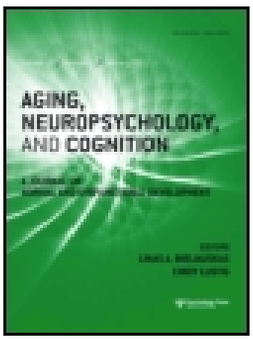

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Age differences in social-cognitive abilities across the stages of adulthood and path model investigation of adult social cognition

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ABSTRACT

Accumulating evidence points toward an association between older age and performance decrements in social cognition (SC). We explored age-related variations in four components of SC: emotion recognition, theory of mind, social judgment, and blame attributions. A total of 120 adults divided into three stages (18–34 years, 35–59 years, 60–85 years) completed a battery of SC. Between and within age-group differences in SC were investigated. Path analyses were used to identify relationships among the components. Emotion recognition and theory of mind showed differences beginning either in midlife, or after. Blame attributions and social judgment did not show a significant difference. However, social judgment varied significantly within groups. Path models revealed a relationship between emotion recognition and theory of mind. Findings highlight age-related differences in some components and a link between two components. Strategies promoting social functioning in aging might help to maintain or improve these abilities over time.

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Social cognition; aging; modeling; group analysis; cross-sectional studies

Introduction

Normal aging has been extensively associated with a wide range of changes in sensorimotor functioning, language processes, and cognitive abilities (Burke & Shafto, 2008; Cadar, 2018; Jurado & Rosselli, 2007; Seidler et al., 2010). Over the adult lifespan, poorer performances were observed in diverse "fluid" cognitive components such as speed of processing, memory, visuospatial abilities, and executive functioning, including attention control, working memory, inhibition, planning, reasoning, and decision-making (Craik & Bialystok, 2006; Harada et al., 2013; Lezak et al., 2012; Murman, 2015; Salthouse, 2010). Empirical support for differential trajectories of age-related differences across cognitive domains has also accumulated in recent years. Processing speed, abstraction, inhibition, mental flexibility, and some aspects of attention and memory have been identified as being especially sensitive to the effects of aging, whereas "crystallized" abilities such as general knowledge and vocabulary remain relatively intact over the lifespan and may

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even slightly improve in late adulthood (Hedden & Gabrieli, 2004; Hoogendam et al., 2014; Lezak et al., 2012; Van Hooren et al., 2007). Some reports suggest age-related decline for cognitive processes such as reasoning, memory, and speed of processing prior to 60 years of age, in early or middle adulthood (Salthouse, 2009, 2015; Singh-Manoux et al., 2012; Soubelet & Salthouse, 2011). In contrast, the quality of social relations appears to positively impact middle-aged and older adults' cognitive functioning (e.g., social network size and frequency of contact positively influence performance on measures of global cognition) (Kelly et al., 2017; Rutter et al., 2020).

Social cognition and typical aging

Beyond what can be termed intrapersonal neurocognitive functions, interpersonal or social cognitive (SC) functions have attracted increasing attention from researchers. These latter functions encompass the processes through which people perceive and understand social information, interact in everyday life, and develop social relationships. Following the studies conducted by the National Institute of Mental Health (NIHM; Green et al., 2008) and RAND panelists of the Social Cognition Psychometric Evaluation (SCOPE project) (Pinkham et al., 2018, 2014, 2016), a consensus emerged concerning the nature of the SC components identified by the panel as emotion processing, social perception, attributional style/bias, and theory of mind (ToM). Pinkham et al. (2014) defined emotion processing as the identification and understanding of facial expressions, while social perception was defined as the interpretation of social cues in others, including contextual social judgments (Pinkham et al., 2014). Gunther Moor et al. (2010) described it as a social feedback process underlying the ability to form judgments about other people based on context-dependent signals, prior expectations, and self-knowledge (e.g., for social acceptance). The RAND Panel defined ToM as inferences about others' mental states. ToM involves a cognitive component (inferring people's beliefs, intentions, thoughts, and desires) and an affective component (making inferences about emotions) (Shamay-Tsoory & Aharon-Peretz, 2007). Finally, attributional style/bias refers to the habitual way that individuals ascribe causes to their life experiences (Pinkham et al., 2014). Previous studies highlighted the importance of SC abilities as predictors of social and community functioning (Couture et al., 2006; Fett et al., 2011; Mancuso et al., 2011), social competence (Couture et al., 2011), and interpersonal relations (Penn et al., 1997; Poole et al., 2000; Reis & Downey, 1999; Silberstein et al., 2018).

Research on normal aging has shown age-related variations in SC abilities. Moreover, a large body of literature of SC focused on the contribution of neurocognitive abilities to social information processing. Social and nonsocial cognitive domains were found to be related, but distinct constructs (Mehta et al., 2013; Sergi et al., 2007). Most studies of SC included neurocognitive measures, as many studies have shown a significant correlation between the latter and the former. Accordingly, the MATRICS committee identified cognitive domains to be included in studies of SC and schizophrenia (Nuechterlein et al., 2008). In this context, social cognition has been found to be a mediator between neurocognition and functional outcomes (Schmidt et al., 2011). In other clinical and non-clinical contexts, neurocognitive variables are regularly included to avoid confounding deficits in neurocognition and SC, such as measures of language functions (Baksh et al., 2018; Lugnegård et al., 2013; Martinez et al., 2017; Valle et al., 2015) as well as measures of

executive functions, attention, and working memory (Dolcos et al., 2020; Dziobek et al., 2006; Gonzalez-Gadea et al., 2013; Keightley et al., 2006; Spreng & Turner, 2019).

There is relatively less research on SC and middle age as compared to that in young adults and older adults (Bernstein et al., 2011; Hedden & Gabrieli, 2004; Hess, 2006; Stanley & Blanchard-Fields, 2008). Only a few studies considered age differences in SC across three stages of adulthood – young adult, middle age, and late adulthood – either in the context of a control group or a cross-sectional study. Moreover, to our knowledge, no study has yet investigated age differences in SC components within and between three stages of adulthood, young, middle, and late adulthood, using a battery composed of multiple components of SC that was previously found to be reliable and valid.

There is empirical support from longitudinal and cross-sectional studies for differences in emotion recognition with advancing age (Gonçalves et al., 2018; Hayes et al., 2020; Keightley, Magai, 2008; Pressman et al., 2016; Ruffman et al., 2008; Winocur, Burianova, Hongwanishkul, & Grady, 2006). Sullivan and Ruffman (2004) found an age-related decline in older adults (aged 60–82 years old) in emotion recognition even after controlling for fluid abilities. Keightley et al. (2006) found impaired identification of fear and sadness in older adults but the age differences were not related to performance on a battery of neurocognitive tests. Holland et al. (2019) reported evidence for age differences in emotion recognition favoring young (18–39 years old, M_{age} = 29.8 years) and middle-aged adults (40–59 years old, M_{age} = 50.8 years) in a large sample of 1822 subjects, while older adults (60–86 years, M_{age} = 68.5 years) performed worse than both younger groups. However, Isaacowitz et al. (2007) reported that middle-aged adults (40–59 years old, M_{age} = 48.01 years) performed more poorly when identifying happiness and disgust than young (18–39 years old, M_{age} = 27.05 years) and older adults (60–85 years old, M_{age} = 71.90 years), but the older group's performance was worse than the other groups when identifying fear and anger.

There are numerous studies of normal aging in ToM although the results are mixed. An early controversial study because of a possible sampling bias (Happé et al., 1998) found an improved ToM performance with age (see however Maylor et al., 2002; Sullivan & Ruffman, 2004). In a subsequent meta-analysis review (Henry et al., 2013) including 22 studies, results indicated that older adults performed more poorly on most ToM tasks included in the analysis, compared to young adults. Other findings suggested age-related differences in cognitive ToM versus affective ToM (Wang & Su, 2013). Bailey et al. (2018) reported preserved affective ToM with advanced age in response to another's pain. Similarly, Bottiroli et al. (2016) found impairments in cognitive ToM in aging while the affective component was preserved. Their results also showed a link between executive functions and cognitive ToM deficits. Later investigations reported ToM impairments in typical aging (usually 60+ years old) that were at least partially mediated by cognitive abilities such as executive functioning and verbal abilities (Cho et al., 2019; German & Hehman, 2006; Li et al., 2013; Moran, 2013; Rakoczy et al., 2017; Sandoz et al., 2014). Overall, the heterogeneity of results obtained with widely divergent age groups can be accounted for by the variety of tasks, sample size, methods, paradigms (stories, videos, cartoons, animated shapes), levels of inferences, aspects (cognitive, affective, mixed ToM), cognitive demands, and assessment modalities (visual, verbal) used in ToM research.

There are only a few studies that provide data on ToM performance in middle adulthood. Bernstein et al. (2011) found that late middle-aged (51–59 years old, M_{age}

= 56.3 years) and older adults (60–85 years old, M_{age} = 67.6 years) performed worse in a false belief task than young adults (17–22 years old, M_{age} = 19.2 years), even after adjustment for a variety of cognitive factors, while the older groups did not differ significantly. Duval et al. (2011) found that middle-aged adults (45–59 years old, M_{age} = 52.55 years) performed better than older adults (61–83 years old, M_{age} = 70.14 years) on a false belief task, but worse than the younger group (21–34 years old, M_{age} = 23.80 years) even after accounting for executive functions. Franco and Smith (2013) reported similar findings using the Strange Stories task (Happé, 1994; Happé et al., 1998), with middle-aged adults (30–59 years old, M_{age} = 39.5 years) scoring lower than young adults (16–29 years old, M_{age} = 19.1 years), but slightly better than the older group (60–80 years old, M_{age} = 69.4 years). The results from Bernstein et al. (2011), Duval et al. (2011), and Franco and Smith (2013) studies suggest that a decrease in ToM performance may occur as early as midlife.

It remains largely unclear whether there are age related differences in social knowledge and social judgment with increasing age, since they received less attention in SC and aging research among healthy adults. According to Freund and Isaacowitz (2014), social judgments rely on the detection of complex environmental cues and their use to form impressions of others, which is believed to remain stable with advancing age. However, Hess et al. (1999) found that young adults used different criteria than middle-aged and older subjects (who used similar criteria), when making social/moral judgments of honest versus dishonest people.

Some evidence suggests that there are age differences in causal attributions across adulthood, with older adults showing a higher internal/dispositional tendency (vs. situational) than younger adults (Horhota et al., 2014). Beyond these differences, SC age related differences over the adult lifespan, especially those occurring in middle adulthood, require further examination. Identifying age differences in SC abilities across three different stages of adulthood (young adults: 18–34 years old; middle-aged adults: 35–49 years old; older adults: 60–85 years old) may help to better understand and address interindividual differences across the lifespan. It may also provide a template for assessing normal aging, and by inference, deviations from the normal. The lack of information regarding age differences in SC abilities has the potential of affecting decisions concerning the pertinence of early intervention as well as interpreting data.

Social cognition and quality of interpersonal relationships

The quality of interpersonal relationships is related to the ability of partners, colleagues, friends to explore and share experiences, to find solutions to problems, to find ways to improve the relationship such that each feels valued, supported, and understood, which in turn leads to the creation, preservation and strengthening of social relationships (adapted from Carmeli et al., 2009; Reis et al., 2004). When examining the quality of interpersonal relationships for age differences, older adults show a tendency to limit their social activities (e.g., visiting relatives, meetings, club/society) compared to young adults (Bailey et al., 2008) which can impact the quality of their relationships. Additionally, older adults appear to have smaller social networks, be less connected and have fewer interactions with their network members than middle-aged adults (Cornwell et al., 2008). On the other hand, some evidence supports maintenance or improvement of relationship

quality in late adulthood (Sze et al., 2012). The decrease in the number of one's relationships can reflect a selection of higher quality relationships with advancing age (Carr & Moorman, 2011). Lang and Carstensen (1994) results suggest that the number of very close social partners remains stable in late adulthood (versus a reduction of less close social partners), and Luong et al. (2010) reported that older adults experience more satisfying and positive social relationships than younger adults. Instruments developed to assess the quality of social relationships vary considerably in terms of their structure, function, and degree of subjectivity (for a review of existing instruments, see Valtorta et al., 2016). Most questionnaires focus on only one domain of relationships, such as family (Aguilar-Raab et al., 2015) or on only one aspect of social relationships (e.g., involvement in relationships) (Valtorta et al., 2016). On the other hand, semi-structured interviews covering different social relationship dimensions frequently assess social relationships in a broader framework, such as general quality of life. Such tools are time consuming to administer, transcribe and interpret (Aguilar-Raab et al., 2015), thus reducing their usefulness when time is a consideration.

An alternative to semi-structured interviews are structured questionnaires, used to assess different types of social relationships, one of which, the Interpersonal Relationship Quality Scale (IRQS) (Senécal et al., 1992) focuses on respondents' satisfaction with the quality of their relations in various domains (romantic relationships, family, friends, colleagues/other students, people in general). The scale was selected by the committee of experts of the Institut national de santé publique du Québec (Canuel et al., 2019) as a standardized, psychometrically validated instrument for measuring social support in the population (see Methods).

Relationships between each component of social cognition

Only a few studies explored the associations between the various components of SC in healthy subjects. What evidence there is suggests a relationship between some components. The pertinent studies focused particularity on the relationship between emotion recognition and ToM abilities. For example, Gourlay et al. (2020) reported associations between emotion recognition and ToM, while Halberstadt et al. (2011) found in their study that emotion recognition fully mediates the relationship between age and ToM. Mitchell and Phillips (2015) found that lower-level perceptual processes, including emotion recognition, occur at an earlier temporal stage than the higher-level process that is ToM, which requires integration and inference of more complex social information. According to Coccaro et al. (2009), the way an individual encodes contextual social cues may influence the ability to recognize facial emotions and consequently affect the interpretation of others' intentions. In the same vein, Mitchell (2006) reported that an individual's accumulated social knowledge about his/her mental states might be used to infer others' mental states in similar contexts. According to Ziaei et al. (2016), the capacity to identify facial affect (e.g., fear) and eye-gaze cues were associated with recognizing complex emotions expressed in the eye region, for younger but not older adults. Additionally, the higher social cognitive process of empathy, a construct close to ToM (Pinkham et al., 2014), was positively associated, with processing of angry faces of their own age group, in young but not in older adults (Ziaei et al., 2019).

No association was found between attributional bias and ToM in Jeon et al. (2013)'s study, but biases appear to be negatively related to social judgment and positively associated with reduced emotional regulation and aggressive behaviors (Coccaro et al., 2009). In sum, it is likely that the four components being investigated in the current study (emotion recognition, ToM, attributional bias, social judgment) interact with each other although the interaction may be age dependent.

Models of social cognition

The mechanisms through which specific SC abilities and neurocognition interact and influence functional outcome have been explored individually or in pairs over the past years (e.g., Barbato et al., 2013; Bell et al., 2009; Hajdúk et al., 2018; Schmidt et al., 2011). The identification of a multicomponent structure through a variety of statistical procedures (mediation models, path analysis, structural equation modeling) would help to better understand the processes by which the components relate to each other and to functional outcomes and target effective interventions. As an example, some SC abilities (social perception and social knowledge) were found to fully mediate the relationships between neurocognition and functional outcome in schizophrenia research (Schmidt et al., 2011). Another study (Hoe et al., 2012) found evidence for associations between cognitive abilities (verbal fluency, memory, sustained attention, and mental flexibility) and emotion processing in schizophrenia, such that these cognitive abilities and emotion processing together influence psychosocial functioning. In an integrative approach, some studies (Lam et al., 2014; Mehta et al., 2014) added clinical symptoms in their mediation analysis to clarify how they may influence the outcomes among other predictors.

Considering the relative recency of the publication of the SCOPE panel, it follows that there are few conceptual models integrating the components of SC identified by the panel of experts. Such a conceptual model can provide important information and premises about the organization and relationship between SC components' and outcome measures. In addition, the field of SC lacks a statistical (versus descriptive) approach to empirically validate the associations among its components in healthy adults. Modeling social information may help quantify deficits, identify intact SC antecedents related to the impaired SC components, specify intervention targets, and more clearly measure social outcomes such as social functioning and interpersonal relationships.

A series of conceptual models were developed over the years to schematize and describe social information processing. Among them, Adolphs (2001) model posits that perceptual processing which is postulated to be the earliest stage of social information processing, includes the perception of faces and recognition of facial expressions. According to this model, selective processing of threatening information and social judgment (e.g., trustworthiness judgments) modulate the perceptual processes and contribute to higher-order SC processes, such as ToM, empathy, motivation, self-regulation, and social decision-making, to construct a representation of the social environment and to plan social behavior. In the final step of the model, social behavior is initiated through brain structures involved in motor control. Similarly, Nelson et al. (2005)'s model presents a network in which systems are categorized in three "nodes": 1) a *detection* node dedicated to perceptual functions; 2) an *affective* node that processes the emotional significance of perceived social cues; 3) a *cognitive-regulatory* node comprised of higher-

level functions consisting of perception of mental states (referring to ToM), inhibitory control, and generation of goal-directed behaviors.

Other conceptual models were developed to schematize social information processing in childhood (Beauchamp & Anderson, 2010; Crick & Dodge, 1994; Yeates et al., 2007) and schizophrenia (Couture et al., 2006). These models offer a multilevel representation of SC and integrate distinct levels of cognitive complexity, ranging from basic processes (e.g., face processing, emotion identification) to higher cognitive functions (e.g., theory of mind, social inferences, social problem-solving, social decision-making). They also link SC processes to different social outcomes, such as social behavior, social competence, and social adjustment. Except for Adolphs's (2001) theory, only one model (Crick & Dodge, 1994) includes social knowledge and rules, which influence a series of six stages of social information processing. Lastly, attributional style/bias is a component in two models (Couture et al., 2006; Crick & Dodge, 1994) that postulate that it influences the interpretation of perceived social cues.

Social cognition, education, neurocognition, sand biological sex

Existing literature has shown mixed results regarding the effect of biological sex and education on SC performances in healthy adults, with emotion recognition and ToM being the most investigated components. Previous studies found sex-related differences in recognition of basic and complex emotions (Abbruzzese et al., 2019; Baron-Cohen et al., 2015; Kirkland et al., 2013; Olderbak et al., 2018; Thompson & Voyer, 2014; Williams et al., 2009) and ToM abilities (Faísca et al., 2016; Fischer et al., 2016; Russell et al., 2007). In contrast, other results did not provide evidence for sex variations in emotion recognition (Navarra-Ventura et al., 2017; Di Tella et al., 2020) and ToM (Franco & Smith, 2013; Di Tella et al., 2020). This inconsistency is likely due to methodological differences (Adenzato et al., 2017) or a limited approach that does not consider the various components of SC (Di Tella et al., 2015). Two studies examined sex differences in attributional biases, one in which women showed an elevated blame bias in ambiguous situations compared to men (Jeon et al., 2013), and the other in which men showed elevated hostility and aggression biases in ambiguous or intentional situations compared to women (Combs et al., 2007).

Similar to biological sex, very few studies have explored the effect of education on SC performances in healthy subjects. An effect of education on SC performances has been reported in ToM (Franco & Smith, 2013) whereas no effect was observed in MacPherson et al.'s (2002) study although the older group was significantly less educated then young and middle-aged adults. As for emotion recognition, the results are also inconsistent. Some data indicate variations in emotion recognition related to education (Keightley et al., 2006) while other evidence point toward no relationship (Orgeta & Phillips, 2007). These conflicting findings clearly suggest the need for future research to clarify the impact of sociodemographics on SC abilities.

Objectives

The current study extends prior research that was focused on the psychometric qualities of SC measures of SC (Gourlay et al., 2020), with the primary objectives of 1) identifying age variations in SC abilities across the stages of adulthood and 2) clarifying the nature of

the relations among SC components in a pathway through which they might relate to social relationships. To accomplish these research objectives, we opted to perform exploratory analyses in a first step, to identify potential factors that may affect the variables being studied (i.e., age and SC components). In a second step, between and within-group comparisons were examined to address the primary objective. In a third step, associations between the SC components and the quality of interpersonal relations were explored in a single model to address the second objective.

First, we expected to find positive associations between three SC variables (emotion recognition, TdE, social judgment), the quality of social relationships and neurocognitive variables. It was also expected to find negative associations between the Blame score and the other SC variables (emotion recognition, ToM, social judgment, quality of interpersonal relationships). It was hypothesized that biological sex would be related to emotion recognition and ToM performance, while education would be positively associated with these two last components and social judgment performance. As for age, we expected that it would predict change in all four components of SC.

Second, based on limited previous findings in healthy samples, we expected differences in SC abilities between early/middle adulthood and late adulthood. Based on the cognitive changes between groups, we presumed that changes would also occur over the within-group age spans although there is not enough information available to be able to make a more precise prediction of changes within the two younger age groups, 18–34, 35–59.

Third, based on theoretical models and the associations between the components found in the literature, we hypothesized that, in a single model, facial emotion recognition would be related to ToM, which in turn would be associated with the quality of interpersonal relationships, while attributional bias would be related to emotion recognition and ToM. In addition, since context might exert an influence on other SC abilities (Verhaeghen & Hertzog, 2014), and since social judgment is a context-dependent process (Gunther Moor et al., 2010), it was hypothesized that social judgment would be associated with all other variables in the model. This is in line with previous reports indicating that social evaluation may differ depending on the available information in the environment, including facial expression, that will guide one's predictions about a person's behavior (Baez et al., 2018; Calbi et al., 2017; Lee & Harris, 2013). The following conceptual model (Figure 1) was tested using path analysis. Confounding variables were added in further analysis.

Methods

Participants

The study comprised 120 adults recruited from the local community through advertising and word of mouth. All participants met the inclusion criteria of being at least 18 years of age and using French as their first, usual or instructional language. Potential participants were excluded if they had insufficient French language skills to complete the study procedures. They were also excluded if they had a history of psychiatric or neurological disorders that would interfere with the purpose of the study. Potential subjects completed a telephone screening to ascertain eligibility based on the inclusion and exclusion

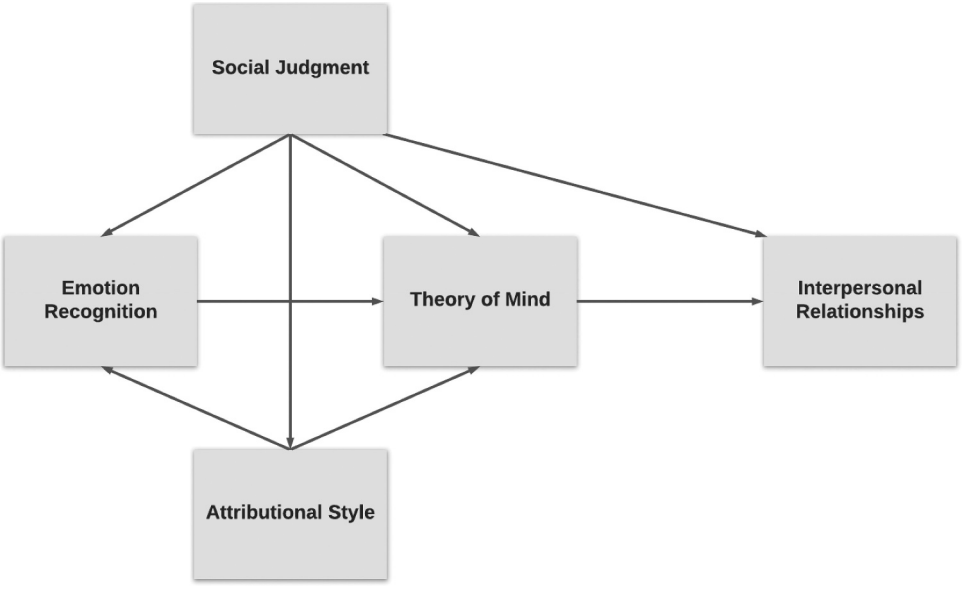

Figure 1. Conceptual model. Hypothesized pathways including 5 observed variables: emotion recognition, theory of mind, attributional bias, social judgment, and quality of interpersonal relationships.

criteria listed above. Individuals aged 50 years and older were screened for cognitive impairment using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), where a score of ≥26 was considered eligible. Seven potential participants were excluded due to a MoCA performance below the cutoff score. Participation was voluntary; only transportation-related expenses were reimbursed. The Human Sciences Scientific and Ethics Committee of the Université du Québec à Montréal approved this study and all subjects provided written informed consent before participation. Three groups of subjects were created based on stages of adulthood: Stage I – young adulthood: N = 41, age range: 18–34; Stage II – middle age: N = 39, age range 35–59; Stage III – late adulthood: N = 40, age range 60–85.

Study procedures

Data collection and measures

A battery of SC and neurocognitive measures was individually administered to all subjects in a counterbalanced order across two 1.5-hour sessions with an average interval between sessions of 14.80 ± 17.21 days. Among the complete sample, two subjects had incomplete data that were coded as missing values in the dataset.

Four SC measures were used to assess distinct SC components: emotion recognition, attributional bias, social judgment, and theory of mind (ToM). The four SC instruments previously underwent a comprehensive validation process in a sample of 100 healthy adults aged 18–85 years old: for detailed description of the psychometric evaluation, see Gourlay et al. (2020). The SC tasks used in the present study were selected based on their psychometric properties which were previously deemed to be satisfactory.

Additionally, neurocognitive measures were used to control for the contribution of neurocognitive functioning to SC performance. All subjects completed three WAIS-IV subtests (Matrix reasoning, Similarities, Vocabulary). The measures are described below.

Social cognition domains

Facial emotions recognition test (Test de reconnaissance des émotions faciales – TREF). The TREF was developed by *Gaudelus* et al. *(2014)* to assess facial emotion recognition. The test included 54 color photos of men and women of various ages (young, middle-aged, older) expressing an emotion (happiness, sadness, fear, disgust, anger, or contempt) at 9 intensity levels ranging from 20% to 100%. Photos were presented separately for 10 seconds each. After each presentation, participants were asked to identify the emotion displayed on the person's face, from a provided list. The test was computer-administered. An accuracy score was calculated for each emotion (/9), as well as a total recognition score (/54) encompassing all six emotions. Although it was not used in this study, a detection threshold can be derived for each emotion, consisting of the lowest accurately detected emotion of each type. In the present study, only the total recognition score (labeled *Emotion score*) was included in the analysis. The Emotion score reflects a general emotion recognition ability. It previously showed acceptable internal consistency (α = .74), satisfactory interrater reliability (74.90% agreement between subjects, Cohen's kappa = .61) and expected differential performances between younger (18–49 years old) and older adults (50–85 years old) (Gourlay et al., 2020). As for concomitant validity, a positive association was found with the quality of friendships.

The Ambiguous Intentions Hostility Questionnaire (AIHQ). The AIHQ was developed by Combs et al. (2007) to evaluate hostile attributional bias in three types of negative situations (15 situations total) that vary according to the character's level of intentionality (intentional, accidental, ambiguous). Subjects were asked to read a short vignette in which a negative situation was described. They were then asked to pretend that the scenario was happening to them. After each scenario, responders rated on a Likert scale: 1) how much the character's action was done on purpose (ranging from 1 to 6), 2) how angry it would make them feel (ranging from 1 to 5), and 3) how much they would blame the character (ranging from 1 to 5). All three ratings across the vignettes were summed and then divided to produce a mean blame score (labeled as *Blame score*). Lower scores on the AIHQ-blame index indicate lower blame attributions. The AIHQ-blame score previously showed satisfactory properties in a sample of healthy adults: reliability was strong (Cronbach's α = .90), and a negative association was found with the quality of relationships with people in general, in terms of concomitant validity, while discriminant analysis revealed no sex-related differences in performance (Gourlay et al., 2020).

Social Judgment Task (SJT). The SJT (Langdon et al., 2014) evaluates social judgments that are made on the basis of social rules, norms, and standards. Participants were asked to read five stories, each describing an everyday life situation in which the series of actions of a character vary according to their level of appropriateness (socially appropriate; violation of social norms; inappropriate but understandable if the characters' thoughts are taken into account). Overall, 19 behaviors were rated by subjects as being either

"normal," "unusual," or "shocking." An accuracy mean score was calculated, as well as percentages of ratings in each category of behaviors. In the present study, only the accuracy mean score (*identified as judgment score*) was added to the analyses. The accuracy score previously demonstrated acceptable psychometric qualities. Interrater analysis showed high degree of agreement between subjects in judgment accuracy (Cohen's kappa = .68), while discriminant analysis revealed no age and sex-related differences between groups. Associations were found between social judgment accuracy and recognition of specific facial emotions (Gourlay et al., 2020).

Strange Stories-Revised (SS-R). A modified version of the Strange Stories Task, initially developed by Happé (1994) to evaluate ToM, was administered to all subjects. Full structure, administration and scoring procedures (for 1st and 2nd order inferences) of the revised version, along with its psychometric properties, are reported in Gourlay et al. (2020). Answers in each ToM stories were rated by two trained judges and summed to provide a ToM score (maximum of 59 points). In the current study, the average ICC measure of the *ToM score* was .878 with a 95% CI ranging from .825 to .915, $F(117, 117) = 8.227$, $p < .001$. In the previous validation study (Gourlay et al., 2020), the SS-R ToM total score revealed a one-factor structure reflecting ToM ability, and an acceptable internal consistency (Cronbach's α = .63), considering the scale was in an exploratory phase. Discriminant validity analysis indicated age and sex-related differences, while associations were found with emotion recognition performances.

Neurocognition domains

Wechsler Adult Intelligence Scale-fourth edition (WAIS-IV). Participants were administered three WAIS-IV (Wechsler, 2008) subtests to assess cognitive functioning: Matrix Reasoning as a measure of problem solving and abstract reasoning; Similarities for abstract verbal reasoning abilities; Vocabulary as a measure of verbal semantic knowledge.

Functional outcome

Interpersonal Relationship Quality Scale (IRQS). The IRQS (Senécal et al., 1992) is a questionnaire designed to assess one's quality of interpersonal relationships through five subscales: family, romantic relationship, friends, other students/colleagues, people in general. In each subscale, subjects were asked to rate on a 5-point scale (0 = not at all, 4 = extremely) the degree to which they consider their current relationships being harmonious, rewarding, satisfying, and trustful. A total score ranging from 0 to 16 was calculated for each subscale, along with a mean total score covering all domains of relationships taken together. The IRSQ was validated among young adults and proved to be a reliable (internal consistency: α = .89 to .97 in all subscales; test-retest: r = .68 to .83 across subscales) and valid (confirmatory factor analysis supported a five-factor structure) tool to measure interpersonal relationships. The scale is related to mental health indexes, such as self-esteem and satisfaction in life, and is negatively associated with depressive symptoms. Other studies reported high internal consistency among young (α = .93 and .94) and older adults (α = .91) (Marchetti et al., 2016; Philippe et al., 2010; Schmit et al., 2011).

Statistical analysis

Statistical analyses were performed using SPSS (version 25) in conjunction with Mplus 8 (Muthén & Muthén, 2005–2017). A *p*-value of .05 was used for statistical significance. A standard error for skewness between −1.5 and +1.5 was considered acceptable for normality of distributions (Tabachnick & Fidell, 2013). Preliminary analyses showed that all SC variables were normally distributed. Regression analyses were conducted to explore whether independent variables (age, age squared) and covariates predict each SC variable. Pearson's correlation coefficients (*r*) were computed to examine the relationship between SC performance and cognitive abilities. Coefficients were interpreted as follows: $|r|$ values of 0.1–0.3 indicating a small linear relationship, 0.3–0.5 as moderate, and >0.5 as large (Cohen, 1988). Differences in SC performance between three age groups were investigated using a univariate analysis of variance (ANOVA) and analysis of covariance (ANCOVA) with demographic and cognitive factors as covariates. Partial eta squared (η^2) was used to determine effect sizes and were interpreted as follows: .01 as small, .06 as medium, and .14 as large (Cohen, 1988). In addition, we conducted a path analysis with a series of multiple regression analyses using Mplus to examine the relationships between the four SC predictor domains and the quality of interpersonal relationships within a single model. According to Kline (2015) and Barbeau et al. (2019), assumptions of path analysis include: linear relationships between the parameters, unidirectionality of the effects, endogenous variables are continuous or categorical data, same sample size for all regressions and no outliers, normal distributions, low collinearity between the variables. The variance inflation factor (VIF) was used to detect multicollinearity between the SC variables, with acceptable values <2.5. Model fit indices were interpreted following the criteria suggested by Hu and Bentler (1998, 1999) and Caron (2018) under maximum likelihood: chi-squared statistic (χ^2) and corresponding *p*-value >.05, root mean squared error of approximation (RMSEA) <.08, standardized root mean squared residual (SRMR) <.08, and comparative fit index (CFI) and Tucker-Lewis Index (TLI) >.95. Standardized regression coefficients (β weights) were interpreted similar to correlation coefficients (Acock, 2014): $\beta < 0.20$ is a weak effect, 0.2–0.5 is a moderate effect, and $\beta > 0.5$ is a large effect. Statistical power was considered to determine the appropriate sample size for path analysis. Sample size was determined using Monte Carlo simulations carried with Mplus 8 (Muthén & Muthén, 2002) to reach 80% statistical power for a moderate effect ($\beta = 0.3$) with a level of significance of .05. The number of subjects required to obtain sufficient statistical power was 120.

Results

Sample characteristics

Characteristics of the valid sample (i.e., the degree to which the sample covers a large span of ages and includes equivalent groups based on sex) are shown in Table 1, as well as demographic information stratified by age groups. Comparison analysis (ANOVA or χ^2) were conducted to explore between-group differences in demographic data. The groups did not differ in terms of biological sex, education, or ethnicity, but age $F(2,117) = 391.24$,

$p < .001$ and vocational status $\chi^2(4, N= 120) = 94.37$, $p < .001$ were different across groups, as expected.

Exploratory analyses

Associations between SC, demographics, neurocognition and quality of relationships

Given the mixed results found in the literature regarding moderators of SC performance, an initial exploratory approach was used to identify potential confounding factors. Correlations between biological sex, years of education, and scores on the individual tasks for the complete sample and different age groups are shown in Table 2. Three SC scores (Emotion, judgment, ToM) were significantly correlated with several variables in the younger and older groups. Results revealed significant associations between the SC abilities among the complete sample: emotion recognition was positively correlated with social judgment accuracy ($r = .23$, $p = .012$) and ToM ($r = .46$, $p < .001$), while ToM showed a positive association with social judgment accuracy ($r = .19$, $p = .043$). Blame score did not show any significant association within the matrix, except with interpersonal quality in the younger group ($r = -.34$, $p= .027$).

Sex-related differences

Previous analyses (Gourlay et al., 2020) found sex-related variations in ToM and recognition of specific emotions. Consequently, an analysis of variance (ANOVA) was performed to investigate a possible interaction between age group and biological sex. Results indicated a significant age by sex interaction effect on ToM performance, $F(6, 113) = 4.251$, $p = .017$. Within the correlational matrix (see Table 2), sex was correlated with ToM in the middle-aged group. Women were associated with higher ToM scores in this age group ($r = -.51$, $p < .001$). Despite this association, the sex variable was not considered to be a confounding variable in further group investigations since the effect was limited to one test in one group, within the complete matrix . Data from both groups (men and women) were thus combined in subsequent analyses.

Relationship between age and SC variables

In a last exploratory step, four regression analyses were performed on each SC variable using age and age squared as independent variables, as well as other covariates (education, neurocognition) to reveal possible relationships between age and SC performance. Results indicated a significant model between the predictor variables and emotion recognition accuracy (Emotion score), $R^2 = .414$, $F(6,112) = 13.168$, $p < .001$. There was a significant effect of age squared with an unstandardized beta of −.003 ($p = .030$). There was also a significant model between the predictive variables and social judgment accuracy (judgment score), $R^2 = .145$, $F(5, 113) = 3.826$, $p = .003$. The effect of age squared was significant, with an unstandardized beta of −.001 ($p = .028$).

There was a significant model prediction for ToM: $R^2 = .489$, $F(6,111) = 5.817$, $p < .001$. We removed the effect of age squared since it was not related to ToM score ($p = .337$). The linear effect of age was then −.097 (unstandardized beta) with a $p < .001$. There were no predictive effects on blame attributions (Blame score), $F(6,112) = .959$, $p= .456$, even if we

removed age squared, $F(5,113) = 1.157$, $p = .335$. All the effects are depicted in Figure 3 (dotted lines).

Difference between age groups in SC tasks

An analysis of variance (ANOVA) was carried out to examine any significant effect of age in SC performance. Data were divided into three age groups to investigate age-related differences across three stages of adulthood: young adults ($n = 41$); middle-aged adults ($n = 39$); older adults ($n = 40$). Social cognitive variables were normally distributed in all three groups. Also, Levene's test for homogeneity of variances for all SC measures was not significant in each group. Results revealed a significant main effect of age in three SC variables: Emotion score, $F(2, 117) = 19.60$, $p < .001$, $\eta^2 = .25$; ToM score, $F(2,116) = 13.24$, $p < .001$, $\eta^2 = .19$; and judgment score, $F(2,117) = 4.56$, $p = .012$, $\eta^2 = .07$. There was no significant difference between the groups on the Blame score: $F(2,117) = 2.47$, $p = .089$, $\eta^2 = .04$. Post hoc Bonferroni comparisons revealed significant differences between young and older adults for the Emotion and the judgment scores. As for the Emotion, judgment and ToM scores, middle-aged adults fell in between the young and older groups. In the case of the Emotion score, there was a significant difference between middle-aged adults and the older group, but not the young adult group. No difference was observed between the middle-aged and older adults on the judgment score. Lastly, for the ToM score, post-hoc comparisons revealed that the three groups differed significantly from each other, with middle-aged and older adults performing increasingly worse than younger adults. There was no statistically significant difference between groups in the Blame score.

Given the associations between education and most SC scores, it was included as covariate in a subsequent analysis of covariance (ANCOVA) that was performed for each SC task, followed by Bonferroni comparisons if significant. Assumptions of normality (residuals) and homogeneity of variances were met in each group for every SC variable. Significant main effects obtained in the ANOVA were unchanged after controlling for education (see Table 3). Post-hoc comparisons showed similar findings except that the difference between both older groups regarding the ToM score was no longer statistically significant (see Figure 2). Effect sizes were also similar, ranging in magnitude from small/medium to large (range of partial eta squared; $\eta^2 = .04$-$.26$).

When cognitive variables related to abstract reasoning, verbal reasoning and verbal knowledge were included as covariates, the main effect of age remained significant for two SC variables: Emotion score, $F(2,112) = 23.85$, $p < .001$, $\eta^2 = .30$, with older adults performing significantly worse than younger and middle-aged adults; ToM score, $F(2,111) = 12.49$, $p < .001$, $\eta^2 = .18$, with older adults performing significantly worse than younger adults while the middle-aged group fell in between the younger and older groups and differed significantly from younger adults. These results, shown in Figure 2, indicate an age-related decline in ToM and emotion recognition that could not be accounted for years of education nor cognitive factors related to abstract reasoning, verbal reasoning, and crystallized verbal knowledge. After controlling for these variables, no significant main effect was found on the judgment score: $F(2,112) = 2.59$, $p = .080$, $\eta^2 = .04$, and Blame score: $F(2,112) = 2.57$, $p = .081$, $\eta^2 = .04$.

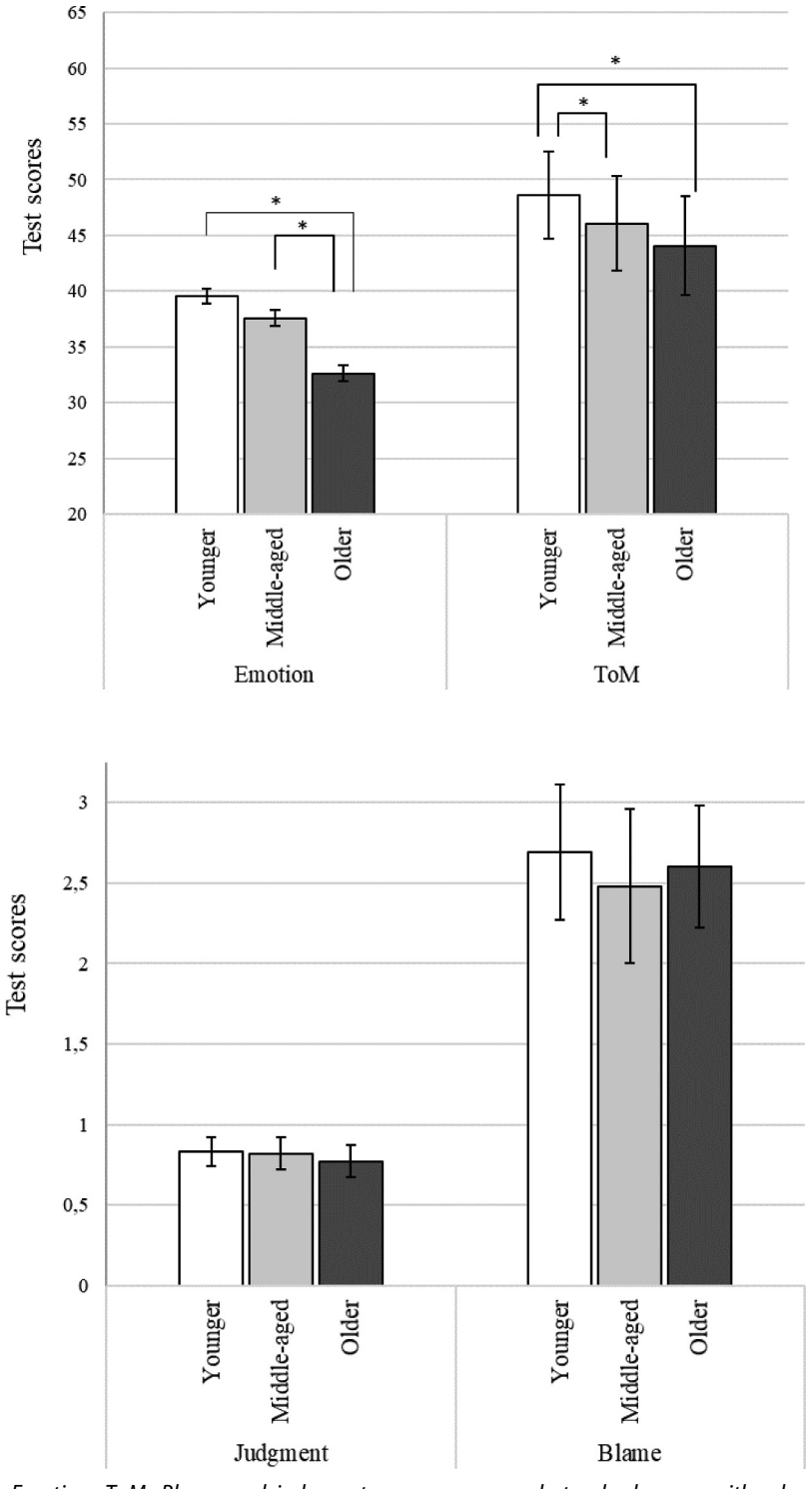

Figure 2. *Emotion, ToM, Blame and judgment mean scores and standard errors with education and cognitive factors as covariates.* * = $p < .05$.

Within-group comparisons

Coefficient correlation comparisons (Guilford, 1965) were performed to examine possible within-group differences in the strength of the relationship (Pearson's *r*) between age and SC scores. Results indicated that the younger group (linear relationship: *r*= .32) differed significantly from both middle-aged ($r = -.13$, $p = .044$) and older ($r = -.21$, $p = .017$) groups in terms of social judgment accuracy, whereas the two older groups did not differ statistically ($p = .720$). As seen in Table 4, no differences were found between the three groups in the Emotion, ToM, and Blame scores, possibly due to a lack of statistical power. In these analyses, low statistical power is likely due to having fewer subjects (two groups only included in each comparison) and only one source of variance (within) taken into account.

Partial correlation coefficients comparisons (Guilford, 1965) were used to investigate within-group differences after eliminating the effect of the covariates (education, neurocognition). As shown in the Table 4, the only remaining significant difference in the judgment score in terms of linear relationship, after adjustment for confounders, was between the younger (linear relationship: $r = .32$) and older ($r = -.21$, $p = .019$) groups. Figure 3 shows performance variations within and between age groups for the Emotion score, judgment score, ToM score, and Blame score. Each scatterplot presented in Figure 3 shows the standardized regression residuals corresponding to the linear relationships between age group and task performance after adjustment for education and neurocognition. Scatterplots were generated to display the distribution of values.

Path analytic procedures

A path analysis was performed (N = 120) to explore whether and how SC abilities may be associated with the quality of interpersonal relationships. All the assumptions were satisfied. The VIF values were within the acceptable limit of multicollinearity (1.03–1.31). Because the association between some components (social judgment, emotion recognition) and some predictors was not linear (as presented earlier in the Results section), we addressed this issue by adding the quadratic term to the model. All the other relationships between the variables were linear, although some slopes were not significantly different from 0 (see Table 2).

We first tested the conceptual model, which posits that emotion recognition and attributional style are both related to ToM abilities, which is associated with the quality of social relationships. Based on Adolphs (2001) conceptualization of perceptual processes, we predicted that attributional style would be linked with emotion recognition as well. Also, the model hypothesizes that accuracy in contextual social judgments would be related to all other variables in the model.

This model showed a good index fit, $\chi^2(2) = 0.46$; $p = .796$; CFI = 1.00; SRMR = .01; RMSEA = .00. Interrelationships within the model (Figure 4) revealed a significant direct path from emotion recognition accuracy to ToM ability ($\beta = .44$, $p < .001$) with a moderate/large effect size, and from social judgment accuracy to emotion recognition ($\beta = .23$, $p = .008$) with a small/moderate effect size. These results indicate that the relation between social judgment and ToM might be explained by a path through emotion recognition. Social judgment accounted for 5.3% of the variance in emotion recognition. In turn, emotion

Table 1. Demographic information stratified by age groups and characteristics of the complete sample.

Age group	Younger	Middle-aged	Older	Total	*p*-value
Sample size	41	39	40	120	
	M (*SD*) or Nb. (%)	*M* (*SD*) or Nb. (%)	*M* (*SD*) or Nb. (%)	*M* (*SD*) or Nb. (%)	
Age (years)	*26.68(4.53)*	*45.21(8.37)*	*68.30(6.75)*	*46.58(18.43)*	.001
Range	18–34	35–59	60–85	18–85	
Sex					.722
Men	20(48.80)	20(51.30)	17(42.50)	57(47.50)	
Women	21(51.20)	19(48.70)	23(57.50)	63(52.50)	
Education (years)	*15.21(2.71)*	*15.04(2.81)*	*14.89(3.12)*	*15.05(2.86)*	.883
Range	10–21	11–21	8–24	8–24	
Ethnicity					.252
Caucasian	36(87.80)	36(92.30)	40(100.00)	112(93.30)	
North African	2(4.90)	2(5.10)	0	4(3.30)	
Caribbean	1(2.40)	0(0.00)	0	1(0.80)	
Hispanic	0(0.00)	1(2.60)	0	1(0.80)	
Asian	2(4.90)	0(0.00)	0	2(1.70)	
Vocational status					.001
Employed	25(61.00)	33(84.60)	7(17.50)	65(54.20)	
Student	16(39.00)	3(7.70)	0(0.00)	19(15.80)	
Retired	0(0.00)	3(7.70)	33(82.50)	36(30.00)	

recognition accounted for 19.6% of the variance in ToM. On the other hand, ToM and social judgment accuracy were not directly associated with the quality of interpersonal relationships, and attributional bias was not significantly correlated with any variable. It is worth noting that the quality of the model fit is mainly due to the lack of associations between the SC variables (Caron, 2018).

In a second step, consistent with specifying procedures (e.g., Kline, 2005; Schumacker & Lomax, 2004), significant pathways were retained, while paths with non-significant contributions to variance were fixed to 0 in order to keep them in the equation without being tested. These relationships were removed hierarchically, starting from the largest *p*-value (attributional style→emotion recognition; β = .001, $p = .989$) to the smallest *p*-value (attributional style→theory of mind; β = .09, $p = .260$) until only significant pathways remained. Hierarchical trimming was carried out to simplify the conceptual model so that interrelationships can be summarized in a reduced, parsimonious form. The modifications did not produce a significant decline in model fit from the initial model. In fact, the analysis of the revised model with only the significant pathways showed good data fit, $\chi^2(8) = 5.82$; $p = .668$; CFI = 1.00; SRMR = .05; RMSEA = 0.00. The parameter estimates corresponding to the direct path from social judgment accuracy to emotion recognition remained the same (β = .23, $p = .008$) as in the initial model. In contrast, the standardized coefficient related to the direct effect between emotion recognition and ToM increased slightly (β = .46, $p < .001$). This time, emotion recognition accounted for 21.3% of the variance in ToM, while social judgment accounted for 5.3% of the variance in emotion recognition.

Table 2. Correlation matrix of task performance, sex, and years of education.

Age group	18–34 years old				35–59 years old				60–85 years old				Total sample			
Sample size	41				39				40				120			
Variable	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1. Emotion	1				1				1				1			
2. Blame	−.07	1			−.22	1			.15	1			−.01	1		
3. Judgment	.09	.04	1		−.05	−.16	1		.23	−.06	1		**.23***	−.06	1	
4. ToM	.26	.05	−.13	1	.06	−.03	.24	1	**.57****	.13	.16	1	**.46****	.08	**.19***	1
5. Interpersonal relationships (IRSQ)	.20	**−.34***	−.17	.01	.11	.01	.29	−.12	−.06	.11	.13	**.33***	.08	−.06	.12	.12
6.Matrix Reasoning	.27	.19	−.17	.13	−.14	−.05	.29	.05	−.05	−.07	.26	.70	.15	.00	**.23***	.18
7. Vocabulary	**.44****	−.15	−.15	.26	.07	−.01	.21	.09	**.53****	.14	.11	.30	**.31****	−.03	.03	.16
8. Similarities	**.42****	−.17	−.14	**.32***	−.09	−.19	.18	−.02	**.40****	.05	.16	**.43****	**.19***	−.09	.04	**.19***
9. Sex	−.09	.19	−.21	−.23	−.22	−.10	−.15	**−.51****	−.14	.10	.12	.11	−.09	.05	−.05	−.17
10. Education	**.40***	.18	.24	**.39***	−.12	−.22	.27	.05	**.41****	.06	.30	**.39***	**.26****	.00	**.26****	**.27****

* = $p < .05$; ** = $p < .01$; Emotion score, Facial Emotions Recognition Task; Blame score, Ambiguous Intentions Hostility Questionnaire; judgment score, Social judgment Task; ToM score, Strange Stories-Revised; Interpersonal Relationship Quality Scale – total mean score.

Table 3. ANCOVA results for SC variables across age groups with years of education as covariate.

Variable	*F*	*df*	*p*	η^2
Emotion score	20.09	2, 116	**<.001**	.26
ToM score	13.46	2, 115	**<.001**	.19
Blame score	2.45	2, 116	.091	.04
Judgment score	4.46	2, 116	**.014**	.07

Emotion score, Facial Emotions Recognition Task; ToM score, Strange Stories-Revised; Blame score, Ambiguous Intentions Hostility Questionnaire; judgment score, Social judgment Task. Bold values denote statistical significance.

In a third step, age, education, and cognitive variables (abstract reasoning, verbal reasoning, and verbal knowledge) were added to the revised model as covariates to adjust for demographic characteristics and neurocognitive factors. Results are presented in Figure 5. Age and education did not correlate ($r = -.04$, $p = .685$). Verbal reasoning showed a significant association with verbal semantic knowledge ($r = .47$, $p < .001$), and with perceptual reasoning ($r = .18$, $p = .044$). After accounting for demographic and cognitive factors, a small/moderate direct effect between emotion recognition and ToM ability remained statistically significant ($\beta = .27$, $p = .005$), while the path from social judgment to emotion recognition was non-significant ($\beta = .07$, $p = .332$). Taken together, emotion recognition and all covariates accounted for 28.9% of the variance in ToM. Overall, the results revealed that the specified interrelations, adjusted for age, education and neurocognition, fit the data well across all fit indices, $\chi^2(8) = 3.69$; $p = .884$; CFI = 1.00; SRMR = .02; RMSEA = .00.

Discussion

Typical social-cognitive aging and the underlying structure by which the multifaceted aspects of SC interact have yet to be clarified and elucidated. In this study, we explored the age-related differences in various components of SC across three stages of the adult lifespan, and we developed a model to link these abilities. Our results extend previous findings demonstrating age-related differences in some SC processes in extreme adult (i.e., young, older) age groups (e.g., Beadle & de la Vega, 2019; El Haj et al., 2015; Maylor et al., 2002; Moran et al., 2012). Unlike previous studies of normal aging using these two age groups only, we focused on SC abilities previously found to have good psychometric qualities in a non-clinical group, across the adult lifespan, including three age groups (18–34 years old; 35–59 years old; 60–85 years old). It is noteworthy that the field of SC is lacking a consensus concerning the oldest age to be included and assessed in aging research. Normative data for neuropsychological tests frequently vary in terms of their upper age limit. For example, the WAIS-IV (Wechsler, 2008) provides data for ages 16–90, the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) is normed based on ages 8–89, the Test of Everyday Attention (TEA; I. H. Robertson et al., 1996; I. Robertson et al., 1994) is normed on a sample aged 18–80 years old, and the Brief Visuospatial Memory Test-Revised (BVMT-R; Benedict, 1997) is normed based on ages 18–79. Our study used an upper limit of 85 years old according to our primary objective, identifying age differences in SC abilities rather than developing normative data.

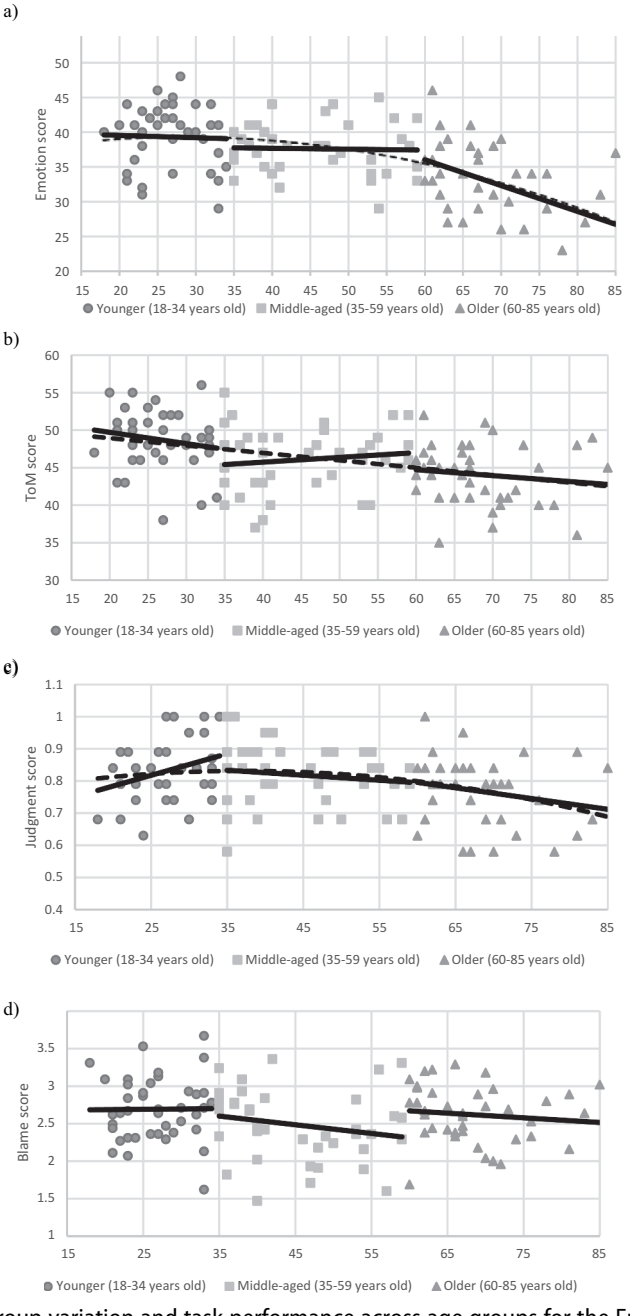

Figure 3. Within-group variation and task performance across age groups for the Emotion, judgment, ToM, and Blame scores after adjustment for education and neurocognition. Individual bold lines show linear relationships between task performance and age in each group. Dotted lines depict quadratic (Emotion, judgment scores) or linear functions (ToM score) throughout the adult lifespan.

Our results indicated that emotion recognition, ToM, and social judgment were correlated in the complete sample, consistent with Mitchell and Phillips (2015) review

Table 4. Coefficient correlations comparisons between age groups with and without control variables.

	Coefficient correlations (no control variables)			Partial correlations coefficients (controlling for education, neurocognition)		
Variable	Young vs. Middle-aged	Young vs. Older adults	Middle-Aged vs. Older adults	Young vs. Middle-aged	Young vs. Older adults	Middle-Aged vs. Older adults
Emotion	Young: $r = -.03$	Young: $r = -.03$	Middle: $r = -.03$	Young: $r = -.11$	Young: $r = -.11$	Middle: $r = -.05$
	Middle: $r = -.03$	Old: $r = -.43$	Old: $r = -.43$	Middle: $r = -.05$	Old: $r = -.40$	Old: $r = -.40$
	$p = .986$	$p = .063$	$p = .064$	$p = .808$	$p = .173$	$p = .111$
ToM	Young: $r = -.17$	Young: $r = -.17$	Middle: $r = .12$	Young: $r = -.24$	Young: $r = -.24$	Middle: $r = .14$
	Middle: $r = .12$	Old: $r = -.13$	Old: $r = -.13$	Middle: $r = .14$	Old: $r = -.10$	Old: $r = -.10$
	$p = .201$	$p = .861$	$p = .272$	$p = .103$	$p = .533$	$p = .309$
Judgment	Young: $r = .32$	Young: $r = .32$	Middle: $r = -.13$	Young: $r = .32$	Young: $r = .32$	Middle: $r = -.10$
	Middle: $r = -.13$	Old: $r = -.21$	Old: $r = -.21$	Middle: $r = -.10$	Old: $r = -.21$	Old: $r = -.21$
	$p = .044$	**$p = .017$**	$p = .720$	$p = .061$	**$p = .019$**	$p = .645$
Blame	Young: $r = .01$	Young: $r = .01$	Middle: $r = -.20$	Young: $r < -.01$	Young: $r < -.01$	Middle: $r = -.20$
	Middle: $r = -.20$	Old: $r = -.11$	Old: $r = -.11$	Middle: $r = -.20$	Old: $r = -.08$	Old: $r = -.08$
	$p = .352$	$p = .606$	$p = .678$	$p = .378$	$p = .734$	$p = .587$

Emotion, Facial Emotions Recognition Task; ToM, Strange Stories-Revised; Blame, Ambiguous Intentions Hostility Questionnaire; judgment, Social judgment Task. Bold values denote statistical significance.

regarding the link between perceptual processes (i.e., emotion perception) and ToM. Several associations were also found between the SC components and neurocognitive variables (abstract reasoning, verbal reasoning, semantic knowledge). These associations were expected since SC and neurocognitive variables were previously linked in clinical and non-clinical groups (e.g., Ahmed & Stephen Miller, 2011; Franco & Smith, 2013; Keightley et al., 2006; Maylor et al., 2002; Scherzer et al., 2015; Zhang et al., 2016). However, attribution of blame showed only one association within the complete correlational matrix. This is in line with prior research which found no association between attributional bias and ToM (Jeon et al., 2013). Similarly, biological sex showed only one association in one age group but was not correlated with any other variable in the complete sample. This result aligns with previous research (Fischer et al., 2016; Di Tella et al., 2020), reporting no sex-related differences in emotion recognition and ToM among healthy subjects.

It is also noteworthy that very few associations were found between the components of SC and the social outcome within the correlational matrix, and no such associations were detected in the path models. An explanation for these results may be that the processes undertaken to evaluate the psychometric properties of the Quality of Interpersonal Relationships Questionnaire (Senécal et al., 1992) was completed using a sample of young adults only, whereas our complete sample was 46.58 years old on average. Another explanation may be that the components of social interactions may not be associated with a unique outcome. For example, recent studies (e.g., Buck et al., 2016; Harvey et al., 2018; Hasson-Ohayon et al., 2017) used various measures to evaluate different aspects of interpersonal functioning (e.g., social competence, social skills) in different formats (e.g., questionnaires, role-play conversations) from different sources of information (self-report, informant). The nature of the social cognition-to-social functioning link deserves more attention in future research, particularly studies that include

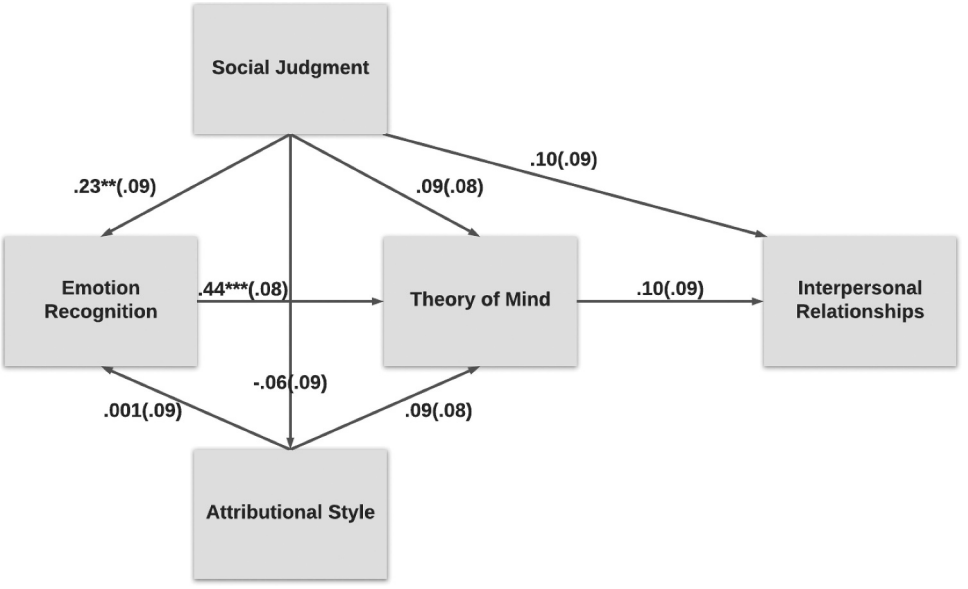

Figure 4. *Standardized estimates (beta weights and standard deviations) for the conceptual model*. Path model results and interrelations between the SC components in the conceptual model. Standardized coefficients and standard errors are presented. ** = $p < .01$; *** = $p < .001$.

multiple types of social outcomes to better reflect the various levels at which individuals function in their social environments, and possible ways that SC might be linked to overall quality of social functioning.

Regression models predicted age-related differences in emotion recognition, ToM, and social judgment accuracy. The observed variations are consistent with those reported in previous studies investigating SC abilities in aging (Ahmed & Stephen Miller, 2011; Keightley et al., 2006; Maylor et al.; 2002). However, similarly to Mojtahedi, Ioannou, Hammond and Synnott's (2019) results, we did not find such variations in attribution of blame.

Our analyses revealed a significant difference in ToM between early and middle adulthood, even after accounting for potential confounders, and a significant difference between younger and older adults. According to these results, ToM ability is not only a function of age but also appears to be characterized by interindividual differences in the gap between early and middle age. These findings indicate that ToM is likely to show age group variations prior to 60 years of age for some components and are consistent with Bernstein et al. (2011)'s patterns of responses in a false belief ToM task across three stages of adulthood, despite their small group sizes and absence of psychometric data for their sole measure of SC. The results are also partially consistent with those of Duval et al. (2011) regarding a difference in performance on a ToM task, with middle age falling in-between young and older adults. Duval et al. (2011) examined several aspects of SC (cognitive ToM and recognition of emotions) that are a prerequisite for a more comprehensive representation of the multidimensional nature of SC. However, their study revealed some methodological issues (limited examination of tasks' properties including potential floor/ceiling effects, sample size), which we addressed in our study. Overall, our

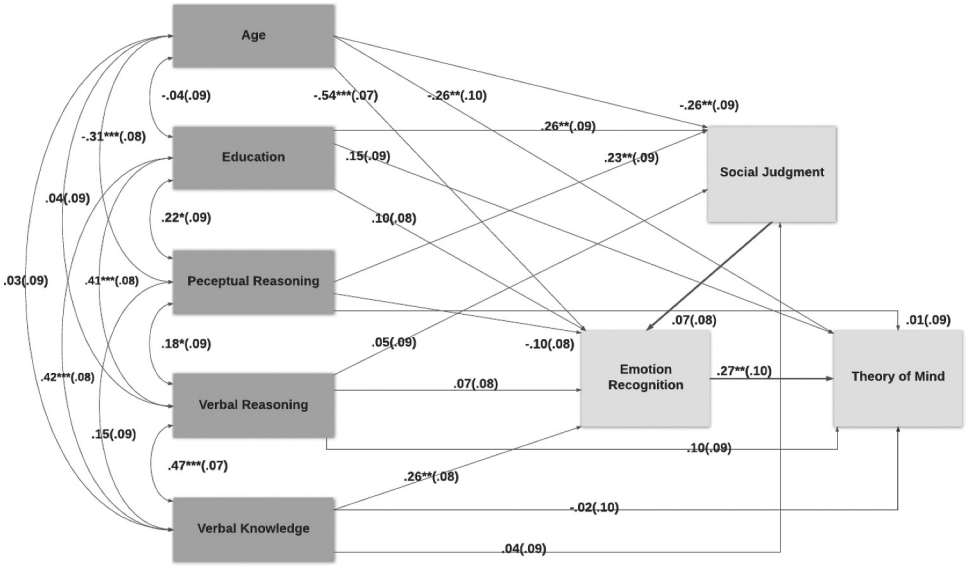

Figure 5. Summarized relationships with age, education, and neurocognitive factors as covariates. Interrelations between social judgment, emotion recognition and ToM with demographic and cognitive variables as covariates. Standardized coefficients and standard errors are presented; * = $p < .05$; ** = $p \leq .01$; *** = $p \leq .001$. The double-headed, curved arrow denotes a correlation.

results indicate that there is progressive change in ToM from young adulthood to older age with performance of middle-aged adults falling in between. Most of the literature on ToM only compares the earliest and most advanced ages. The current findings suggest that models of ToM might be reconsidered in typical aging to include midlife as a pivotal period.

We also found a significant age cohort difference in emotion recognition accuracy between young and older adults. This difference in performance has been extensively demonstrated in the literature using various emotion processing tasks (Hayes et al., 2020; Visser, 2020). More importantly, performance on our task differed significantly between middle and late adulthood, with the latter group scoring lower than the former even when confounders were taken into account. The results reflect previous findings concerning recognition of basic facial emotions (Lambrecht et al., 2012; Mill et al., 2009; Sze et al., 2012; West et al., 2012) and complex expressions displayed on the eye region (Khanjani et al., 2015; Pardini & Nichelli, 2009). Our results are an indication of either variations in recognition of basic emotions occurring with advanced age; or 2) a marked difference in emotion identification performance occurring later than the crucial drop observed in ToM (young > middle age) on the adult lifespan. It can be hypothesized that age related differences in the availability of processing resources in normal aging (Park et al., 2001) first reduces the effectiveness of more complex (i.e., high-order cognitive processes) components of SC. This hypothesis is in accordance with Siman-Tov et al. (2017)'s results from an imaging study indicating a decline in high-order cognitive networks as early as middle adulthood. Early detection of a variation in ToM performance and

intervention (e.g., cognitive training) may help support the ability and limit potential adverse social outcomes.

In contrast, variables related to social judgment and blame attributions did not demonstrate variations throughout adulthood after adjustment for potential confounding factors. These social-cognitive abilities may therefore be less vulnerable to age-related processes. It should be emphasized that the two constructs appear to be closely related to each other, as Blanchard-Fields et al. (2012) showed that individuals are more likely to blame others when their social representations (i.e., social knowledge, norms and values) regarding appropriate behaviors in a relationship are perceived to be violated. Their results also revealed age-related differences in blame attributions, such that young (18–34 years old) and middle-aged (35–59 years old) adults demonstrated a reduced tendency toward the attribution of blame in comparison to older (60–83 years old) adults. Our results did not support age-related variations, possibly due to the homogeneity of the overall sample in terms of some demographic characteristics (ethnic and urban uniformity), which in turn could have contributed to a greater harmonization of social standards among age groups, and thus, reduced generational differences. Future research is needed to clarify whether knowledge accumulated over time could help social judgment and attribution bias to remain relatively stable with age.

We observed a significant difference between young and older adults regarding the linear relationship (direction and strength) between age and social judgment accuracy. Despite the absence of between-group differences, analyses provided support for within-group variations (young vs older adults). Specifically, while the younger group showed a moderate positive trend of improvement in judgment accuracy from 18 to approximately 35 years of age, the older group demonstrated a negative trend of poorer performance with increasing age. The results highlight the positive and negative associations between age and the ability to judge social behaviors' appropriateness in the adult lifespan. To date, no study has provided data about the linear relationships between social judgment and age within three different stages of adulthood. Although the other components of SC (ToM, emotion recognition, blame attributions) did not show group differences regarding linear relationships, the results provide more refined information about the strength and direction of the relationships within each stage. The sharper decrease in emotion recognition performance in the older group, the positive aspect of the middle-aged group's curve in ToM, and the reduced tendency to attribute blame in middle adulthood compared to the other groups are especially relevant data that pave the way for further investigations.

Finally, the path analysis results did not fully support the original conceptual model of SC. However, a direct path from emotion recognition to ToM remained significant after controlling for demographic and neurocognitive factors, denoting a link between the two. This result echoes those obtained by Halberstadt et al. (2011) in a regression model in which emotion recognition fully mediated age-related differences in faux pas discrimination (i.e., ToM performance). This path is especially important since it represents a target for practitioners when developing interventions aiming to improve SC abilities in healthy populations. The fact that no other relationships in the model were significant is surprising considering a) the number of studies that focused on those facets of SC; b) the validation process used with these measures. One possibility is that the other components (social judgment, blame attributions) may be related to emotion recognition and ToM in

a complementary aggregate of independent systems instead of a single causal chain. Another possibility is that a more refined model using structural equation modeling with additional subcomponents and larger samples could account for social interactions' multidimensional and complex nature. In every case, further research is needed to determine more precisely what role each of these components plays in the very act of understanding social information.

Limitations

This study has some limitations. First, a cross-sectional design was used, which means that results may have been influenced by cohort effects or selection bias (Lezak, 2012). On the other hand, a longitudinal protocol presents a heightened risk for attrition and the effect of prior test experience (i.e., practice effects). As suggested by Salthouse (2012), future research in aging and SC could use a longitudinal design combined with alternative or parallel test versions to minimize the possibility of research bias. Second, we used only one scale to measure the outcome, precluding the assessment of various aspects of functioning; additional variables (e.g., density of social networks, people's involvement in and access to social relationships) and instruments (e.g., measuring the purpose of relationships, such as receiving and providing social support) and may have improved the evaluation of interpersonal relationships. Third, our hypotheses included a conceptual model in which the components of SC were organized based on the previous literature and linked to social functioning. The model hypothesized unidirectionality of the flow, whereas bi-directional relationships could also be possible. Fourth, additional neurocognitive variables (processing speed, working memory, inhibitory control) may have affected results related to ToM (Moran, 2013). However, the slowing of processing speed that occurs with aging is not likely to account for our findings since the tasks we used are not timed. As for working memory and inhibitory control, Cavallini et al. (2013) found age-related differences in performance on the Strange Stories task in a sample of healthy adults even after controlling for these executive functions. Despite these potential limitations, our main findings add to the current body of literature on social-cognitive aging.

Conclusion

In conclusion, the current study used cross-sectional data to explore age-related differences in four key components of SC and the associations among them. The results provide important insights into the processes underlying SC. Consistent with our expectations, several age-related variations were found within and between age groups, and an association was observed in the model between two of the components after adjustments. However, further work is required to determine more precisely how the SC functions are articulated, connected and organized to influence interpersonal functioning. Our results suggest that the pattern of age differences varied across specific components and align with research indicating heterogeneity in social-cognitive profiles across the adult lifespan (e.g., Demenescu et al., 2014; Horning et al., 2012; Phillips et al., 2011). Understanding the variations in SC abilities across the stages of adulthood is particularly important in developing additional targeted prevention strategies and detecting at an early stage any potential decline with aging. Thus, our results have potentially important

implications for the understanding and appropriate screening of age-related social-cognitive differences, as well as for aging prevention programs. In future work, the development of such strategies could benefit high-risk groups and prevent functional impairments in the social domain.

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