't bring a paper towel. Anna returns to the dining room. 1. What does Joe think that Anna thinks about the shirt's condition, when she returns to the dining room? 2. What does Anna think of the shirt's condition? (Shamay-Tsoory, 2007)	3. What is the shirt's condition? 4. What were Joe and Anna doing? (Shamay-Tsoory, 2007)
Faux Pas	Identification of socially inappropriate behaviour or utterance (experimental task). Control tasks include identification of socially appropritae behaviour and understanding of the physical event.	Verbal modality, although can be accompanied by visual-static images.	Sally has short blonde hair. She was at her Aunt Carol's house. The doorbell rang. It was Mary, a neighbor. Mary said "Hello," then looked at Sally and said "Oh, I don't think I've met this little boy. What's your name?" Aunt Carol said, "Who'd like a cup of tea?." Whose house was Sally at? 1. Who said something that it should not have been said?" 2. Why do you think they did say it? (Baron-Cohen, 1999)	Jill has short brown hair. She was at her Uncle Ted's house. The doorbell rang. It was Mrs. Smith, a neighbor. Mrs. Smith said "Hello," then looked at Jill and said "Oh, I don't think I've met this little girl. What's your name?" Uncle Ted said "Who'd like some tea?". 1. Whose house was Jill at? 2. Did Mrs. Smith know that Jill was a little girl? (Baron-Cohen, 1999)

Table 3. Construct of Facial Emotion Recognition: The ability to infer an emotion from people's facial expressions.

Task	Typical Task Requirements	Modality	Sample Item	Control Item
Faces	Use information in photograph in order to infer an emotion, most commonly one of the six basic emotions and a neutral state. The intensities of emotions may vary. Typically, participants have to match a word describing the depicted emotion.	Visual-static presentation of real or virtual actors (avatar).	Participants have to judge what emotion is displayed by an actor or animation (avatar) (Pictures of Facial Affect: Ekman & Friesen, 1976)	Corsi block trial: Participants are presented with nine circles (three circles per row in three rows), one of which is coloured and participants are asked to report the location of the target (one red circle) (Garcia-Rodriguez, 2009).
Isolated Facial Regions	Use information in photograph that is limited to the eye or mouth region only in order to infer an emotion, most commonly one of the six basic emotions. Typically, participants have to match a word describing the depicted emotion.	Visual presentation.	Participants have to judge what emotion is displayed. E.g. Bubble task (Smith, 2018), Eye region (Richard-Mornas, 2012). RMET (Baron-Cohen, 2001)	Participants have to judge the age or gender of the person.
Videos	Use information in video in order to infer an emotion, most commonly one of the six basic emotions and a neutral state. The intensities of emotions may vary. Typically, participants have to match a word describing the depicted emotion.	Visual-dynamic presentation.	The Peter and Mary emotion task battery includes videos that consist of a full shot (8-9 secs.) presenting the context followed by a medium close-up shot (2 secs.) giving an insight into the emotion of the character of interest who is marked by wearing an armband. In the context-face task, the two videos are presented successively. They can be congruent or incongruent. Questions regarding the congruency and shown emotions are asked: "Does the emotion expressed by the character match the context? What is the emotion expressed by the character?"). In the face task, only the medium close-up shot is shown and participants are asked to choose from five alternative emotions one that matches best. (Duclos, 2018)	The Peter and Mary emotion task battery includes videos that consist of a full shot (8-9 secs.) presenting the context followed by a medium close-up shot (2 secs.) giving an insight into the emotion a character. In the context-face task, the two videos are presented successively. A context question is asked: e.g.“Who is showing his muscles?”. In the context task, a context video is followed by the medium close-up shot and participants have to answer questions regarding the context e.g. "Who hits all the bullseyes?”. (Duclos, 2018)

Table 4. Construct of Social Decision Making: The ability to make decisions in a social context.

Task	Typical Task Requirements	Modality	Sample Item
Gambling Task (Bechara, 1994)	Make the most advantageous decisions in one's own favour.	Digitally (on a computer screen) or in real life.	Iowa Gambling Task: Participants are presented with four decks of cards and a loan of a certain amount of money. Their task is to maximize their profit by choosing cards from one of the four decks. Each chosen card may reward or punish the participant monetarily. What the participant does not know is that the decks are manipulated, two in favour of the participant and two against. (MacPherson, 2002)
Ultimatum Game	Make an offer at your own discretion.	Digitally (on a computer screen) or in real life.	Ultimatum Game: A participant is asked to split a sum of 10 Dollars with their opponent. It is up to the participant to decide to split it up fairly or unfairly. The opponent can either accept or deny the offer. The game is played only once to exclude reciprocity.
Dictator Game	Make an offer at your own discretion.	Digitally (on a computer screen) or in real life.	Dictator Game: A participant is asked to split a sum of 10 Dollars with their opponent. It is up to the participant to decide to split it up fairly or unfairly. The Opponent can only accept. The game is played only once to exclude reciprocity.

Table 5. Construct of Visual Perspective Taking: Visual perspective taking (VPT) is the ability to see the world from another person's perspective, taking into account what they see and how they see it (Flavell, 1977).

Task	Typical Task Requirements	Modality	Sample Item	Control Item
Level 1 Task	Demonstrate judgement whether or not the target object can be seen from a different perspective i.e., from the point of view of an avatar. (Flavell, 1977)	Visual static or visual dynamic presentation.	The most common VPT task entails a scene in which an avatar is surrounded by objects and the participant is asked how many objects that avatar is able to see.	Spatial perspective taking e.g. Is the ball located in front of the chair or behind it? (Surtees et al. 2013)
Level 2 Task	Demonstrate judgement on how the target object or scene can be seen from different perspectives. (Falvell, 1977)	Visual static or visual dynamic presentation.	Two persons can be seen looking at a car and both of them can see different parts e.g. one can see the front and one can see the back of the car. (Pearson et al. 2013)	Spatial perspective taking e.g. Is the ball located on the left or on the right? (Surtees et al. 2013)

8.2. PRISMA Checklists

Table 6. The PRISMA for Abstracts Checklist

TITLE	**CHECKLIST ITEM**	REPORTED ON PAGE #
1. Title:	Identify the report as a systematic review, meta-analysis, or both.	1
BACKGROUND		
2. Objectives:	The research question including components such as participants, interventions, comparators, and outcomes.	58
METHODS		
3. Eligibility criteria:	Study and report characteristics used as criteria for inclusion.	58
4. Information sources:	Key databases searched and search dates.	58
5. Risk of bias:	Methods of assessing risk of bias.	58
RESULTS		
6. Included studies:	Number and type of included studies and participants and relevant characteristics of studies.	58
7. Synthesis of results:	Results for main outcomes (benefits and harms), preferably indicating the number of studies and participants for each. If meta-analysis was done, include summary measures and confidence intervals.	58
8. Description of the effect:	Direction of the effect (i.e. which group is favoured) and size of the effect in terms meaningful to clinicians and patients.	58
DISCUSSION		
9. Strengths and Limitations of evidence:	Brief summary of strengths and limitations of evidence (e.g. inconsistency, imprecision, indirectness, or risk of bias, other supporting or conflicting evidence)	58
10. Interpretation:	General interpretation of the results and important implications	58
OTHER		
11. Funding:	Primary source of funding for the review.	-
12. Registration:	Registration number and registry name.	58

Table 7. The PRISMA checklist for systematic reviews

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	58
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	11/12
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	23
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	22
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	23-25
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	23
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	23
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	23
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	25/26
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	25
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	26
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	27
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	27-28

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	27
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	27
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	29/30
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	97-108
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	109-111
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	33-44
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	33-44
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	109-111
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	-
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	44-53
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	53/54
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	54-56
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	-

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PloS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

8.3. Search strings

Figure 1. Search String PsychInfo

(theory of mind OR social decision making OR emotion recognition OR visual perspective taking OR social cognition OR Social Behavior OR social perception OR social reasoning) AND (mild cognitive impairment or mci) OR subjective cognitive decline OR (healthy aging in older adults or healthy older adults)

Figure 2. Search String Web of Science

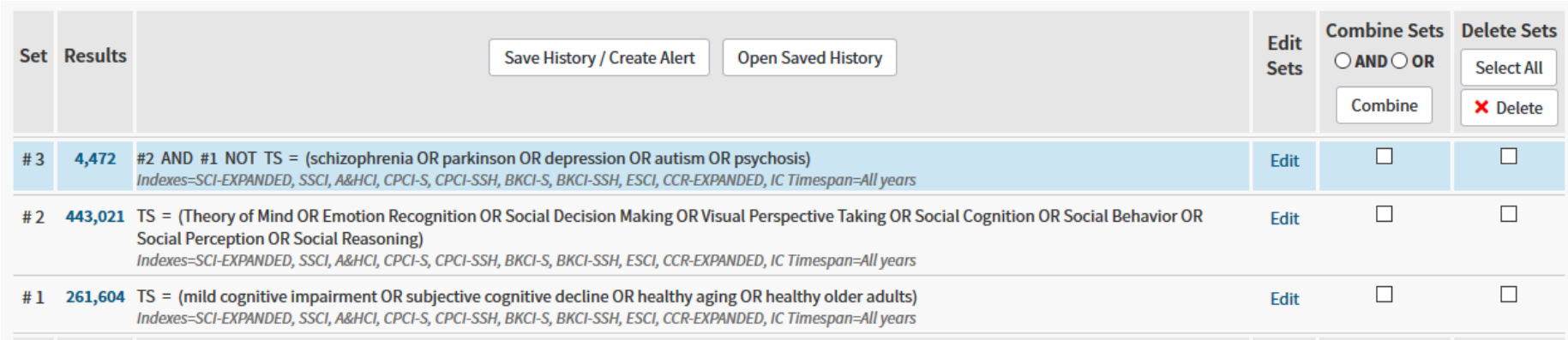
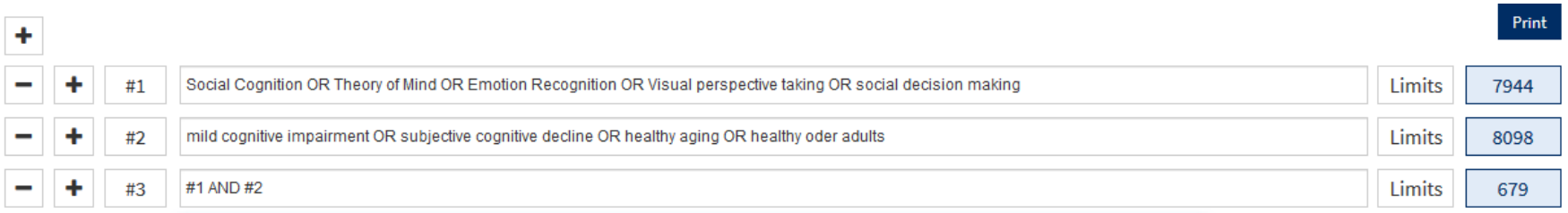


Figure 3. Search String CENTRAL



8.4. Preliminary and final study selection

Table 7. Studies selected for the full-text screening.

Author, Year	Name of the study	Young adults	Old adults	SCD	MCI	Outcomes	Exclusion
Abbruzzese 2019	Age and Gender Differences in Emotion Recognition						Age restriction differs from our inclusion criteria (Young Aged group includes 50 year olds)
Agustí 2017	An emotional Stroop task with faces and words. A comparison of young and older adults						Executive Test
Ahmed 2013	Relationship Between Theory of Mind and Functional Independence Mediated by Executive Function						No comparison group
Aktürk 2019	Age related differences in the recognition of facial expression:Evidence from EEG event-related brain oscillations	X	X			Emotion Recognition, PoFA	
Baglio 2011	Theory of Mind in Amnestic Mild Cognitive Impairment: An fMRI Study		X		X	ToM, First order false belief task, second order false belief task, complex ToM tasks, selection from strange stories	
Bailey 2008	Empathy and social functioning in late adulthood	X	X			ToM: RMET	
Bailey 2008	Growing Less Empathic With Age: Disinhibition of the Self-Perspective	X	X			ToM: RMET	
Baksh 2018	The Edinburgh Social Cognition Test (ESCoT): Examining the effects of age on a new measure of theory of mind and social norm understanding	X	X			ToM: ESCoT, RME, RMF, JoP, SNQ	
Baksh 2020	Executive Functions do not Underlie Performance on the Edinburgh Social Cognition Test (ESCoT) in Healthy Younger and Older Adults	X	X			ToM, ESCoT, Visual Perspective Taking Task	
Baran 2014	The Impact of Aging and Alzheimer's Disease on Emotional Enhancement of Memory						Free Recall not Recognition
Beadle 2012	Effects of age-related differences in empathy on social economic decision-making	X	X			Social decision-making	
Beadle 2013	Aging, Empathy, and Prosociality	X	X			Social decision-making	
Bediou 2009	Impaired Social Cognition in Mild Alzheimer Disease		X		X	Emotion Recognition	
Bediou 2012	A comparison of facial emotion processing in neurological and psychiatric conditions						Comparison of included studies (Bedinou 2009)
Bottiroli 2016	Theory of Mind in aging: Comparing cognitive and affective components in the faux pas test	X	X			Cognitive and Affective Faux Pas Test	
Bull 2008	The role of control functions in mentalizing: Dual-task studies of Theory of Mind and executive function						Only young participants, no aged control
Calder 2003	Facial expression recognition across the adult life span	X	X			Facial Emotion Recognition	

Calso 2019	Frontal Lobe Functions in Normal Aging: Metacognition, Autonomy, and Quality of Life	X	X		ToM, First order false belief task, second order false belief task, Facial expression recognition. MPS-TOMQ.	
Castelli 2010	Effects of aging on mindreading ability through the eyes: An fMRI study	X	X		ToM: EDD, First order false belief task, second order false belief task, complex ToM tasks, selection from strange stories	
Chaby 2015	Compensating for age limits through emotional crossmodal integration	X	X		Emotion Recognition	
Chard 2019	Atypical emotion recognition from bodies is associated with perceptual difficulties in healthy ageing					Body Emotion Recognition, not Face
Chiu 2015	"Now I see it, now I don't": Determining Threshold Levels of Facial Emotion Recognition for Use in Patient Populations					No comparison group
Cook 2007	Aging and brain activation with working memory tasks: an fMRI study of connectivity	X	X		Emotion Recognition	
de Gelder 2015	The Facial Expressive Action Stimulus Test. A test battery for the assessment of face memory, face and object perception, configuration processing, and facial expression recognition					Age restriction differs from our inclusion criteria (Middle Aged group: 47-62 years)
de Souza 2018	The effects of gender, age, schooling, and cultural background on the identification of facial emotions: a transcultural study	X	X		Emotion Recognition, FERT	
Dodich 2014	Emotion recognition from facial expressions: a normative study of the Ekman 60-Faces Test in the Italian population	X	X		Emotion recognition, EK-60F	
Dodich 2016	Differential Impairment of Cognitive and Affective Mentalizing Abilities in Neurodegenerative Dementias: Evidence from Behavioral Variant of Frontotemporal Dementia, Alzheimer's Disease, and Mild Cognitive Impairment		X	X	ToM: SET, intention and emotion attribution	
Duclos 2018	Role of context in affective theory of mind in Alzheimer's disease	X	X		Affective ToM assessment	
Duval 2011	Age effects on different components of theory of mind	X	X		Affective and Cognitive ToM task	
Éthier-Majcher 2013	Reverse correlating trustworthy faces in young and older adults					Trustworthiness not Emotion Recognition
Foster 2011	Perception of Emotion in Older Adults with Mild Cognitive Impairment		X	X	Facial Emotion Recognition	Doctoral thesis
Fujie 2008	The Role of the Uncinate Fasciculus in Memory and Emotional Recognition in Amnestic Mild Cognitive Impairment		X	X	Facial Emotion Recognition	
García-Casal 2018	Usability Study and Pilot Validation of a Computer-Based Emotion Recognition Test for Older Adults With Alzheimer's Disease and Amnestic Mild Cognitive Impairment		X	X	Facial Emotion Recognition	
García-Rodríguez 2009	The role of interference in identification of emotional facial expressions in normal ageing and dementia	X	X		Facial Emotion Recognition	

Gaudreau 2013	Verbal Irony Comprehension in Older Adults With Amnestic Mild Cognitive Impairment		X	X	ToM stories, First and Second order ToM	
Gaudreau 2015	Mental State Inferences Abilities Contribution to Verbal Irony Comprehension in Older Adults with Mild Cognitive Impairment		X	X	ToM: Combined Stories Task, Short Scenario Irony Comprehension Task	
German 2006	Representational and executive selection resources in 'theory of mind': Evidence from compromised belief-desire reasoning in old age	X	X		ToM: False and True Belief Tasks	
Giovagnoli 2019	Theory of mind across lifespan from ages 16 to 81 years	X	X		ToM: Faux Pas Task	
Girardi 2018	Theory of mind and the Ultimatum Game in healthy adult aging	X	X		ToM: Faux Pas Task, Judgment of Preference task; Social decision making: Ultimatum Game	
Halberstadt 2011	Emotion Perception Explains Age-Related Differences in the Perception of Social Gaffes	X	X		ToM: Faux pas discrimination; Emotion Recognition	
Happe 1998	The Getting of Wisom: Theory of Mind in Old Age	X	X		ToM stories: Double bluffs, mistakes, persuations and white lies	
Harlé 2012	Social economic decision-making across the lifespan: An fMRI investigation	X	X		Social decision-making: Ultimatum Game	
Henry 2009	Threat Perception in Mild Cognitive Impairment and Early Dementia		X	X	Facial Emotion Recognition	
Henry 2009	Threat Perception in Mild Cognitive Impairment and Early Dementia					Double
Henry 2012	Perception of Biological Motion and Emotion in Mild Cognitive Impairment and Dementia		X	X	Facial Emotion Recognition	
Holland 2018	Emotion identification across adulthood using the Dynamic FACES database of emotional expressions in younger, middle aged, and older adults	X	X		Facial Emotion Recognition	
Hot 2013	Fear recognition impairment in early-stage Alzheimer's disease: When focusing on the eyes region improves performance	X	X		Facial Emotion Recognition	
Hunter 2010	Effects of Age on Cross-Modal Emotion Perception	X	X		Emotion Recognition: Unimodal facial emotion identification (FEEST); Cross-modal emotion identification	
Insch 2015	The Impact of Aging and Alzheimer's Disease on Decoding Emotion Cues from Bodily Motion					Body Emotion Recognition, not Face

Jarvis 2016	Self-projection in younger and older adults: a study of episodic memory, prospection, and theory of mind	X	X		ToM: First order false belief task, second order false belief task, bluff and double-bluff understanding, faux pas, white lies, irony and sarcasm	
Jaworska 2020	Healthy aging delays the neural processing of face features relevant for behavior by 40 ms					Detection of Face not Emotion Expression
Karlawish 2019	Social Cognition and the Aging Brain					Editorial in a magazine
Keightley 2006	Age Effects on Social Cognition: Faces Tell a Different Story	X	X		ToM: Stories; Facial Emotion Recognition	
Kessels 2013	Assessment of perception of morphed facial expressions using the Emotion Recognition Task: Normative data from healthy participants aged 8–75	X	X		Emotion Recognition Task	
Kiffel 2005	Categorical Perception of Faces And Facial Expressions: The Age Factor	X	X		Facial Emotion Recognition	
Kovalchik 2005	Aging and decision making: a comparison between neurologically healthy elderly and young individuals	X	X		ToM: p-beauty contest	
Laillier 2019	Neurocognitive determinants of theory of mind across the adult lifespan				ToM: MASC; Facial Emotion Recognition: Amsterdam Dynamic Facial Expression Set	No comparison group
Lambrecht 2012	Age-Related Decrease in Recognition of Emotional Facial and Prosodic Expressions	X	X		Facial Emotion Recognition	
Lambrecht 2013	Gender differences in emotion recognition: Impact of sensory modality and emotional category					No comparison group
Lautenbacher 2016	Age Differences in Decoding Pain from the Facial Expression of Healthy Individuals and Patients with Dementia	X	X		Facial Emotion Recognition	
Lavrencic 2015	Social cognition is not associated with cognitive reserve in older adults				Facial Emotion Recognition: Pain	No comparison group
Lecce 2017	Theory of Mind and social relationships in older adults: the role of social motivation					No comparison group
Lecce 2019	Theory of mind, mental state talk and social relationships in aging: The case of friendship					No comparison group
Lee 2013	Development and Standardization of Extended ChaeLee Korean Facial Expressions of Emotions					No comparison group
Lima 2011	Emotion recognition in music changes across the adult life span					Auditory testing
MacPherson 2002	Age, Executive Function, and Social Decision Making: A Dorsolateral Prefrontal Theory of Cognitive Aging	X	X		ToM: Faux Pas Task; Social decision making: Gambling task; Emotion recognition task	
Maki 2012	Communicative Competence in Alzheimer's Disease: Metaphor and Sarcasm Comprehension	X	X	X	ToM: MMST	
Manenti 2017	Age-related changes in implicit emotion processing	X	X		Emotional priming	

Martin 2019	Visual perspective taking in young and older adults	X	X		Visual perspective taking task; Social emotion cognition task;Tom: Reading the mind in the eyes	
Mattan 2017	Prioritization of self-relevant perspectives in ageing	X	X		Visual perspective taking task: 3PP–3PP task, 1PP–3PP task	
Maylor 2002	Does performance on theory of mind tasks decline in old age?	X	X		ToM: Stories	
McCade 2013	Emotion Recognition Deficits Exist in Mild Cognitive Impairment, But Only in the Amnestic Subtype		X	X	Emotion Recognition: FEEST, Emotion identification task, Movie still task	
McCade 2013	Emotion recognition in mild cognitive impairment: relationship to psychosocial disability and caregiver burden		X	X	Emotion Recognition: FEEST	
McCade 2018	Visual Processing of Emotional Faces is Preserved in Mild Cognitive Impairment		X	X	Visual processing, Emotion Recognition: FEEST	
McKinnon 2007	Domain-general contributions to social reasoning: Theory of mind and deontic reasoning re-explored	X	X		ToM: Faux pas	
Michelian 2019	Theory of Mind in Mild Cognitive Impairment – Relationship with Limbic Structures and Behavioural Change		X	X	ToM: RMET	
Montagne 2007	The Emotion Recognition Task: A Paradigm to Measure The Perception of Facial Emotional Expressions At Different Intensities				Emotion Recognition, PoFA	Age restriction differs from our inclusion criteria (Middle Aged group: 45-75 years)
Moreau 2015	Different Patterns of Theory of Mind Impairment in Mild Cognitive Impairment		X	X	False belief tasks	
Nazlidou 2015	Social cognition in adults: the role of cognitive control	X	X		ToM: Indirect Speech Understanding Task: Irony, Humor, Sarcasm and Faux Pas Understanding Task; Emotion Recognition	
Otti 2015	Is the Medial Prefrontal Cortex Necessary for Theory of Mind?					No comparison group
Pardini 2009	Age-Related Decline in Mentalizing Skills Across Adult Life Span				ToM: RMET	Editorial in a magazine
Park 2017	Behavioral and Neuroimaging Evidence for Facial Emotion Recognition in Elderly Korean Adults with Mild Cognitive Impairment, Alzheimer's Disease, and Frontotemporal Dementia		X	X	Facial Emotion Recognition	
Park 2019	Corrigendum: Behavioral and Neuroimaging Evidence for Facial Emotion Recognition in Elderly Korean Adults with Mild Cognitive Impairment, Alzheimer's Disease, and Frontotemporal Dementia					Double
Parra 2013	Medial temporal lobe function during emotional memory in early Alzheimer's disease, mild cognitive impairment and healthy ageing: an fMRI study					No facial emotion recognition

Pernigo 2015	Behavioural and neural correlates of visual emotion discrimination and empathy in Mild Cognitive Impairment		X		X	Facial Emotion Recognition	
Phillips 2002	Age and the Understanding of Emotions: Neuropsychological and Sociocognitive Perspectives	X	X			ToM:RMET	
Phillips 2011	Lifespan aging and belief reasoning: Influences of executive function and social cue decoding	X	X			ToM: ToM videos task, False belief trials, True belief trials, Filler trials, ToM stories task	
Pietschnig 2016	Facial emotion recognition in patients with subjective cognitive decline and mild cognitive impairment		X	X	X	Facial Emotion Recognition	
Poletti 2012	Alteration of affective Theory of Mind in amnestic mild cognitive impairment		X		X	ToM: RME	
Radecki 2018	Theory of Mind and Psychosocial Characteristics in Older Men						No comparison group
Rakoczy 2012	The decline of theory of mind in old age is (partly) mediated by developmental changes in domain-general abilities	X	X			ToM Tasks: ToM Stories, Video Task	
Richard-Mornas 2012	Perceived Eye Region and the Processing of Fearful Expressions in Mild Cognitive Impairment Patients		X		X	Emotion Recognition	
Richoz 2018	Tracking the recognition of static and dynamic facial expressions of emotion across the life span	X	X			Emotion Recognition	
Roalf 2011	Risk, Reward, and Economic Decision Making in Aging	X	X			Social decision-making: Ultimatum Game, Dictator Game	
Rosi 2016	Promoting theory of mind in older adults: does age play a role?						No comparison group
Rossetto 2018	Cognitive and Affective Theory of Mind in Mild Cognitive Impairment and Parkinson's Disease: Preliminary Evidence from the Italian Version of the Yoni Task		X		X	ToM: Deceptive Box Task, Look & Say Perdiction Task, RME Test, Strange Stories	
Rossetto 2020	Social Cognition in Rehabilitation Context: Different Evolution of Affective and Cognitive Theory of Mind in Mild Cognitive Impairment						Interventive Study
Rossetto 2020	Social Cognition in Rehabilitation Context: Different Evolution of Affective and Cognitive Theory of Mind in Mild Cognitive Impairment						Double
Ruffman 2006	Differences in the Way Older and Younger Adults Rate Threat in Faces But Not Situations	X	X			Emotion Recognition Task	
Ruffman 2016	Your Way to a Better Theory of Mind: A Healthy Diet Relates to Better Faux Pas Recognition in Older Adults						No comparison group
Sapey-Triomphe 2015	Neuroanatomical Correlates of Recognizing Face Expressions in Mild Stages of Alzheimer's Disease						AD and MCI combined
Sarabia-Cobo 2015	Emotional processing in patients with mild cognitive impairment: The influence of the valence and intensity of emotional stimuli. The valence and intensity of emotional stimuli influence emotional processing in patients with mild cognitive impairment		X		X	Facial Emotion Recognition	
Savaskan 2007	Age determines memory for face identity and expression						Memory task

Schefter 2013	Recognition memory for emotional faces in amnestic mild cognitive impairment: An event-related potential study					Memory task
Seaman 2016	Adult Age Differences in Decision Making Across Domains: Increased Discounting of Social and Health-Related Rewards					No social decision making but decision making
Sheardova 2014	Famous Landmark Identification in Amnestic Mild Cognitive Impairment and Alzheimer's Disease		X	X	Facial Emotion Recognition	
Slessor 2007	Exploring the Specificity of Age-Related Differences in Theory of Mind Tasks	X	X		ToM stories: Double bluffs, mistakes and white lies; RMET; ToM-Video tasks.	Age restriction differs from our inclusion criteria (young group included participants under the age of 18)
Smith 2018	Transmitting and decoding facial expressions of emotion during healthy aging: More similarities than differences	X	X		Facial Emotion Recognition: Bubble Task	
Spoletini 2008	Facial Emotion Recognition Deficit in Amnestic Mild Cognitive Impairment and Alzheimer Disease		X	X	Facial Emotion Recognition	
Sullivan 2004	Social understanding: How does it fare with advancing years?	X	X		ToM: Strange Stories & Video Task, Facial emotion Recognition	
Sullivan 2004	Emotion Recognition Deficits in The Elderly	X	X		Facial Emotion Recognition	
Sutter 2005	Trust and trustworthiness across different age groups	X	X		Trust Game	
Suzuki 2007	Decline or improvement? Age-related differences in facial expression recognition	X	X		Facial Emotion Recognition	
Teng 2007	Deficits in Facial Emotion Processing in Mild Cognitive Impairment		X	X	Facial Emotion Recognition, FAB	
Tonini 2016	Reconnaissance des émotions faciales et raisonnement social dans le vieillissement normal, le MCI et la maladie d'Alzheimer					Language
Varjassyova 2013	Recognition of Facial Emotional Expression in Amnestic Mild Cognitive Impairment		X	X	Facial Emotion Recognition	
Verdon 2007	Social Cognition: An Early Impairment in Dementia of the Alzheimer Type	X	X		ToM: Cartoon task	
Walzak 2018	The role of illness burden in theory of mind performance among older adults					No comparison group
Waring 2017	Effects of Mild Cognitive Impairment on Emotional Scene Memory					No social cognition testing
Waring 2019	Emotional Response Inhibition Is Greater in Older Than Younger Adults	X	X		Facial Emotion Recognition: Go/No-Go Task	
Weiss 2008	Impairment in Emotion Recognition Abilities in Patients With Mild Cognitive Impairment, Early and Moderate Alzheimer Disease Compared With Healthy Comparison Subjects		X	X	Facial Emotion Recognition: Penn Emotion Recognition Test	
Werheid 2010	Biased Recognition of Positive Faces in Aging and Amnestic Mild Cognitive Impairment	X	X		Emotion Recognition	

Williams 2009	Explicit identification and implicit recognition of facial emotions: I. Age effects in males and females across 10 decades	X	X			Emotion Recognition	
Wright 2006	Novel fearful faces activate the amygdala in healthy young and elderly adults						Memory task
Yang 2015	Emotional face recognition deficit in amnestic patients with mild cognitive impairment: behavioral and electrophysiological evidence		X		X	Facial Emotion Recognition	
Yildirim 2020	An investigation of affective theory of mind ability and its relation to neuropsychological functions in Alzheimer's disease			X	X	Reading Mind in the Eye Test, Faux Pas Recognition Test	
Yildirim 2020	Affective theory of mind in human aging: is there any relation with executive functioning?	X	X			Reading Mind in the Eyes Test (RMET)	
Zhou 2019	Selective impairment of musical emotion recognition in patients with amnesic mild cognitive impairment and mild to moderate Alzheimer disease						Auditory testing
Ziaei 2016	The impact of aging on the neural networks involved in gaze and emotional processing	X	X			Emotion Recognition: Ekman Emotion Recognition Test; ToM: RMET	Age restriction differs from our inclusion criteria (young group included participants under the age of 18)
Zinchenko 2017	The Influence of Negative Emotion on Cognitive and Emotional Control Remains Intact in Aging						Auditory Testing

Table 8. Final selection of included studies. Studies investigating healthy young and older individuals.

Study and Year	Sample Total (n)	Criteria	Age (in years, Mean ± SD)	Gender (F:M)	Education (in years, Mean ± SD)	Cognitive Tasks	Social Cognition Task	Characteristics	Outcome	Result Evaluation
Aktürk 2019	Total = 30 (15 Healthy Young; 15 Healthy Old)		Healthy Young: 24.00 (± 2.77) Healthy Old: 62.07 (± 6.01)	7 : 8 9 : 6	17.93 (± 2.50) 9.40 (± 4.27)	MMSE	Facial Emotion Recognition (POFA)	MMSE >25.00 in Healthy Old	FER of neutral, fearful, sad emotions impaired in elderly.	High scores associated with health.
Bailey 2008	Total = 69 (36 Healthy Young; 33 Healthy Old)		Healthy Young: 19.50 (± 2.10) Healthy Old: 72.20 (± 5.56)	25 : 11 22 : 11	14.08 (± 1.66) 13.09 (± 2.84)	Addenbrooke's Revised Cognitive Examination	False Belief Video Tasks, RMET	>83.00 >83.00	FB and RMET impaired in elderly.	High scores associated with health.
Bailey 2008	Total = 129 (80 Healthy Young; 49 Healthy Old)		Healthy Young: 20.80 (± 1.13) Healthy Old: 70.40 (± 5.51)	57 : 23 33 : 16	16 (± 1.08) 13 (± 4.06)	-	RMET	-	RMET impaired in elderly.	High scores associated with health.

Baksh 2018	Total = 61 (30 Healthy Young; 31 Healthy Old)	Healthy Young: 26.20 (± 5.21) Healthy Old: 72.45 (± 6.05)	15 : 15 14 : 17	17.03 (± 2.82) 14.58 (± 2.88)	WASI-II (VCI; PRI)	ESCoT: RMET, RMF, JoP	-	Affective and Cognitive ToM impaired in elderly.	High scores associated with health.
Baksh 2020	Total = 61 (30 Healthy Young; 31 Healthy Old)	Healthy Young: 22.57 (± 2.36) Healthy Old: 72.29 (± 3.99)	12 : 18 16 : 15	16.73 (± 1.14) 16.12 (± 3.27)	ECAS	ESCoT; VPT	ECAS: 119.70 (± 6.13) ECAS: 119.33 (± 8.03)	Affective and Cognitive ToM impaired in elderly. Larger processing costs in elderly.	High scores associated with health. Processing cost means mean time/proportion correct.
Beadle 2012	Total = 80 (40 Healthy Young; 40 Halthy Old)	Healthy Young: 30.80 (± 6.60) Healthy Old: 66.20 (± 7.60)	23 : 17 25 : 15	-	-	Ultimatum Game	-	Elderly with high cognitive empathy showed less prosocial behavior.	Rejection rate by offer type as a function of age group and level of cognitive empathy.
Beadle 2013	Total = 48 (24 Healthy Young; 24 Healthy Old)	Healthy Young: 19.83 (± 2.01) Healthy Old: 77.92 (± 7.71)	15 : 9 15 : 9	12.42 (± 1.25) 15.50 (± 2.32)	MMSE	Dictator Game	- MMSE: 29.00 (± 1.10)	Prosocial behaviour due to empathy induction in elderly.	Higher monetary offerings associated with more empathy.
Bottiroli 2016	Total = 62 (20 Healthy Young; 42 Healthy Old)	Healthy Young: 22.75 (± 2.55) Healthy Old: 70.09 (± 6.18)	11 : 9 27 : 15	15.90 (± 1.86) 13.98 (± 4.54)	MMSE	Cognitive and Affective Faux Pas Test	- MMSE: 28.57 (± 1.62)	Cognitive ToM impaired in elderly. Affective ToM similar in both groups.	High scores associated with health.
Calder 2003	Total = 48 (24 Healthy Young; 24 Healthy Old) Total = 125 (32 Healthy Young; 93 Healthy Old) Total = 96 (51 Healthy Young; 45 Healthy Old)	Healthy Young: 25.00 (± 3.84) Healthy Old: 65.08 (± 3.84) Healthy Young: 35.00 (± 2.69) Healthy Old: 61.91 (± 5.11) Healthy Young: 28.71 (± 6.02) Healthy Old: 60.96 (± 6.79)	12 : 12 12 : 12 20 : 12 51 : 42 25 : 26 23 : 22	-	NART-R	Facial Emotion Recognition (POFA)	113.21 (± 7.22) 114.08 (± 10.49) 112.19 (± 8.22) 111.86 (± 10.66) 111.67 (± 8.42) 109.36 (± 12.02)	Fear and sadness impaired in elderly, disgust better than in younger. Fear poorer in elderly. Disgust recognition perserved in elderly.	High rates associated with health.
Calso 2019	Total = 80 (30 Healthy Young; 50 Healthy Old)	Healthy Young: 25.60 (± 4.90) Healthy Old: 74.66 (± 7.88)	15 : 15 35 : 15	16.20 (± 2.80) 12.80 (± 4.18)	MMSE	RMET, MPS-TOMQ	- 27.84 (± 1.87)	RMET, False Belief, MPS-TOMQ impaired in elderly.	High scores associated with health.

Castelli 2010	Total = 24 (12 Healthy Young; 12 Healthy Old)	Healthy Young: 25.20 (± 3.50) Healthy Old: 65.20 (± 5.70)	10 : 2 8 : 4	16.75 (± 2.26) 11.33 (± 2.46)	MMSE	RMET, EDD, First and Second Order False Belief, Strange Stories	MMSE: 29.28 (± 1.40) MMSE: 28.33 (± 1.87)	Poorer performance in older participants in say-prediction tasks and Strange Stories.	High scores associated with health.
Chaby 2015	Total = 62 (31 Healthy Young; 31 Healthy Old)	Healthy Young: 25.80 (± 6.40) Healthy Old: 67.20 (± 5.80)	16 : 15 17 : 14	14.18 (± 1.60) 13.55 (± 2.80)	MMSE	Facial Emotion Recognition (Karolinska Directed Emotional Faces)	- MMSE: 29.33 (± 0.60)	Poorer performance in older participants at recognising negative emotions.	High percentage associated with health.
Cook 2007	Total = 20 (9 Healthy Young; 11 Healthy Old)	Healthy Young: 25.90 (± 6.00) Healthy Old: 68.30 (± 4.90)	-	-	-	Facial Emotion Recognition (POFA)	-	-	-
de Souza 2018	Total = 179 (78 Healthy Young; 101 Healthy Old)	-	-	-	MMSE	Facial Emotion Recognition (POFA)	-	Surprise, fear, anger and neutral impaired in elderly.	High scores associated with health.
Dodich 2014	Total = 132 (51 Healthy Young; 81 Healthy Old)	-	-	-	MMSE	Facial Emotion Recognition (POFA)	-	FER impaired in elderly.	High scores associated with health.
Duclos 2018	Total = 40 (20 Healthy Young; 20 Healthy Old)	Healthy Young: 24.60 (± 2.30) Healthy Old: 77.30 (± 5.90)	12 : 8 15 : 5	14.30 (± 2.20) 10.80 (± 4.20)	MMSE	Affective ToM, Facial Emotion Recognition (own material)	- MMSE: 29 (± 1.10)	Affective ToM and FER impaired in elderly.	High scores associated with health.
Duval 2011	Total = 50 (25 Healthy Young; 25 Healthy Old)	Healthy Young: 23.80 (± 3.12) Healthy Old: 70.14 (± 6.94)		15.44 (± 1.26) 10.36 (± 5.17)	sCDS	Cognitive ToM: Stories, False Belief Task; RMET; Composite ToM (Affective and Cognitive Task): Tom's Taste	sCDS: 19.96 (± 7.19) sCDS: 20.88 (± 9.97)	Cognitive and affective ToM impaired in elderly.	High scores associated with health.
García-Rodríguez 2009	Total = 36 (18 Healthy Young; 18 Healthy Old)	Healthy Young: 31.83 (± 4.93) Healthy Old: 74.66 (± 6.47)	9 : 9 9 : 9	-	MMSE	Facial Emotion Recognition (animation)	- MMSE: 31.80	FER impaired in elderly.	High percentage associated with health.
German 2006	Total = 47 (27 Healthy Young; 20 Healthy Old)	Healthy Young: 19.51 (± 1.51) Healthy Old: 78.22 (± 8.27)	18 : 9 19 : 1	12.78 (± 0.93) 13.20 (± 1.64)	WTAR	ToM Stories, True and False Belief Task	40.67 (± 5.48) 38.40 (± 8.67)	Poorer performance in older patients.	High scores associated with health.

Giovagnoli 2019	Total = 141 (79 Healthy Young; 62 Healthy Old)	-	43 : 36 24 : 38	-	-	Faux Pas Task	-	No difference between young and elderly.	High scores associated with health.
Girardi 2018	Total =52 (22 Healthy Young; 30 Healthy Old)	Healthy Young: 19.55 (± 1.60) Healthy Old: 69.77 (± 6.60)	19 : 3 21 : 9	14.23 (± 1.70) 14.37 (± 2.20)	ACE-R	Faux Pas, Judgement of Preference Task, Ultimatum Game	ACE-R: 95.68 (± 2.64) ACE-R: 96.13 (± 3.13)	No difference in Faux Pas or Judgement of Preference Task between old and young. UG: Elderly accept more unfair offers.	High scores associated with health.
Halberstadt 2011	Total = 121 (60 Healthy Young; 61 Healthy Old)	Healthy Young: 20.50 Healthy Old: 70.50	34 : 26 36 : 25	-	-	Faux Pas Discrimination, Facial Emotion Recognition (FEEST)	-	Poorer performance in elderly participants at Faux Pas discrimination task.	Appropriateness depends on the task type.
Happe 1998	Total = 86 (67 Healthy Young; 19 Healthy Old)	Healthy Young: 21.00/22.50 Healthy Old: 73.00	34 : 33 9 : 10	14.60 14.60	-	ToM Stories	-	Elderly participants performed better on ToM stories.	High scores associated with health.
Harlé 2012	Total = 38 (18 Healthy Young; 20 Healthy Old)	Healthy Young: 22.40 Healthy Old: 64.10	10 : 8 13 : 7	-	MMSE	Ultimatum Game	- MMSE: 29.60 (± 0.60)	Higher acceptance rates in less moderately unfair offers and comparable acceptance rates for fair and unfair offers as young participants.	Acceptance rate in relation to offer type must be considered.
Holland 2018	Total = 1128 (639 Healthy Young; 489 Healthy Old)	Healthy Young: 29.80 (± 5.90) Healthy Old: 68.70 (± 5.20)	-	-	-	Facial Emotion Recognition (Dynamic FACES)	-	Anger impaired in elderly participants.	High percentage associated with health.
Hot 2013	Total = 34 (17 Healthy Young; 17 Healthy Old)	Healthy Young: 21.00 (± 2.40) Healthy Old: 74.10 (± 4.10)	7 : 10 7 : 10	-	MMSE	Facial Emotion Recognition (Morphed Faces Database; Bediou, 2005)	- MMSE: 29.20 (± 0.70)	Fear and anger impaired in elderly participants.	High score associated with number of correct responses.

Hunter 2010	Total = 50 (25 Healthy Young; 25 Healthy Old)	Healthy Young: 22.64 (± 5.86) Healthy Old: 66.96 (± 6.10)	16 : 9 10 : 15	15.08 (± 2.25) 15.40 (± 3.67)	-	Facial Emotion Recognition (FEEST)	-	Surprise, fear, anger and sadness impaired in elderly participants.	High percentage associated with health.
Jarvis 2016	Total = 61 (30 Healthy Young; 31 Healthy Old)	Healthy Young: 20.30 (± 0.88) Healthy Old: 76.20 (± 9.11)	18 : 13 24 : 7	15.08 15.87	MMSE	Cognitive, Affective and Mixed ToM Stories	-	Cognitive, affective and mixed ToM impaired in elderly.	High scores associated with health.
Keightley 2006	Total = 60 (30 Healthy Young; 30 Healthy Old)	Healthy Young: 25.70 (± 5.10) Healthy Old: 72.50 (± 7.80)	15 : 15 15 : 15	17.50 (± 3.40) 14.80 (± 3.20)	MMSE	ToM Stories, Facial Emotion Recognition (JACFEE, JACNeuF)	MMSE: 29.70 (± 0.50) MMSE: 28.80 (± 0.90)	Fear and sadness impaired in elderly participants. No difference in ToM tasks.	High scores associated with health.
Kessels 2013	Total = 168 (124 Healthy Young; 44 Healthy Old)	-	84 : 40 16 : 28	13.13 (± 3.26) 11.13 (± 3.25)	-	Facial Emotion Recognition (Perret Lab)	-	Anger, fear, happiness, and sadness impaired in elderly.	High scores associated with health.
Kiffel 2005	Total = 38 (8 Healthy Young; 30 Healthy Old)	Healthy Young: - Healthy Old: -	3 : 5 18 : 12	-	MMS	Facial Emotion Recognition (POFA)	MMS: >28.00 MMS: >28.00	Elderly performed poor on the identification of disgust-happiness morphed faces.	High percentage means poorer performance.
Kovalchik 2005	Total = 101 (51 Healthy Young; 50 Healthy Old)	Healthy Young: 20.00 Healthy Old: 82.00	26 : 25 35 : 15	-	-	Gambling Task, p-Beauty contest	-	No difference between young and elderly.	-
Lambrecht 2012	Total = 66 (32 Healthy Young; 34 Healthy Old)	-	16 : 16 18 : 16	-	-	Facial Emotion Recognition (unknown material)	-	No difference between young and elderly.	High scores associated with health.
Lautenbacher 2016	Total = 46 (24 Healthy Young; 22 Healthy Old)	Healthy Young: 23.60 (± 4.40) Healthy Old: 69.60 (± 4.30)	12 : 12 12 : 10	-	-	Facial Emotion Recognition (own set)	-	FER impaired in elderly.	High scores associated with health.
MacPherson 2002	Total = 60 (30 Healthy Young; 30 Healthy Old)	Healthy Young: 28.80 (± 6.00) Healthy Old: 69.90 (± 5.50)	15 : 15 15 : 15	15.00 (± 2.40) 12.40 (± 3.20)	-	Faux Pas Task, Facial Emotion Recognition (JACFEE), Gambling Task	-	FER impaired in elderly. No difference in the Gambling Task nor Faux Pas Task between age groups.	High scores associated with number of errors.

Maki 2012	Total = 135 (31 Healthy Young; 104 Healthy Old)	Healthy Young: 19.30 (± 1.40) Healthy Old: 72.10 (± 4.20)	21 : 10 79 : 25	13.30 (± 0.60) 12.00 (± 2.30)	MMSE	Metaphoric and Sarcastic Scenario Test	- MMSE: 28.40 (± 1.40)	Sarcasm impaired in elderly.	High scores associated with health.
Manenti 2017	Total = 44 (22 Healthy Young; 22 Healthy Old)	Healthy Young: 26.90 (± 3.50) Healthy Old: 67.50 (± 3.70)	14 : 8 14 : 8	17.10 (± 1.90) 12.80 (± 4.20)	MMSE	Emotion Priming	- MMSE: 29.20 (± 0.70)	Emotion Priming impaired in elderly.	High percentage associated with health.
Martin 2019	Total = 172 (122 Healthy Young; 50 Healthy Old)	Healthy Young: 23.83 (± 3.80) Healthy Old: 66.18 (± 5.97)	63 : 59 28 : 22	-	-	RMET, Visual Perspective Taking	-	VPT impaired in elderly.	High scores associated with health.
Mattan 2017	Total = 64 (33 Healthy Young; 31 Healthy Old)	Healthy Young: 19.10 (± 0.77) Healthy Old: 71.10 (± 6.04)	26 : 7 17 : 16	-	OCS	Visual Perspective Taking	-	Perspective taking impaired in elderly. Prioritisation of the self in different perspectives in comparison to young participants.	High accuracy scores associated with health.
Maylor 2002	Total = 60 (30 Healthy Young; 30 Healthy Old)	Healthy Young: 21.20 (± 2.50) Healthy Old: 80.60 (± 4.70)	16 : 14 17 : 13	15.60 (± 1.50) 11.20 (± 2.30)	-	ToM Stories	-	Elderly perform worse on ToM Stories Tasks than younger.	High scores associated with health.
McKinnon 2007	Total = 24 (12 Healthy Young; 12 Healthy Old)	Healthy Young: 20.16 Healthy Old: 78.18	-	14.74 15.90	MMSE	First and Second Order ToM Tasks	MMSE: >23.00 MMSE: >23.00	Second Order ToM impaired in elderly.	High scores associated with health.
Nazlidou 2015	Total = 50 (26 Healthy Young; 24 Healthy Old)	Healthy Young: 23.40 (± 4.00) Healthy Old: 71.60 (± 5.80)	12 : 14 12 : 12	-	MMSE	Indirect Speech Understanding Task, Faux Pas Task, Facial Emotion Recognition (EET)	- MMSE: 28.80 (± 1.60)	Faux Pas, Indirect Speech Understanding and Emotion Recognition impaired in elderly.	High scores associated with health.
Phillips 2002	Total = 60 (30 Healthy Young; 30 Healthy Old)	Healthy Young: 29.90 (± 7.10) Healthy Old: 69.20 (± 6.10)	19 : 11 15 : 15	14.45 (± 2.79) 12.20 (± 3.11)		RMET, Facial Emotion Recognition (POFA)		RMET impaired in elderly. No difference in Facial Emotion Recognition.	High scores associated with health.

Phillips 2011	Total = 88 (52 Healthy Young; 36 Healthy Old)	Healthy Young: 25.81 (± 5.45) Healthy Old: 73.67 (± 5.06)	27 : 25 21 : 15	-	-	ToM Video Task, ToM Stories Task: True Belief/False Belief Tasks	-	ToM Video Task and ToM Stories: Impaired in elderly.	High percentage associated with health.
Rakoczy 2012	Total = 47 (27 Healthy Young; 20 Healthy Old)	Healthy Young: 22.67 (± 2.80) Healthy Old: 73.30 (± 9.55)	14 : 13 9 : 11	-	MMSE	ToM Stories, Video Task (Emotion Recognition, Sullivan & Ruffman, 2004)	MMSE: >28.00 MMSE: >28.00	ToM Video Task and ToM Stories: Impaired in elderly.	High scores associated with health.
Richoz 2018	Total = 186 (85 Healthy Young; 101 Healthy Old)	-	63 : 22 73 : 28	-	MMSE	Facial Emotion Recognition (Gold et al. database, 2013)	- MMSE: >24.00	FER impaired in elderly.	High scores associated with health.
Roalf 2011	Total = 59 (29 Healthy Young; 30 Healthy Old)	Healthy Young: 30.14 (± 5.53) Healthy Old: 71.30 (± 4.36)	14 : 15 15 : 15	15.00 (± 2.80) 15.00 (± 3.60)	MMSE	Ultimatum Game, Dictator Game	- MMSE: >28.97 (± 1.03)	UG: Elderly required larger offers to be accepted. DG: Elderly more likely to distribute funds equally.	Acceptance rate in relation to offer type must be considered.
Ruffman 2006	Total = 79 (39 Healthy Young; 40 Healthy Old)	Healthy Young: 21.00 (± 4.53) Healthy Old: 69.00 (± 6.47)	23 : 16 23 : 17	-	-	Facial Emotion Recognition (Adolphs et al. database, 1998)	-	No difference between young and elderly.	High rates associated with health.
Smith 2018	Total = 34 (17 Healthy Young; 17 Healthy Old)	Healthy Young: 24.80 (± 4.90) Healthy Old: 70.10 (± 5.00)	14 : 3 11 : 6	-	-	Facial Emotion Recognition (FACES)	-	No difference between young and elderly.	High percentage associated with health. High amount of information inversely associated with pathology.
Sullivan 2004	Total = 48 (24 Healthy Young; 24 Healthy Old)	Healthy Young: 30.00 (± 7.50) Healthy Old: 73.00 (± 6.00)	11 : 13 16 : 8	-	MMSE	ToM Stories, Facial Emotion Recognition (POFA), ToM Videos Task	- MMSE: >26.00	ToM Video Task, Facial Emotion Recognition and ToM Stories: Impaired in elderly.	High scores associated with health.

Sullivan 2004	Total = 61 (31 Healthy Young; 30 Healthy Old)	Healthy Young: 26.00 Healthy Old: 72.00	19 : 12 18 : 12	-	-	Facial Emotion Recognition (POFA)	-	Sadness and anger impaired in elderly.	High scores associated with health.
Sutter 2005	Total = 350 (282 Healthy Young; 68 Healthy Old)	Healthy Young: - Healthy Old: 68.00	-	-	-	Trust Game	-	Trust and trustworthiness is similar in both groups.	-
Suzuki 2007	Total = 68 (34 Healthy Young; 34 Healthy Old)	Healthy Young: 20.60 (± 1.80) Healthy Old: 69.70 (± 4.80)	17 : 17 17 : 17	13.60 (± 1.70) 13.20 (± 2.60)	MMSE	Facial Emotion Recognition (JACFEE)	- MMSE: 29.00 (± 1.10)	Disgust improved in elderly. Sadness impaired in elderly.	High scores associated with health.
Verdon 2007	Total = 40 (20 Healthy Young; 20 Healthy Old)	Healthy Young: 27.00 (± 5.75) Healthy Old: 82.00 (± 4.52)	11 : 9 12 : 8	16.00 (± 6.86) 15.00 (± 4.50)	MMSE	ToM Cartoon Task	- MMSE: 29.00 (± 0.54)	No difference between young and old.	High scores associated with health.
Waring 2019	Total = 80 (44 Healthy Young; 36 Healthy Old)	Healthy Young: 19.00 (± 1.14) Healthy Old: 70.42 (± 7.32)	20 : 24 19 : 17	12.70 (± 1.00) 15.92 (± 2.27)	MMSE	Go/No-Go Task	- MMSE: 29.17 (± 1.06)	Younger adults: Faster reaction time. Elderly had greater response inhibition.	High scores associated with pathology.
Werheid 2010	Total = 40 (20 Healthy Young; 20 Healthy Old)	Healthy Young: 24.40 (± 4.20) Healthy Old: 66.20 (± 5.10)	14 : 6 12 : 8	11.90 (± 0.50) 11.80 (± 1.50)	MMSE	Facial Emotion Recognition (own material)	-	No difference between young and old.	High percentage associated with health.
Williams 2009	Total = 731 (311 Healthy Young; 420 Healthy Old)	-	187 : 124 212 : 208	-	-	Facial Emotion Recognition (WebNeuro)	-	Except happiness, facial emotion recognition was impaired in elderly. Reaction time was increased in elderly.	High percentage associated with health. High reaction time correlates with pathology.
Yildirim 2020	Total = 97 (50 Healthy Young; 47 Healthy Old)	Healthy Young: 21.60 (± 2.10) Healthy Old: 59.20 (± 6.10)	30 : 20 26 : 21	15.12 (± 1.35) 14.34 (± 3.38)	MMSE	RMET	- MMSE: >26.00	No difference between young and old.	High scores associated with health.

Table 9. Studies investigating healthy older individuals and individuals with SCD.

Pietschnig 2016	Total = 137 (68 SCD; 69 MCI)	Jessen (SCD) Petersen (MCI)	SCD: 68.96 (± 7.51) MCI: 71.66 (± 7.96)	-	-	MMSE	Facial Emotion Recognition (VERT-K)	-	SCD perform better than MCI but worse than controls.	High scores associated with health.
Yildirim 2020	Total = 63 (32 SCD; 31 MCI)	Jessen (SCD) Petersen (MCI)	SCD: 64.53 (± 6.92) MCI: 64.52 (± 8.71)	20 : 12 11 : 20	11.91 (± 4.95) 10.58 (± 4.71)	MMSE	RMET, Faux Pas Task	MMSE: >25.00	RMET impaired in MCI. No difference in the Faux Pas Task.	High scores associated with health.

Table 10. Studies investigating healthy older individuals and individuals with MCI.

Baglio 2011	Total = 31 (15 Healthy; 16 aMCI)	Petersen	Healthy: 71.00 (± 5.80) aMCI: 66.90 (± 6.40)	6 : 9 9 : 7	10.80 (± 3.50) 9.90 (± 4.80)	MMSE	ToM, First Order False Belief Task, Second Order False Belief Task, Complex ToM Tasks, Selection from Strange Stories	MMSE: 29.00 (± 1.30) MMSE 27.00 (± 1.80)	aMCI impaired only in FB2.	High scores associated with health.
Bediou 2009	Total = 20 (10 Healthy; 10 aMCI)	Petersen	Healthy: 70.00 ± 6.00 aMCI: 73.00 ± 9.00	5 : 5 5 : 5	-	MMSE	Facial Emotion Recognition (own material)	MMSE: 27.00 (± 2.00) MMSE: 30.00	No difference.	High percentage associated with health.
Dodich 2016	Total = 80 (65 Healthy; 15 aMCI)	IWG	Healthy: 66.89 (± 8.66) aMCI: 73.07 (± 6.15)	34 : 31 5 : 10	12.18 (± 4.49) 12.33 (± 4.86)	MMSE	Comic Strip, Intention and Emotion Attribution	MMSE: 28.64 (± 1.09) MMSE: 25.64 (± 2.29)	No difference.	High scores associated with health.
Fujie 2008	Total = 30 (16 Healthy; 14 aMCI)	Petersen	Healthy: 74.10 (± 3.20) aMCI: 71.70 (± 7.10)	10 : 4 12 : 4	12.00 (± 2.20) 11.00 (± 2.20)	MMSE, WMS	Facial Emotion Recognition (Adolphs et al. database, 1998)	MMSE: 28.80 (± 1.40) MMSE: 27.20 (± 2.30)	Impaired in MCI (sadness and anger).	High scores associated with health.
García-Casal 2018	Total = 128 (69 Healthy; 59 aMCI)	IWG	Healthy: 73.14 (± 6.28) aMCI: 77.60 (± 5.01)	26 : 43 28 : 31	7.76 (± 3.45) 7.09 (± 3.89)	MMSE	Facial Emotion Recognition (Affect-GRADIOR)	MMSE: 28.38 (± 1.31) MMSE: 24.02 (± 2.36)	MCI impaired.	High scores associated with health.
Gaudreau 2013	Total = 64 (33 Healthy; 31 aMCI)	Petersen	Healthy: 73.10 (± 8.20) aMCI: 74.50 (± 6.80)	-	14.20 (± 4.00) 13.60 (± 5.40)	MOCA, DRS, TMT, color-word	ToM Stories, First- and Second-Order ToM	MOCA: 26.80 (± 2.60) MOCA: 23.10 (± 3.50)	MCI impaired in second-order ToM.	High scores associated with health.

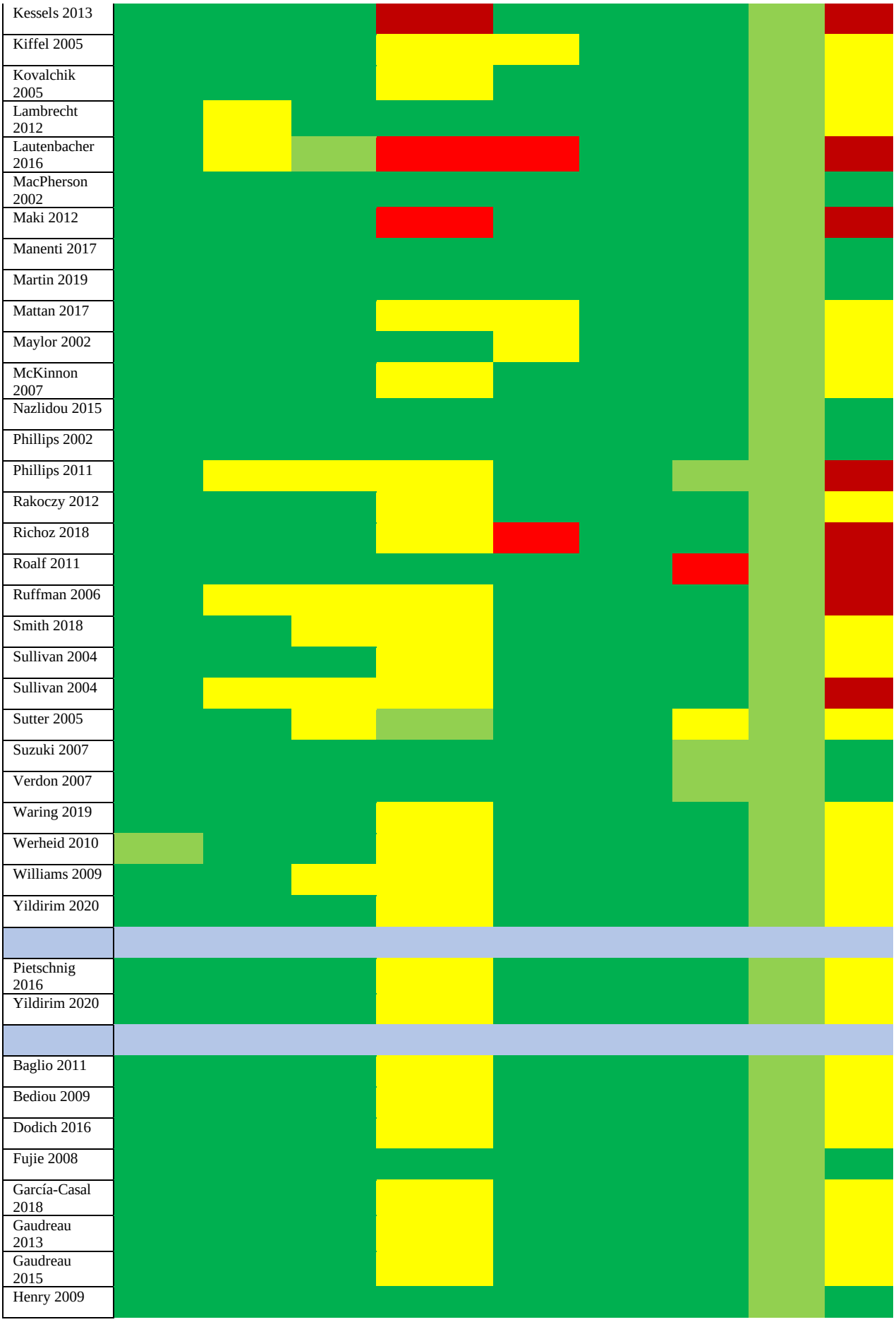
Gaudreau 2015	Total = 60 (30 Healthy; 30 MCI)	Albert	Healthy: 71.90 (±8.20) aMCI: 73.90 (±6.10)	19 : 11 18 : 12	14.2 (± 4.0) 13.6 (± 5.3)	MOCA	ToM: Combined Stories Task, Short Scenario Irony Comprehension Task	MOCA: 26.5 (± 2.4) MOCA: 23.0 (± 3.2)	MCI impaired in second-order ToM.	High scores associated with health.
Henry 2009	Total = 72 (34 Healthy; 38 aMCI)	Petersen	Healthy: 77.20 (± 4.30) aMCI: 78.70 (± 4.53)	21 : 17 18 : 18	11.60 (± 3.58) 11.60 (± 3.56)	MMSE	Facial Emotion Recognition (Adolphs et al. database, 1998)	MMSE: 28.60 (± 1.44) MMSE: 27.90 (± 1.52)	MCI impaired.	High scores associated with health.
Henry 2012	Total = 74 (38 Healthy; 36 aMCI)	IWG	Healthy: 77.40 (± 4.40) aMCI: 78.30 (± 4.10)	23 : 15 17 : 19	11.50 (± 3.43) 11.90 (± 3.64)	MMSE	Facial Emotion Recognition (POFA)	MMSE: 28.80 (± 0.98) MMSE: 27.60 (± 1.90)	MCI impaired.	High accuracy associated with health.
Maki 2012	Total = 146 (104 Healthy; 42 aMCI)	IWG	Healthy: 72.10 (± 4.20) aMCI: 74.00 (± 5.40)	79 : 25 24 : 18	12.00 (± 2.30) 11.10 (± 3.00)	MMSE	Metaphoric and Sarcastic Scenario Test	MMSE: 28.40 (± 1.40) MMSE: 25.80 (± 1.70)	MCI impaired.	High scores associated with health.
McCade 2013	Total = 78 (22 Healthy; 56 MCI)	Petersen	Healthy: 65.18 (± 8.37) MCI: 66.80 (± 8.20)	13: 9 31: 25	12.73 (± 2.79) 13.84 (± 3.60)	MMSE, digit span, WMS, TMT, fluency, BNT	Facial Emotion Recognition (FEEST)	MMSE: 29.32 (± 0.84) MMSE: 27.87 (± 1.74)	MCI Impaired, aMCI particularly in anger recognition.	High scores associated with health.
McCade 2013	Total = 56 (19 Healthy; 37 MCI)	Petersen	Healthy: 64.79 (± 8.45) MCI: 66.78 (± 8.17)	10 : 9 23 : 14	12.89 (± 2.87) 13.58 (± 3.40)	MMSE	Facial Emotion Recognition (FEEST)	MMSE: 29.32 (± 0.82) MMSE: 27.73 (± 1.74)	aMCI impaired, naMCI comparable with controls.	High scores associated with health.
McCade 2018	Total = 50 (18 Healthy; 32 MCI)	IWG	Healthy: 64.61 (± 8.37) MCI: 65.59 (± 8.10)	11 : 7 20 : 12	12.83 (± 2.94) 13.29 (± 3.08)	MMSE, WTAR	Facial Emotion Recognition (FEEST)	MMSE: 29.22 (± 0.88) MMSE: 27.75 (± 1.83)	aMCI impaired in anger, naMCI comparable with controls.	High scores associated with health.
Michaelian 2019	Total = 166 (52 Healthy; 114 MCI)	IWG	Healthy: 62.20 (± 7.10) MCI: 63.40 (± 6.80)	38 : 14 64 : 50	14.00 (± 3.20) 13.90 (± 3.20)	MMSE	RMET	MMSE: 29.30 (± 0.90) MMSE: 28.40 (± 1.70)	MCI significantly worse than healthy, aMCI more than naMCI.	High scores associated with health.
Moreau 2015	Total = 45 (25 Healthy; 20 MCI)	Petersen	Healthy: 72.96 (± 7.59) MCI: 75.95 (± 6.60)	-	12.52 (± 4.11) 9.70 (± 5.01)	List learning, TMT, Fluency, cart sorting, Logical memory, Zoo map, LNS, MMSE	False Belief Task, The Referential Communication Task	MMSE: 29.08 (± 1.22) MMSE: 25.89 (± 1.79)	ToM impaired.	Number of correct answers associated with health.

Park 2017	Total = 65 (33 Healthy; 32 aMCI)	Petersen	Healthy: 70.97 (± 6.45) MCI: 74.34 (± 4.56)	22 : 11 21 : 11	12.27 (± 3.19) 10.25 (± 3.43)	MMSE	Facial Emotion Recognition (own material)	MMSE: 27.91 (± 1.96) MMSE: 24.69 (± 2.42)	No difference.	High scores associated with health.
Pernigo 2015	Total = 48 (24 Healthy; 24 aMCI)	Mayo (Petersen)	Healthy: 73.80 (± 5.90) MCI: 74.40 (± 5.90)	13 : 11 13 : 11	9.80 (± 4.40) 8.90 (± 4.50)	MMSE, MOCA	Facial Emotion Recognition (POFA)	MOCA: 27.30 (± 2.20) MOCA: 23.80 (± 3.10)	No difference.	High scores associated with health.
Pietschnig 2016	Total = 207 (138 Healthy; 69 MCI)	Petersen	Healthy: 66.49 (± 10.49) MCI: 71.66 (± 7.96)	-	-	MMSE, Verbal fluency, TMT, List learning, Stroop, 5-point, Maze	Facial Emotion Recognition (VERT-K)	MMSE: 28 med. MMSE: 28 med.	aMCI impaired, non-aMCI no difference.	High scores associated with health.
Poletti 2012	Total = 40 (20 Healthy; 20 aMCI)	Petersen	Healthy: 70.10 (± 6.10) aMCI: 71.70 (± 6.30)	15 : 5 14 : 6	9.10 (± 3.30) 8.20 (± 4.80)	MMSE, List learning, verbal, Fluency, TMT, FAB, RPM	RMET	MMSE: 29.50 (± 2.60) MMSE: 27.00 (± 1.90)	aMCI impaired.	High percentage associated with health. High scores correlate with health.
Richard-Mornas 2012	Total = 29 (17 Healthy; 12 aMCI)	Petersen	Healthy: 68.50 (± 5.30) aMCI: 70.00 (± 5.30)	7 : 5 7 : 10	-	MMSE	Facial Emotion Recognition (Morphed Faces Database; Bediou, 2005)	MMSE: 26.40 (± 1.30) MMSE: 30.00 (± 0.70)	Fear recognition is impaired in aMCI (Face).	High rates associated with health.
Rossetto 2018	Total = 34 (18 Healthy; 16 aMCI)	DSM 5	Healthy: 74.06 (± 3.39) aMCI: 75.88 (± 3.65)	10 : 8 8 : 8	12.00 (± 3.24) 11.81 (± 2.40)	MMSE, MOCA	Strange Stories, RMET, Yoni Task, Deceptive Box Task, Look & Say Prediction Tasks	MMSE: 29.50 (± 0.10) MMSE: 28.21 (± 1.56)	RMET, Yoni Task and Strange Stories worse than HC.	High scores associated with health.
Sarabia-Cobo 2015	Total = 100 (50 Healthy; 50 MCI)	Petersen	Healthy: 75.36 (± 5.47) MCI: 77.86 (± 5.66)	25 : 25 25 : 25	8.04 (± 3.75) 6.38 (± 2.40)	MMSE	Facial Emotion Recognition (animation)	MMSE: 29.52 (± 0.93) MMSE: 23.08 (± 2.17)	MCI impaired.	High percentage associated with health.
Sheardova 2014	Total = 85 (42 Healthy; 43 MCI)	Petersen	Healthy: 71.55 (± 4.95) MCI: 72.14 (± 8.66)	25 : 17 22 : 21	15.79 (± 2.59) 14.35 (± 3.30)	MMSE	Facial Emotion Recognition (POFA)	MMSE: 28.54 (± 1.44) MMSE: 26.32 (± 2.72)	MD-aMCI impaired in FER but not SD-aMCI.	High scores associated with health.

Spoletini 2008	Total = 100 (50 Healthy; 50 aMCI)	Petersen	Healthy: 71.84 (± 7.35) aMCI: 71.20 (± 7.49)	28 : 22 23 : 27	9.06 (± 4.18) 9.78 (± 4.60)	MMSE, list learning, Visual memory, RPM	Facial Emotion Recognition (ER-40)	MMSE: 27.82 (± 1.75) MMSE: 26.68 (± 2.50)	MCI more impaired in low-intensity faces (Fear).	High scores associated with health.
Teng 2007	Total = 91 (68 Healthy; 23 MCI)	Petersen	Healthy: 69.54 (± 9.45) MCI: 75.39 (± 7.20)	29 : 39 9 : 14	16.96 (± 2.86) 16.32 (± 3.46)	MMSE	Facial Emotion Recognition (FAB)	MMSE: 29.24 (± 0.90) MMSE: 26.68 (± 2.69)	MD-MCI impaired in FER but not SD-MCI.	High percentage associated with health.
Varjassyova 2013	Total = 40 (18 Healthy; 22 aMCI)	Petersen	Healthy: 69.30 (± 7.60) aMCI: 76.07 (± 8.18)	12 : 6 13 : 9	18 11	MMSE	Facial Emotion Recognition (POFA)	MMSE: 29.30 (± 0.90) MMSE: 27.52 (± 2.20)	MD-MCI impaired in FER but not SD-MCI.	High scores associated with health.
Weiss 2008	Total = 86 (35 Healthy; 51 aMCI)	Petersen	Healthy: 70.80 (± 7.50) aMCI: 73.68 (± 6.77)	25 : 10 35 : 16	10.70 (± 3.30) 10.10 (± 3.20)	MMSE	Facial Emotion Recognition (ER-40)	MMSE: 28.90 (± 1.00) MMSE: 26.40 (± 1.20)	Sadness, Neutrality and Fear impaired in MD-MCI.	High percentage associated with health.
Yang 2015	Total = 48 (24 Healthy; 24 aMCI)	Petersen	Healthy: 71.79 (± 3.74) aMCI: 71.50 (± 4.53)	12 : 12 14 : 10	9.33 (± 3.55) 8.20 (± 4.12)	MOCA, MMSE	Facial Emotion Recognition (China Faces Emotions Materials database; Wang et al. 2005)	MMSE: 28.79 (± 1.38) MMSE: 26.58 (± 1.86)	MCI impaired.	Higher hit rates associated with health.

8.5. Risk of Bias Assessment

Table 10. Risk of Bias Assessment


Kessels 2013
Kiffel 2005
Kovalchik 2005
Lambrecht 2012
Lautenbacher 2016
MacPherson 2002
Maki 2012
Manenti 2017
Martin 2019
Mattan 2017
Maylor 2002
McKinnon 2007
Nazlidou 2015
Phillips 2002
Phillips 2011
Rakoczy 2012
Richoz 2018
Roalf 2011
Ruffman 2006
Smith 2018
Sullivan 2004
Sullivan 2004
Sutter 2005
Suzuki 2007
Verdon 2007
Waring 2019
Werheid 2010
Williams 2009
Yildirim 2020
Pietschnig 2016
Yildirim 2020
Baglio 2011
Bediou 2009
Dodich 2016
Fujie 2008
García-Casal 2018
Gaudreau 2013
Gaudreau 2015
Henry 2009

Legend:

Risk od Bias assessment:

- Yes
- Probably Yes
- No
- Probably No
- No Information

Overall:

- Low Risk
- High Risk
- Some Concerns

Erklärung des Eigenanteils

Die Konzeption der systematischen Übersichtsarbeit und Meta-Analyse erfolgte durch Prof. Dr. Marcus Meinzer und Dr. Mandy Roheger. Die systematische Literaturrecherche wurde in einem mehrstufigen Verfahren durch Jana Brenning und Dr. Mandy Roheger durchgeführt. Auswertung und Extraktion der Daten erfolgte ebenfalls durch Jana Brenning und Dr. Mandy Roheger. Die qualitative Beurteilung der eingeschlossenen Studien und das Verzerrungsrisiko wurde durch Jana Brenning, Dr. Mandy Roheger und Steffen Riemann durchgeführt. Die Planung des korrekten statistischen Prozederes erfolgte durch Dr. Mandy Roheger. Alle statistischen Berechnungen und Graphiken wurden von Jana Brenning durchgeführt. Die Dissertationsschrift wurde unter Angaben der genannten Quellen von Jana Brenning verfasst. Die Tabellen und Abbildungen der Dissertation wurden von Jana Brenning, mit Verweis auf Quellen, erstellt.

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