

Multimodal pragmatic assessment in healthy aging: The interplay with Executive Functioning, Theory of Mind and Cognitive Reserve

A. Parola^{a,b,1}, I. Gabbatore^{b,c,*,1}, D. Hilviu^b, A. Marini^{d,e},
F.M. Bosco^{b,f,g}

^a Centre for Language Technology, Department of Nordic Studies and Linguistics, University of Copenhagen, Denmark

^b Research Group on Inferential Processes in Social Interaction (GIPSI), University of Turin, Italy

^c Department Humanities, University of Turin, Turin, Italy

^d Department of Languages, Literatures, Communication, Education and Society, University of Udine, Udine, Italy

^e Scientific Institute IRCCS "Eugenio Medea", Piasa di Prato, UD, Italy

^f Department of Psychology, University of Turin, Turin, Italy

^g Neuroscience Institute of Turin - NIT, University of Turin, Turin, Italy

ARTICLE INFO

Keywords:

Aging
Pragmatic ability
Executive Functions
Theory of Mind
Decline

ABSTRACT

Pragmatic competence is crucial for effective social interaction and well-being, and yet it tends to decline with age. While most research has focused on basic linguistic skills, the multimodal nature of communication and the cognitive processes that support it have often been overlooked. The present study aims to address these gaps by assessing pragmatic-communicative ability in aging – including linguistic, extralinguistic, and paralinguistic expressive means – and examining the cognitive mechanisms underlying this decline, in particular Executive Functions (EFs), Theory of Mind (ToM), and Cognitive Reserve (CR). We analyzed communicative-pragmatic ability in 84 healthy adults in three age groups (20–40, 65–75, 76–86 years) using the Assessment Battery for Communication (ABaCo). A comprehensive neuropsychological battery enabled the assessment of basic cognitive functions, EFs, ToM, and CR. The results show that older adults demonstrate lower performance in both pragmatic and cognitive domains. EFs emerged as predictors of communicative-pragmatic competence, while ToM appeared to play a less important role. Noteworthy, CR, particularly as reflected in educational background, attenuated age-related decline in pragmatic ability. This study extends our understanding of the cognitive factors contributing to pragmatic decline, as well as protective mechanisms involved. It also emphasizes the need for targeted cognitive and communicative interventions to promote effective communication in older adults.

1. Introduction

1.1. Communicative-pragmatic ability and aging

Communication is a central factor for social interaction, personal identity, and overall well-being. Impairments in communication—even when mild—can lead to significant consequences, including difficulties in occupational settings, social withdrawal, and increased risk of depression (Agostoni et al., 2021). Among the various aspects of communication, communicative-pragmatic competence (Bara, 2010; Levinson, 1983), which governs the appropriate use of language in social contexts, is particularly relevant to maintaining effective

interpersonal interactions. This competence encompasses linguistic, non-verbal/extralinguistic, and paralinguistic expressive modalities, allowing individuals to convey meaning, interpret others' intentions, and navigate social contexts through effective communicative exchanges (Bosco & Angeleri, 2012; Holler & Levinson, 2019; Parola et al., 2016, 2021). As individuals age, their ability to communicate effectively in social settings gradually declines, affecting daily interactions and overall quality of life. The aging process brings about a range of physiological, cognitive, and socio-emotional changes (Valiengo et al., 2016) that may influence different aspects of language processing and communication (Benichov et al., 2012; Burke & Shafto, 2004; Royle et al., 2019). While previous research has documented age-related

* Corresponding author at: Department of Humanities, University of Turin, via Sant'Ottavio, 20, 10124, Torino, Italy.

E-mail address: ilaria.gabbatore@unito.it (I. Gabbatore).

¹ These authors contributed equally to this work.

declines in lexical, grammatical, and discourse-level abilities (e.g., D'Ortenzio et al., 2025; Marini, Petriglia, Gasparotto, et al., 2026; Marini et al., 2025; Petriglia, Gasparotto, et al., 2025), much less attention has been paid to age-related changes in pragmatic language abilities, with rare exceptions (Bambini et al., 2021; Baraldi & Domaneschi, 2024; Hilviu et al., 2022). The multimodal nature of communication—which involves both verbal and non-verbal cues—has rarely been comprehensively investigated in aging populations. Most studies focus primarily on linguistic abilities, neglecting the extralinguistic (gestures, facial expressions) and paralinguistic (prosody, intonation) aspects that are crucial for effective communication. The few existing studies which embraced this multimodal view of communication, and investigated comprehensively communicative pragmatic skills in aging, suggest that older adults exhibit difficulties also in processing extralinguistic cues such as facial expressions and gestures, paralinguistic features like intonation and speech prosody (Hilviu et al., 2022), and in other pragmatic domains such as comprehension of humour and non-literal meaning (Bambini et al., 2021; Bischetti et al., 2023), and discourse abilities and narrative skills (Baraldi & Domaneschi, 2024; Hilviu et al., 2025). Given the increasing proportion of older individuals in the population, characterizing the communicative-pragmatic decay associated with the aging process and understanding the factors underlying this decline is essential, as these changes may affect their ability to effectively communicate, maintain independence, and seek necessary support and assistance.

1.2. Factors contributing to the decline of communicative-pragmatic ability

One of the key challenges in this area is identifying the cognitive processes underlying the decline in pragmatic ability with age. Aging is linked to both structural and functional brain changes, including a reduction in white matter integrity and altered functional connectivity within key neural networks - such as the default mode network and areas involved in executive control (Andrews-Hanna et al., 2007; Fjell et al., 2017; Gertel et al., 2020; Tomasi & Volkow, 2011). These neural changes are associated with declines in cognitive functions like episodic memory, working memory, and attentional and inhibitory control, all of which are cognitive functions essential for communicative-pragmatic competence (Buckner, 2004; Burke & Shafto, 2004; Mather, 2010; Hippel, 2007).

Pragmatic ability is inherently complex, requiring the orchestration of multiple cognitive functions and inferential abilities to process, produce, and interpret communication in real time (e.g. Bosco, Parola, Valentini, & Morese, 2017; Parola et al., 2020; Parola & Bosco, 2022). Two cognitive constructs may concur to explain pragmatic impairment: Theory of Mind (ToM) – the ability to understand others' mental states and intentions (Premack & Woodruff, 1978), and Executive Functions (EFs) – a set of higher-order cognitive processes that regulate attention, working memory, cognitive flexibility, and inhibition (Miyake et al., 2000).

Prior research has identified a relationship between pragmatic comprehension and declarative memory, as well as a link to executive functions. Pragmatic comprehension has also been moderately correlated with working memory, attention, and ToM, suggesting that a wide range of domain-general cognitive processes may contribute to the difficulties these individuals experience in pragmatic comprehension (Bibby & McDonald, 2005; Bosco, Gabbatore, et al., 2018; Bosco, Parola, Sacco, et al., 2017; Rowley et al., 2017). Nonetheless, none of these cognitive functions alone completely explains the communicative pragmatic deficits (Bosco, Gabbatore, et al., 2018; Bosco, Parola, et al., 2018; Bosco, Parola, Sacco, et al., 2017; Gabbatore et al., 2015; Sacco et al., 2016).

Taken together, the relationship between cognitive functions and pragmatic ability appears to be related to the specific clinical, cognitive, and socio-demographic characteristics of the population studied, even if

this needs more investigation. This variability highlights the need for comprehensive assessment tools able to capture a broad range of communicative phenomena and expressive modalities, while also evaluating multiple cognitive domains.

However, only very few studies have so far assessed these relationships in healthy aging. While cognitive decline has received substantial attention in aging research, with many studies reporting a deterioration of cognitive functions associated with aging, ToM has been less explored. Nonetheless, some evidence suggests that not only general cognitive abilities, but also ToM may be vulnerable to age-related decline (see Henry et al., 2013 for a meta-analytic review). Bottioli et al. (2016), for example, found that specific impairments in mental state inference can begin to emerge around the age of sixty, and that these difficulties may occur independently of broader cognitive decline. Although the complex interplay between these cognitive functions has been widely investigated in the literature, there is still no definitive picture of the exact relationship among these abilities (e.g., Bambini et al., 2016; Bosco et al., 2019; Bosco & Gabbatore, 2017; Katsos & Andrés-Roqueta, 2021; Kissine, 2021; Parola et al., 2018, 2020). Moreover, only few studies have specifically examined how EFs, ToM, and pragmatic ability interact in aging. Among these, Bambini et al. (2021) reported that EFs significantly predicted pragmatic ability in aging, beyond demographic factors and ToM. Among EFs, working memory emerged as the strongest predictor, because pragmatic processing requires the simultaneous handling of multiple pieces of information, while inhibition was not found to be a robust predictor of pragmatic performance. Cognitive flexibility also played a role in specific pragmatic tasks, such as figurative language and inferencing. The authors concluded that EFs do play a role in the pragmatic processing irrespective of the role played by ToM skills and that their results support models where pragmatics has interdependent relationships with other cognitive domains, including both EFs and ToM (see also Bambini et al., 2016; Bosco, Parola, Sacco, et al., 2017; Hyter, 2017). Not completely overlapping results have been reported by Baraldi and Domaneschi (2024) who showed that pragmatic difficulties tend to emerge more prominently after age 70, particularly in comprehension rather than production domain. Interestingly, the authors found that in their regression model, a significant contribution of inhibition, along with working memory and ToM, in explaining participants' pragmatic performance was only found after the inclusion of two participants with low scores in terms of inhibitory control, who had originally been excluded due to their poorer inhibitory abilities compared to the rest of the sample. As such results were not apparent a priori in a more homogeneous sample, the authors suggested that less preserved inhibition skills, might contribute to other cognitive variables (e.g., working memory and ToM) coming into play and serve as further support for certain pragmatic tasks. Hilviu et al. (2025) found age-related effects on various aspects of language production using a story-telling task, including phonology, semantic retrieval, sentence complexity, coherence, cohesion, and lexical informativeness. The results highlighted that an age-related decline in social skills such as ToM and emotion recognition can partly mediate the decay in macrolinguistic functions observed in the elderly, even if more research is needed to make more solid claims about the causal pathway between these variables. More generally, such a variety of data encourages more research on how cognitive decline may contribute to pragmatic decay in healthy aging. Indeed, the relationship between pragmatic ability, ToM, and EFs in aging remains complex and, at times, controversial. However, identifying the factors responsible for this impairment is crucial for many reasons: first, from a theoretical perspective, it can improve our understanding of which cognitive functions are most supportive of communicative-pragmatic ability, thus helping to better characterise and detect early signs of decline. In addition, it can help to develop and tailor training programs targeted to older adults that can maintain and enhance communicative-pragmatic ability and mitigate the decline of these functions (Bambini et al., 2022; Bosco & Gabbatore, 2025;

Gabbatore et al., 2015; Gabbatore et al., 2017; Parola & Bosco, 2018).

1.3. Cognitive Reserve as a protective factor in aging

While aging is typically linked to a decline in multiple cognitive abilities, some individuals maintain relatively intact communicative skills despite age-related neurobiological changes. This variability points to the presence of protective factors, one of the most widely studied being Cognitive Reserve (CR). Cognitive Reserve is a theoretical concept used to account for differences in how individuals withstand cognitive decline and neurological damage (Stern et al., 2020). According to this framework, a combination of lifetime experiences and genetic predispositions equips some individuals with enhanced cognitive flexibility, allowing them to compensate for the effects of aging or brain disease more effectively (Fittipaldi et al., 2024).

Previous research suggests that education is one of the primary contributors to CR, often serving as a proxy measure for this construct (Staekenborg et al., 2020). Higher levels of education have been associated with a reduced risk of cognitive decline and dementia in large-scale population studies. Beyond formal education, CR is believed to be strengthened by lifelong engagement in mentally stimulating activities, occupational complexity, and an active social life. This growing body of evidence underscores the importance of maintaining a cognitively and socially rich lifestyle as a preventive strategy against cognitive decline (see Barulli & Stern, 2018).

While CR has been shown to influence verbal comprehension and vocabulary retention in healthy older adults (Christensen et al., 1997), its role in pragmatic language abilities remains largely unexplored. Despite the theoretical plausibility that CR could buffer against age-related declines in these areas, empirical findings remain scarce and inconsistent (e.g., Marini, Petriglia, D'Ortenzio, et al., 2026).

Understanding the role of CR in pragmatic communication is critical for several reasons: it may help clarify how pragmatic ability is supported and intertwined with cognitive and lifestyle factors in aging; furthermore, if CR is closely linked to communicative-pragmatic performance, it should be considered when assessing pragmatic impairments in subclinical, e.g., mild cognitive impairment, and clinical populations such as Parkinson's disease and dementia. Indeed, if CR can protect pragmatic ability, then promoting behaviors that enhance CR—such as lifelong learning, intellectual engagement, and social interaction—may help preserve communicative skills in aging.

Despite the theoretical relevance of CR in preserving linguistic ability (Montemurro et al., 2021), empirical evidence on the pragmatic domain remains inconclusive. Few studies have explored this relationship, and results are mixed. For instance, Montemurro et al. (2019) found that CR played a protective role in individuals with dementia, whereas Baraldi and Domaneschi (2024) reported different and inconsistent patterns of association between CR and pragmatic performance. In a recent longitudinal study with healthy aging, Gabbatore et al. (2025) found that a specific aspect of the CR, i.e., the index related to the type of leisure time activities, correlates with participants' pragmatic ability.

At present, however, it remains unclear whether CR consistently predicts pragmatic competence in healthy aging, or whether its effects vary across different pragmatic subcomponents. Moreover, the protective effects of CR are not uniform across cognitive domains. Some functions appear to be influenced primarily by education, whereas others, such as lexical retrieval, seem less related to CR. This suggests that CR may differentially impact distinct aspects of cognition and communication, further complicating its role in pragmatic language.

Given the limited and conflicting findings, further research is needed to clarify whether CR plays a significant role in sustaining pragmatic competence in aging, and which aspects of pragmatic communication are most influenced by CR. Ultimately, identifying protective factors such as CR is crucial not only for understanding aging-related changes in communication but also for developing targeted interventions. If CR

proves to be a key factor in preserving pragmatic ability, this would provide strong justification for promoting cognitively enriching activities as a means of supporting successful communication in late adulthood.

1.4. The present study

Although recent evidence points to the importance of assessing the decline of communicative-pragmatic ability in aging, several gaps remain in the literature. The primary objective of this study was thus to comprehensively assess communicative-pragmatic ability across three age groups: two cohorts of older adults (65–75 and 76–86 years old) and a younger adult group (20–40 years old). This investigation aimed to expand upon and validate the findings of Hilviu et al. (2022) by offering an examination of age-related changes in pragmatic competence with a larger sample and by investigating, in addition to pragmatic performance, the role of ToM, EFs and cognitive reserve.

In order to investigate pragmatic performance, the Assessment Battery for Communication was used (ABaCo, Angeleri et al., 2012; Bosco et al., 2012). ABaCo allows a comprehensive assessment of pragmatic ability, across different expressive modalities (linguistic, extralinguistic, and paralinguistic) and diverse pragmatic domains (non-literal language understanding, social norms of communication, conversational abilities, etc.). It was validated for assessing communicative-pragmatic ability in the Italian population, demonstrating good psychometric properties in terms of content validity, inter-rater agreement and internal consistency (Angeleri et al., 2015; Sacco et al., 2008). Specifically, the internal consistency of the scales composing ABaCo ranges from $\alpha = 0.626$ to $\alpha = 0.91$, indicating a satisfactory level of consistency as values higher than 0.5 (De Vellis, 1991) or 0.6 (Nunnally, 1978) with the only exception of the production subscale within the Context Scale ($\alpha = 0.52$). Regarding the Interrater reliability, Cohen's kappa values were all above 0.76, indicating excellent agreement ($k > 0.75$) (see Landis & Koch, 1977). In addition, two previous studies (Bosco et al., 2018; Parola et al., 2019) showed the convergent validity of ABaCo with a different tool measuring functional communication, i.e., the Communication Activities of Daily Living (Holland et al., 1999) and narrative tasks (Marini et al., 2011; Petriglia, Marini et al., 2025). Furthermore, the validity of ABaCo has been demonstrated in populations with TBI (Bosco, Gabbatore, et al., 2018; Bosco, Parola, et al., 2018; Bosco, Parola, Sacco, et al., 2017), schizophrenia (Bosco et al., 2019; Parola et al., 2018, 2020), and both left and right hemisphere brain lesions (Gabbatore et al., 2014; Parola et al., 2016). Finally, ABaCo has proven its validity also in other cultural contexts and languages, as it has been partially adapted into American English (Davis et al., 2024), Serbian (Dordević et al., 2016), Portuguese (Agrela et al., 2020), and Finnish (Gabbatore et al., 2019).

More specifically, this study aims to address four key research questions:

1) How is communicative-pragmatic ability characterized in healthy aging?

In line with Hilviu et al. (2022), we hypothesize that the performance on communicative-pragmatic tasks decreases in older participant groups compared with the younger one.

2) Are cognitive functions and ToM skills impaired in aging?

To this aim, we provided a comprehensive assessment of a variety of cognitive functions, including general cognitive abilities, EFs and ToM. In line with previous evidence (Buckner, 2004; Mather, 2010; Hippel, 2007), we hypothesize to find a decline in participants' cognitive - in particular EFs - and ToM performance. We also aim to explore whether ToM declines with age, given that prior research shows mixed results (e.g., Baraldi & Domaneschi, 2024; Bottiroli et al., 2016).

3) What is the predictive role of EFs and ToM in explaining older adults' communicative-pragmatic competence?

Given inconsistent findings from previous studies, we aimed to explore the association between EFs, ToM and the decline of communicative-pragmatic ability as measured with ABaCo battery.

4) Does Cognitive Reserve influence the maintenance of pragmatic competence in older adults?

We aim to examine whether higher levels of CR (measured through education, occupational history, and cognitive engagement) would be associated with better pragmatic performance.

By addressing the above-mentioned gaps, the study aimed to clarify the mechanisms underlying pragmatic decline in aging and identify potential protective factors that could inform future cognitive training and rehabilitation strategies.

2. Methods

2.1. Participants

The study includes 84 participants (46 women), divided into three age groups: two groups of older adults, i.e., Old Adults (OA), including 28 individuals aged 65 to 75 years (15 women), and Senior Old Adults (SOA), comprising 28 participants aged 76 to 86 years (17 women). Moreover, a control group of Young Adults (YA), was composed of 28 individuals (14 women), ranging in age from 20 to 40 years. See Table 1 for a detailed description of the participants' demographics. The groups were balanced for gender (chi-square showed a no significant association between gender and age groups, $\chi^2(2, N = 84) = 0.67, p = .71$, Cramér's $V = 0.25$), even if the group of oldest adults (SOA) has a higher number of females (see Table 1), in line with life expectancy and demographic statistics for the Italian population. An ANOVA revealed a significant effect of group on education level, $F(2, 84) = 4.54, p = .013, \eta^2 = 0.101$ (see Table 1). Bonferroni post hoc comparisons indicated a significant difference in education between YA and SOA ($p = .011$), while no significant differences were found between SOA and OA ($p = .656$) or YA and OA ($p = .246$). Educational differences were taken into the account in the main analysis (see Data analysis section). Participants were recruited through various channels, including local branches of the cultural association University of the Third Age, community and social clubs, voluntary and charitable organizations, cultural events, personal networks, and advertisements on major social media platforms such as Facebook, Instagram, and X (Twitter).

Exclusion criteria included the presence of basic cognitive or language impairments, a history of current or past neurological conditions (e.g., epilepsy), substance or alcohol use disorders, significant neurological or neuropsychological illnesses, sensory impairments (hearing or vision problems), a history of head trauma, or the use of mood-stabilizing medications. To be included in the study, participants were required to meet specific cut-off scores on standardized cognitive and language assessments: (1) a cut-off score on the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) based on the Italian regression-based normative data (Conti et al., 2015), incorporating

cultural and educational corrections validated for the Italian population, which typically result in lower MoCA raw scores compared to the original English norms; specifically, we computed age- and education-adjusted MoCA score and retained only participants with an Equivalent Score (ES) ≥ 2 , i.e., adjusted MoCA ≥ 19.501 . This threshold explicitly excludes both pathological performance (ES = 0; ≤ 17.362) and the entire borderline group (ES = 1; 17.363–19.500). (2) A score $\geq 4.5/5$ on the short version of the Token Test (TT; De Renzi & Vignolo, 1962), and (3) a score $\geq 108/120$ on the Naming task of the Aachen Aphasia Test (AAT; Huber et al., 1983).

All participants were thoroughly informed about the purpose and procedures of the study and provided written consent to participate in accordance with ethical guidelines. The study was approved by the Bio-Ethical Committee of the University of Turin (Protocol 202174).

2.2. Material

2.2.1. Communicative-pragmatic assessment (Assessment Battery for Communication)

Participants' pragmatic ability was assessed using the Assessment Battery for Communication (ABaCo), a standardized and validated tool designed to explore multiple dimensions of pragmatic competence (Angeleri et al., 2012, 2015; Bosco et al., 2012). ABaCo comprises five distinct scales: linguistic, extralinguistic, paralinguistic, contextual, and conversational. The full battery includes 72 live interaction items with the examiner and 100 brief video clips (20–25 s each), followed by open-ended questions for each item. ABaCo administration takes approximately 90 min and has strong psychometric properties, with internal consistency within scales, high inter-rater reliability, and good content and construct validity (Angeleri et al., 2012). Normative data are available for individuals aged 16 to 86, stratified by age and education, and ABaCo has been widely used in empirical research (Angeleri et al., 2012, 2026; Hilviu et al., 2022). A brief description of the ABaCo scales is provided below:

Linguistic and Extralinguistic Scales. These scales measure the ability to comprehend and produce fundamental communicative acts, such as statements, questions, commands, and requests (Kasher, 1991). Both direct and indirect communicative acts are assessed. The linguistic scale focuses on communication through verbal means, while the extralinguistic scale evaluates the use of gestures and body movements to convey meaning.

Paralinguistic Scale. This scale examines the ability to interpret and express emotional nuances in communication through prosody and intonation. It includes tasks that assess recognition and production of emotions, paralinguistic inconsistencies, and basic communicative acts.

Context Scale. This scale evaluates the ability to produce and understand communicative acts appropriate to the social and conversational context. It considers adherence to discourse rules (e.g., Grice's maxims) and social norms.

Conversational Scale. This scale assesses participants' ability to engage in face-to-face conversations with the examiner. It measures turn-taking skills, adherence to the topic, and the capacity to enrich dialogue by introducing new ideas.

2.2.2. Cognitive assessment

A brief description of the tasks, widely used, is provided below. More details are also available in Supplementary Material C (SM-C).

2.2.3. General cognitive abilities

In the *Forward Digit Span task* (Wechsler, 1997) participants are asked to repeat a sequence of digits in the same order in which they are presented. The sequence length gradually increases, challenging the participant's ability to retain and recall the digits. This test evaluates phonological short-term memory.

The *Immediate and Deferred Recall Test* (Spinnler & Tognoni, 1987) assesses the ability to encode, store, and retrieve verbal information.

Table 1
Descriptive data for demographic information of each age group.

Group	Age Mean (SD)	Education Mean (SD)	Sex (F/M)
SOA	81.07 (3.17)	9.71 (4.65)	17/11
OA	69.32 (3.17)	11.07 (4.14)	15/13
YA	28.07 (5.42)	13.00 (3.41)	14/14

Note. SOA = Senior-Older Adults (76–86 years old), OA = Older Adults (65–75 years old), YA = Young Adults (20–40 years old). SD = Standard deviation.

Participants listen to a short text read aloud by the examiner and are asked to recall it immediately and again after a delay of approximately 10 min, during which they complete unrelated tasks. Scores are based on the accurate recall of major events and details, with separate scores for immediate and delayed recall (0–8 for each). It assesses long-term memory (LTM).

The *Trail Making Test* (TMT; Reitan, 1958) is characterized by two parts. In Part A, participants connect numbered circles (1–25) in ascending order, assessing sustained attention. In Part B, they alternate between numbers and letters (e.g., 1-A-2-B), which evaluates alternate attention. Performance is measured by the time taken to complete each part, with the difference between Part B and Part A (B-A) providing an index of cognitive flexibility and inhibitory control (Arbuthnott & Frank, 2000).

2.2.4. Executive Functions (EFs)

The *Listening Span Test* (Daneman & Carpenter, 1980) involves presenting participants with groups of sentences. Initially, each group includes two sentences, and the number progressively increases up to six sentences per group. For each sentence, participants must first judge its truthfulness (true/false) and then recall the final word of each sentence within the group. The performance derived by the number of correctly remembered words was used as a working memory index.

The *Stroop Colour and Word Test* (SCWT; Brugnolo et al., 2016) involves three tasks: reading colour words printed in black ink, naming the colours of squares, and naming the ink colour of incongruent colour words (interference condition). The colours included in the version used in the present study are blue, green, red, brown and purple. The participant is required to read the columns aloud, moving from left to right, as fast as possible. Performance is evaluated through the number of correct responses within 30 s (word items - WI, colour items - CI, and colour-word items - CWI) and the total time taken for each task (word time - WT, colour time - CT, and colour-word time - CWT). The number of correct items identified in the interference condition (CWI) serves as a measure of inhibitory control and was used in the regression models described below.

The *Modified Card Sorting Test* (mCST; Nelson, 1976) measures cognitive flexibility and inhibitory control. Participants sort 48 response cards based on shared features (colour – yellow, red, green, blue; shape – circle, cross, triangle, star; number – from 1 to 4) with 4 stimulus cards, discovering the sorting rule through examiner feedback and guidance. Scores include the number of correctly applied rules and perseverative errors (when participants persist in applying an outdated rule).

2.2.5. Theory of Mind (ToM) assessment

The *Strange Stories* task (Happé, 1994) involves listening to short narratives that require understanding the thoughts, feelings, or intentions of characters (e.g., double bluff or white lies). Participants answer questions about the characters' mental states, with higher scores indicating better mentalization abilities.

The *Reading the Mind in the Eyes Test* (RMET; Baron-Cohen et al., 2001) evaluates non-verbal ToM abilities. Participants view 36 images showing only the eye region of faces and select, from four options, the word that best describes the depicted emotion or thought. Scores range from 0 to 36, with higher scores reflecting more accurate interpretations.

Second-order ToM abilities were assessed using two stories: *John and Mary* (Wimmer & Perner, 1983) and *Peter's Birthday* (Sullivan et al., 1994). These tasks require understanding second-order false beliefs and are scored based on correct answers to questions like “What does Mom say to Grandma after she has asked *What does Peter think you got him for his birthday?*”. Higher scores indicate stronger meta-representational skills.

2.2.6. Cognitive Reserve assessment

The *Cognitive Reserve Index* questionnaire (CRIq; Nucci et al., 2013) is

a standardized tool designed to measure an individual's cognitive reserve, which refers to the brain's ability to adapt and maintain functionality despite aging or pathological changes. The CRI evaluates three main domains: education, working activity, and leisure time activities. Each domain is assessed using a series of questions that quantify the duration, intensity, and cognitive engagement involved in various life experiences. The total score provides an estimate of the cognitive reserve, with higher scores indicating greater reserve.

2.3. Procedure

Participants were tested individually in a quiet room at their homes, across three sessions, each lasting approximately 1 h, by psychology master's students previously trained to explain, administer and code the tasks.

As for ABaCo, video clips were shown on a laptop while participants and examiners sat opposite each other at a table. All sessions were video-recorded, and performance was later coded offline by two independent judges, also psychology master's students, trained in the coding procedures outlined in the ABaCo manual (Angeleri et al., 2015). Each item was scored as correct (1 point) or incorrect (0 points), with scores calculated as the mean score of all items, yielding final values between 0 and 1.

As for the cognitive and ToM tasks, these were administered in a paper and pencil format or orally, depending on the structure of the task (see description in the previous section). The same applied to *Cognitive Reserve Index* questionnaire, filled independently by each participant, with the guidance of the examiner. The tasks were administered and coded according to the criteria described in the reference paper/manual for each task. The tasks' order was randomized across participants to ensure the presentation sequence did not affect the participants' performance scores.

2.4. Data analysis

2.4.1. Age-related differences in communicative-pragmatic performance

All analyses were conducted using SPSS Statistics version 26. ABaCo scores were analyzed using a 3×5 repeated measures analysis of covariance (ANCOVA), with Age Group (Younger Adults, Older Adults, Senior Older Adults) as the between-subjects factor, and ABaCo Scales (linguistic, extralinguistic, paralinguistic, contextual, conversational) as the within-subjects factor. A linear contrast analysis was carried out on the overall ABaCo score to assess trends in pragmatic performance across age groups. For significant main effects and interactions, Bonferroni-corrected pairwise comparisons were conducted. Education was included as a covariate to control for its potential influence on pragmatic performance on ABaCo.

2.4.2. Age-related differences in cognitive performance

Participants' performance on the various cognitive measures was analyzed using a 3×1 analysis of covariance (ANCOVA), with Age Group (Younger Adults, Older Adults, and Senior Older Adults) as between-subjects factor. For any significant effects, Bonferroni-corrected pairwise post-hoc comparisons were conducted to examine group differences. Education was included as a covariate to account for its potential impact on cognitive performance.

2.4.3. Role of cognitive functions and theory of mind in explaining communicative-pragmatic performance

To examine how cognitive and ToM abilities affect pragmatic performance in older adults, we conducted a hierarchical linear regression analysis. This method assesses how much additional variance in the dependent variable is explained by new predictors at each step, after controlling for those entered in previous steps. By comparing models with an incremental number of predictors, it allows us to determine whether each added predictor significantly improves the model's

explanatory power (R^2). Given the complex interplay between general cognition, executive functions (EFs), and ToM in supporting pragmatic abilities, this approach is well-suited to isolating the unique contribution of each cognitive domain.

Predictors were introduced in the model in three stages, reflecting their theoretical importance for pragmatic performance. In Step 1, we included core cognitive abilities—short-term memory, long-term memory, and processing speed—which are foundational skills for solving any task. In Step 2 we added EFs (working memory, cognitive flexibility, and inhibitory control), which support top-down regulation of goal-directed behavior (Diamond, 2013; Miyake et al., 2000). This allowed us to assess their impact beyond basic cognitive factors. In Step 3 we introduced ToM scores, following evidence that ToM performance may depend on EFs capacity (Bloom & German, 2000; Honan et al., 2015; Pickup, 2008). The analysis was conducted separately for each ABaCo scale—linguistic, extralinguistic, paralinguistic, contextual, and conversational—and we ensured that multicollinearity among predictors was adequately controlled.

To acknowledge the complex dependency between cognitive functioning, in particular executive functions, and ToM, we ran a second hierarchical regression model in which EFs and ToM were entered as predictors in a different order, that is ToM was entered in Step 2 of the hierarchical model, while EFs were entered in the third and last Step of the model. The analysis is reported in Supplementary Material A (SM-A).

Finally, in order to control for the role of MoCA performance, we performed additional robustness analyses and replicated all regression models by adding MoCA corrected values as first step, as predictor of communicative pragmatic performance on the ABaCo. Such analyses, which fully confirm the main results of the paper, are reported in Supplementary Material B (SM-B).

2.4.4. Relationship between communicative-pragmatic ability and cognitive reserve index

To analyze the association between communicative-pragmatic performance on ABaCo and cognitive reserve index, we used Pearson's correlation coefficient (r). Correlation significance was tested at the 0.05 significance level.

3. Results

3.1. Results of age-related differences on communicative-pragmatic performance at ABaCo

We observed age-related differences across pragmatic domains (see Fig. 1 and Table 2). A repeated-measures ANCOVA with Scale (Linguistic, Extralinguistic, Paralinguistic, Contextual, Conversational) as the within-subjects factor, Age Group (YA, OA, SOA) as the between-subjects factor, and education as a covariate revealed a significant main effect of Age Group, $F(2, 80) = 8.051, p < .001, \eta^2_p = 0.168$, indicating overall age-related differences in pragmatic performance. The main effect of Scale was also significant, $F(4, 320) = 27.397, p < .001, \eta^2_p = 0.255$, confirming that performance varied across pragmatic domains.

The Age Group $\times$ Scale interaction was significant, $F(8, 320) = 2.189, p = .028, \eta^2_p = 0.052$, indicating differential age-related effects across pragmatic domains. Linear contrast analysis confirmed a significant linear trend across age groups ($p < .001$), whereas the quadratic component was non-significant ($p = .070$).

Education was a significant covariate, $F(1, 80) = 8.390, p = .005, \eta^2_p = 0.095$, indicating that higher educational level independently predicted better pragmatic performance.

Bonferroni-corrected post-hoc comparisons showed that YA scored significantly higher than both OA ($p = .003$) and SOA ($p = .002$). OA and SOA did not differ ($p = .999$). At the scale level, YA outperformed both

Table 2
Descriptive data for ABaCo scales and ABaCo Total score by group.

Scales	SOA	OA	YA
	Mean (SD)	Mean (SD)	Mean (SD)
Linguistics	0.81 (0.09)	0.82 (0.09)	0.89 (0.09)
Extralinguistic	0.69 (0.17)	0.71 (0.14)	0.82 (0.11)
Paralinguistic	0.78 (0.13)	0.80 (0.12)	0.90 (0.07)
Contextual	0.86 (0.08)	0.86 (0.13)	0.94 (0.07)
Conversational	0.99 (0.02)	1.00 (0.02)	0.99 (0.03)
ABaCo Total Score	0.78 (0.09)	0.80 (0.09)	0.89 (0.07)

Note. SOA = Senior-Older Adults (76–86 years old), OA = Older Adults (65–75 years old), YA = Young Adults (20–40 years old). SD = Standard deviation.

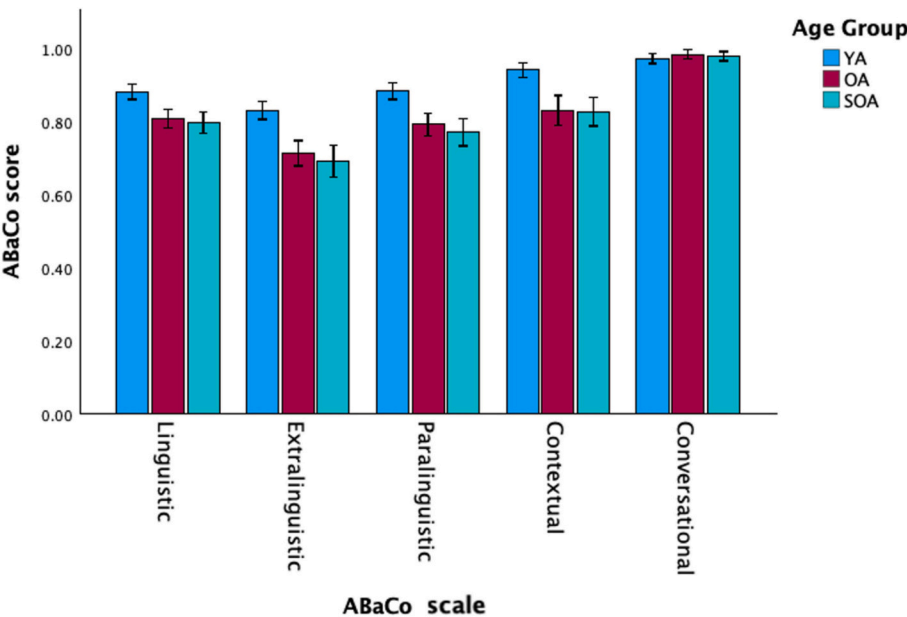


Fig. 1. Performance (mean and 95% CI) in the five ABaCo Scales for the three age groups (YA: young adults; OA: older adults; SOA: senior older adults). Note. YA = Young Adults, 20–40 years old; OA = Older Adults, 65–75 years old; SOA = Senior Older Adults, 76–86 years old.

older groups in the Extralinguistic ($p < .050$), Paralinguistic (p values ranging from 0.007 to 0.014), and Contextual ($p = .016$ for both OA and SOA groups) scales. No group differences emerged for the Linguistic or Conversational scales, all $p > .050$.

3.2. ANCOVA assumptions

3.2.1. Assumption of homogeneity of regression slopes

The assumption was met. The interaction between the covariate (education) and Age Group was not significant, $F(2, 78) = 0.51, p = .60$, indicating that the relationship between education and the dependent variable did not differ across groups.

3.2.2. Assumption of sphericity

Mauchly's test indicated that the assumption was violated for the within-subjects factor Scale, $W = 0.585, \chi^2(9) = 42.1, p < .001$. Therefore, degrees of freedom were corrected using the Greenhouse–Geisser estimate of sphericity ($\epsilon = 0.76$).

The effect of *ABaCo Scale* remained significant after correction, $F(4, 332) = 27.397, p < .001, \eta^2_p = 0.255$. A significant interaction between Age Group and Scale was also observed, $F(8, 245) = 2.189, p = .043, \eta^2_p = 0.052$.

3.2.3. Normality of residuals

Normality was assessed using Shapiro–Wilk tests and Q–Q plots. For three of the five dependent variables, both Shapiro–Wilk ($p > .05$) and visual inspection (see SM2) indicated residuals that were approximately normally distributed. For Contextual Scale, the Shapiro–Wilk test was statistically significant ($p = .01$); however, the Q–Q plot showed only minor deviations in the upper tail, suggesting no meaningful departure from normality. For Conversational Scale, both the Shapiro–Wilk test ($p < .001$) and the Q–Q plot indicated a substantial deviation from normality, characterized by a pronounced ceiling effect that compressed the upper end of the distribution. This result is consistent with previous findings for this scale (Parola et al., 2020), which show that its psychometric properties are lower than those of the others (see Bosco et al., 2012). ANCOVA is considered robust to moderate non-normality, particularly when violations arise from scale limitations; therefore, analyses were retained, with results for Conversational scale interpreted cautiously.

3.3. Results of age-related differences on cognitive performance

The analyses revealed significant age-related differences across

Table 3
Descriptive data for the cognitive and ToM tests by age group.

Measure	SOA	OA	YA
	Mean (SD)	Mean (SD)	Mean (SD)
Forward Span	5.82 (1.93)	6.11 (1.87)	7.32 (1.83)
Backward Span	4.82 (2.37)	5.39 (1.75)	6.25 (1.58)
Listening Span	16.64 (5.51)	16.68 (5.79)	26.29 (5.35)
Story Recall (LTM)	10.38 (3.20)	11.17 (2.84)	13.23 (2.22)
Trail Making Test A (TMT-A)	63.01 (27.45)	48.64 (17.80)	35.43 (12.11)
Trail Making Test B-A (TMT B-A)	91.21 (71.98)	54.36 (47.90)	35.40 (20.04)
Nelson Test – Total Categories	3.36 (1.89)	5.00 (2.05)	6.25 (1.27)
Stroop Test – Color Word Interference	11.37 (5.87)	15.64 (7.19)	27.29 (7.17)
Strange Stories (Mentalistic Condition)	5.07 (1.70)	4.86 (1.21)	5.39 (1.73)
Strange Stories (Physical Condition)	5.14 (2.45)	5.29 (1.98)	5.39 (1.72)
Second-Order Theory of Mind	1.04 (0.69)	1.25 (0.75)	1.86 (0.36)
Reading the Mind in the Eyes (RMET)	17.25 (4.12)	17.50 (3.79)	22.46 (2.91)

Note. SOA = Senior-Older Adults (76–86 years old), OA = Older Adults (65–75 years old), YA = Young Adults (20–40 years old).

multiple cognitive measures (see Table 3). Below, we report the results of the ANOVA F-tests followed by Bonferroni post-hoc comparisons between the three age groups: younger adults (YA; 20–40 years old), older adults (OA; 65–75 years old), and senior older adults (SOA; 76–86 years old).

3.4. General cognitive abilities

The results about the age-related differences detected at the tasks assessing general cognitive abilities, i.e., *Forward Span*, *Long-Term Memory (Prose Memory)*, and *Trail Making Test A (TMT-A)*, are reported in Table 4.

3.5. Executive Functions

The results about the age-related differences detected at the tasks assessing Executive Functions, i.e., *Listening Span*, *Trail Making Test B–A*, *Nelson Categories*, *Stroop Test (Colour–Word Interference)*, are reported in Table 5.

3.6. Theory of Mind

The results about the age-related differences detected at the tasks Theory of Mind, i.e., *Strange Stories (Mentalistic Condition)*, *Strange Stories (Physical Condition)*, *Second-Order ToM*, *Reading the Mind in the Eyes (RMET)*, are reported in Table 6.

3.7. Results on cognitive functions and theory of mind in explaining communicative-pragmatic performance

To explore the relationship between cognitive functions and ToM on pragmatic performance in more detail, we performed a hierarchical regression analysis on the groups of older adults (OA and SOA). The analysis revealed a significant influence of cognitive factors on pragmatic performance:

Linguistic Scale. The overall model at Step 3 was significant, $F(10, 45) = 2.259, p = .031, R^2 = 0.334$ (adjusted $R^2 = 0.186$). Step 1 was not significant ($\Delta R^2 = 0.024$; F -change = 0.430, $p = .732$). Step 2 significantly improved fit ($\Delta R^2 = 0.241$; F -change = 3.946, $p = .008$). Step 3 did not further improve fit ($\Delta R^2 = 0.069$; F -change = 1.544, $p = .216$).

Extralinguistic Scale. Step 1 was not significant ($R^2 = 0.096$; $F(3, 52) = 1.832, p = .153$). Step 2 significantly improved the model ($R^2 = 0.278$; $F(7, 48) = 2.634, p = .022$; $\Delta R^2 = 0.182$; F -change $\approx 3.022, p = .027$). Step 3 did not lead to further improvement ($R^2 = 0.289$; F

Table 4
Age-related differences in General Cognitive Abilities - ANOVA results and post-hoc comparisons.

Measure	ANOVA F-test	p	η^2_p	YA vs. OA	YA vs. SOA	OA vs. SOA
Forward Span	$F_{(2,80)} = 3.721$	0.029	0.085	ns ($p = .094$)	YA > SOA ($p = .040$)	ns ($p = 1.000$)
Story Recall (LTM)	$F_{(2,66)} = 4.662$	0.013	0.124	ns ($p = .086$)	YA > SOA ($p = .013$)	ns ($p = 1.000$)
Trail Making Test A (TMT A)	$F_{(2,66)} = 7.116$	0.002	0.177	ns ($p = .648$)	YA > SOA ($p = .001$)	OA > SOA ($p = .033$)

Note. YA = Young Adults (20–40 years old), OA = Older Adults (65–75 years old), SOA = Senior-Older Adults (76–86 years old). η^2_p = Partial Eta squared.

Table 5
Age-related differences in Executive functions (EFs) - ANOVA results and post-hoc comparisons.

Measure	ANOVA F-test	p	η_p^2	YA vs. OA	YA vs. SOA	OA vs. SOA
Listening Span	$F_{(2,80)} = 22.580$	<0.001	0.361	YA > OA ($p < .001$)	YA > SOA ($p < .001$)	ns ($p = 1.000$)
Trail Making Test B-A	$F_{(2,65)} = 9.982$	<0.001	0.235	ns ($p = 1.000$)	YA > SOA ($p < .001$)	OA > SOA ($p = .001$)
Nelson Categories (errors)	$F_{(2,80)} = 13.611$	<0.001	0.254	ns ($p = .096$)	SOA > YA ($p < .001$)	SOA > OA ($p = .006$)
Stroop Test (Colour-Word Interference)	$F_{(2,64)} = 24.873$	<0.001	0.437	YA > OA ($p < .001$)	YA > SOA ($p < .001$)	ns ($p = .125$)

Note. YA = Young Adults (20–40 years old), OA = Older Adults (65–75 years old), SOA = Senior-Older Adults (76–86 years old). η_p^2 = Partial Eta squared.

Table 6
Age-related differences in Theory of Mind (ToM) abilities - ANOVA results and post-hoc comparisons.

Measure	ANOVA F-test	p	η_p^2	YA vs. OA	YA vs. SOA	OA vs. SOA
Strange Stories (Mentalistic condition)	$F_{(2,80)} = 0.498$	0.610	0.012	ns ($p = 1.000$)	ns ($p = 1.000$)	ns ($p = 1.000$)
Strange Stories (Physical condition)	$F_{(2,79)} = 0.017$	0.983	0.000	ns ($p = 1.000$)	ns ($p = 1.000$)	ns ($p = 1.000$)
Second Order ToM	$F_{(2,80)} = 10.706$	<0.001	0.211	YA > OA ($p = .003$)	YA > SOA ($p = .001$)	ns ($p = .726$)
Reading the Mind in the Eyes (RMET)	$F_{(2,80)} = 13.422$	<0.001	0.251	YA > OA ($p < .001$)	YA > SOA ($p < .001$)	ns ($p = 1.000$)

Note. YA = Young Adults (20–40 years old), OA = Older Adults (65–75 years old), SOA = Senior-Older Adults (76–86 years old). Post-hoc p -values are Bonferroni corrected.

(10, 45) = 1.826, $p = .083$; $\Delta R^2 = 0.011$; F -change = 0.234, $p = .872$).
Paralinguistic Scale. Step 1 was not significant ($R^2 = 0.095$; $F(3, 52) = 1.829$, $p = .153$). Step 2 significantly improved the model ($R^2 = 0.334$; F -change = 4.300, $p = .005$). Step 3 did not add significant variance ($R^2 = 0.406$; F -change = 1.826, $p = .156$).
Contextual Scale. Step 1 explained essentially no variance ($R^2 = 0.000$; $F = 0.006$, $p = .999$). Step 2 significantly improved fit ($R^2 = 0.249$; $\Delta R^2 = 0.249$; $\Delta F = 3.967$, $p = .007$). Step 3 did not improve the model further ($R^2 = 0.289$; $\Delta R^2 = 0.040$; $\Delta F = 0.850$, $p = .474$).
Conversational Scale. Step 1 did not improve fit ($R^2 = 0.025$; $F(3, 52) = 0.444$, $p = .723$). Step 2 produced a non-significant improvement ($R^2 = 0.152$; $\Delta R^2 = 0.127$; F -change = 1.230, $p = .305$). Step 3 also did not significantly increase explained variance ($\Delta R^2 = 0.075$; F -change = 1.325, $p = .247$).

3.7.1. Assumptions of regression models

Multicollinearity: We assessed multicollinearity using Tolerance, VIF, and condition indices. In the final model, VIFs ranged from 1.3 to 2.1, and tolerances from 0.48 to 0.72, indicating no serious multicollinearity.

The highest Condition Index was 29.9. No predictors had variance proportions above 0.80 on this dimension, indicating that multicollinearity was not a concern in the models.

3.8. Associations between ABaCo scores and CRI

A Pearson correlation was conducted to examine the relationship between cognitive reserve index (CRI) and communicative-pragmatic performance at the ABaCo scales (see also Fig. S1 - Supplementary Material). Results showed a significant positive correlation between ABaCo global score ($r(56) = 0.28$, $p < .05$), extralinguistic scale ($r(56) = 0.32$, $p = .017$) and CRI-total score, between ABaCo global score $r(56) = 0.33$, $p < .05$), linguistic ($r(56) = 0.40$, $p = .003$), extralinguistic ($r(56) = 0.302$, $p = .025$), paralinguistic ($r(56) = 0.312$, $p = .020$) scales and CRI-education score, and conversational scale and CRI-free time ($r(56) = 0.282$, $p = .037$) and CRI-work ($r(56) = 0.350$, $p = .009$).

4. Discussion

The present study aimed to investigate age-related differences in communicative-pragmatic performance, executive functions (EFs), Theory of Mind (ToM), and Cognitive Reserve (CRI) in healthy aging, and specifically across three age groups: Young Adults (YA), Older Adults (OA), and Senior Older Adults (SOA).

Building on the findings of Hilviu et al. (2022) our first hypothesis predicted that older groups of participants (OA and SOA) would show a decline in communicative-pragmatic ability, defined as the appropriate use of language and other expressive means in various social contexts (Bara, 2010), compared to the younger group (YA). The results revealed a significant decline in pragmatic ability, as assessed by ABaCo, with YA outperforming both OA and SOA groups. No significant differences emerged between OA and SOA. These outcomes are consistent with prior studies suggesting that the ability to understand and produce communicative-pragmatic acts deteriorates with age (Baraldi & Domaneschi, 2024; Daniluk & Borkowska, 2020; Hilviu et al., 2022) and typically begins around the age of 70. Specifically, in the present study, as in Hilviu et al. (2022), the main differences between older and younger adults emerged in the ability to convey communicative meaning by specific means of expression, as evidenced by significant differences in extralinguistic and paralinguistic scales of ABaCo, as well as in the scores referring to the sensitivity to context. These findings align with prior studies showing that age-related differences affect communicative skills, including the ability to effectively use gestures (Schubotz et al., 2021), prosody (Mitchell & Kingston, 2014; Orbelo et al., 2003) and contextual information (Henry et al., 2009). The study also highlighted the significant role of education, supporting previous research (Champagne-Lavau et al., 2012) suggesting that higher levels of schooling positively influence pragmatic ability in later life. In addition, we found no significant difference in the pragmatic performance of the two groups of elderlies, i.e., SOA and OA. This finding aligns with the study by Baraldi and Domaneschi (2024), which highlighted the challenge in identifying a definitive point at which pragmatic decline occurs in old age.

Our second and third hypotheses were related to the decline of EFs and ToM during the healthy aging, and to their relationship with the pragmatic decline. Our data indicated an age-related difference in these abilities and, overall, the results indicate age-related decrease across various cognitive domains, with more pronounced impairments in SOA group with respect to the other group. Looking more closely at the tasks' performances scores, we can note that EFs, and particularly cognitive flexibility and inhibitory control, showed a progressive deterioration that, in line with the expectations, was particularly evident in SOA compared to both YA and OA. This result supports the idea that EFs are particularly vulnerable to age-related decline (Diamond, 2013; Idowu & Szameitat, 2023). Furthermore, a hierarchical regression analysis, demonstrated that adding EFs the explained variance of ABaCo scores

significantly increased, especially on the paralinguistic and contextual scales. These results suggest that EFs could play a role in communicative-pragmatic performance of healthy aging, possibly by facilitating individuals to flexibly adapt communication strategies depending on contextual demand.

Regarding ToM, the findings reveal a general decline in the ability to infer others' mental states, particularly as measured by Second-Order ToM and the Reading the Mind in the Eyes (RME) test. The absence of significant differences between OA and SOA groups suggests that the decline in ToM may reach a plateau after a certain age, which is consistent with previous studies (Bottiroli et al., 2016; Raimo et al., 2022). However, the hierarchical regression analysis indicated that ToM abilities did not significantly contribute to explaining communicative-pragmatic performance once EFs were accounted for. This result suggests that although ToM abilities decline with age, their impact on communicative-pragmatic ability may be more nuanced, which could explain why we did not observe a clear role for ToM in this context. Our results are in line with Bambini et al. (2021) showing that EFs significantly predicted pragmatic ability in aging beyond ToM, and are in favour of models where pragmatic is an independent domain only partially overlapping with the mindreading one (Bosco, Tirassa, & Gabbatore, 2018; Frau et al., 2024; Gabbatore et al., 2024). Moreover, these findings underscore the complex effects of aging on communicative-pragmatic ability, highlighting the need to consider not only general cognitive processes but also specific skills when evaluating age-related cognitive decline, as communicative pragmatic ability as well as narrative skills (see Hilviu et al., 2025).

Finally, our fourth hypothesis concerned the role of the Cognitive Reserve in communicative-pragmatic ability. We found specific differences related to CR. The significant positive correlations between CRI scores and ABaCo performance across various scales indicate that higher cognitive reserve may act as a protective factor against age-related decline in communicative-pragmatic ability. In particular, the significant associations between CRI-education and multiple ABaCo scales (i. e., linguistic, extralinguistic, paralinguistic) suggest that education may enhance cognitive resources necessary for effective communicative-pragmatic performance, as highlighted by the role of education in overall communicative-pragmatic ability measured by ABaCo. On the other hand, we found correlations between CRI-free time and CRI-work with the conversational scale. This could be explained by the fact that both free time and work-related cognitive reserve foster specific skills for social and goal-oriented communication, with free time potentially supporting more informal and spontaneous conversational abilities, and work-related reserve facilitating structured, pragmatic exchanges. These findings are in line with previous literature emphasizing the protective role of cognitive reserve in older adults' cognitive performance (Montemurro et al., 2021; Stern, 2009) and particularly with a previous study (Gabbatore et al., 2025) showing a correlation between global ABaCo performance in a group of healthy older adults and the CRI free time index.

In conclusion, our findings suggest that EFs play a significant role in supporting communicative-pragmatic ability across aging. As for ToM, while the decline with age is evident, its contribution in explaining communicative-pragmatic decline disappears when the role of EFs is controlled for. However, further research is necessary to draw final conclusions on the role of EFs on the pragmatic decline in aging. Previous research, indeed, showed a limited predictive power of EFs (and ToM) in accounting for the decrease in scores observed across different pragmatic phenomena, such as indirect speech acts, irony and deceit in clinical populations such as in persons with TBI (Bosco, Gabbatore, et al., 2018) or schizophrenia (Bosco et al., 2019). Furthermore, rehabilitative treatments, administered to such populations and specifically created to improve communicative-pragmatic ability, have clearly shown that the improvement or enhancement in pragmatic ability did not necessarily determine an increase in EFs (nor ToM) performance, thus supporting the idea of related but independent abilities (see e.g.,

Bosco et al., 2016; Bosco, Tirassa, & Gabbatore, 2018).

Additionally, another interesting result of the present investigation concerns CR, particularly through educational background, which seems to mitigate some of the negative effects of aging on communicative-pragmatic ability. The differences observed between age groups highlight the need for a deeper understanding of how age-related changes influence communicative-pragmatic ability. Globally considered, the present results have important clinical implications, as they indicate the need to develop and tailor training programs specifically aimed at preserving and enhancing communicative-pragmatic ability in aging and mitigate its decline.

4.1. Limitations, clinical implications and future directions

The present paper is not exempt from limitations. The first one concerns the Cognitive Reserve Index (CRI) that, due to its structure, relies on self-reported data for cognitive reserve, which might have introduced response biases in the findings. Moreover, the present study is cross-sectional rather than longitudinal, which partially limits our ability to draw conclusions about causal relationships between CR, EFs, ToM, and communicative-pragmatic ability. Longitudinal studies are necessary since they would be beneficial to explore more deeply how the investigated skills change over time and how they interact in the aging process.

Moreover, in the present study we used MoCA scores as an inclusion criterion, referring to Italian regression-based norms by Conti et al. (2015). The adjusted scores allowed us to retain only participants with an Equivalent Score (ES) ≥ 2 , i.e., MoCA ≥ 19.501 , enabling us to appropriately account for education- and culture-sensitive interpretation of the scores, based on the Italian context. Although this choice is supported by previous results and by additional robustness analyses performed within the present paper (see SM-B), we are also aware that some scholars may note a mismatch with respect to other international studies using raw MoCA cut-offs (e.g., <23 or <26) derived from ROC-based diagnostic-accuracy, and that this might limit the generalizability of the present results. However, we would like to point out that some cross-cultural reviews have already documented substantial heterogeneity in MoCA cut-offs and emphasized the need for culture- and education-sensitive interpretation. Specifically, O'Driscoll and Shaikh (2017) in their systematic review of MoCA's cross-cultural applicability reported a wide range of suggested MCI cut-offs and substantial variability in diagnostic accuracy across regions, highlighting the elevated risk of misclassification when universal cut-offs are applied to older groups and to groups with lower educational levels. Similarly, Cova et al. (2022) performed a qualitative review of MoCA translations and cultural adaptations, in which they documented numerous culturally distinct versions with frequent item modifications, and concluded that additional evidence is needed before MoCA can be considered fully cross-culturally fair. We believe this evidence supports our methodological choice to strictly adhere to age- and education-adjusted Italian norms; however, we also believe this point deserves attention and highlights the need for culture- and education- sensitive score interpretation in future work.

Finally, although the present results provide valuable insights into the relationships between pragmatic ability, EFs, ToM, and CR, further research is necessary to explore the causal pathways that shape communicative-pragmatic performance across the lifespan. Given the vital role that communicative-pragmatic ability plays in social interaction and daily functioning, understanding these pathways is essential for developing evidence-based strategies that can aid in the prevention, management, and rehabilitation of communicative-pragmatic impairments in older adults or individuals with neurological disorders. In this perspective, previous research has shown that the linguistic component of pragmatics (Bambini et al., 2020), similarly to other cognitive functions (Borella et al., 2010; López-Martínez et al., 2011; Wang et al., 2011) and ToM (Cavallini et al., 2015), is malleable and can benefit

from targeted interventions. Moreover, in light of its multifactorial and multimodal nature (see Bara, 2010; Holler & Levinson, 2019), recent studies suggest that participation in specifically tailored training programs may produce significant improvements, detectable not only in linguistic skills (e.g., D' Ortenzio et al., 2026), but also in the use of gesture and prosodic cues, as well as in the ability to appropriately adapt communication to the contextual demands of the interaction (see Gabbatore et al., 2026).

From a broader perspective, research devoted to the assessment and enhancement of pragmatic ability in aging addresses an important gap in the literature, which has largely overlooked the potential benefits of early detection and intervention in cognitive and communicative decline, particularly in terms of their impact on quality of life.

CRediT authorship contribution statement

A. Parola: Writing – original draft, Formal analysis, Data curation. **I. Gabbatore:** Writing – original draft, Methodology, Funding acquisition, Data curation, Conceptualization. **D. Hilviu:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **A. Marini:** Writing – review & editing, Project administration, Funding acquisition. **F.M. Bosco:** Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization.

Funding

This research was supported by PRIN 2022, Prot. n. 2022CZF8KA, project title: “ACTIVE communication: Assessment and enhancement of pragmatic and narrative skills in hEaLthY aging (ACTIVELY)” Avviso pubblico n. 104 del 02/02/2022 - PRIN 2022 PNRR M4C2 Inv. 1.1. Ministero dell'Università e della Ricerca (Financed by EU, NextGenerationEU) – CUP D53D23009630006. I.G.'s work was supported by UNITA Starting Grant - Digital Transition (proj. AI for Pragmatics).

Declaration of competing interest

The authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.actpsy.2026.107553>.

Data availability

Data will be made available on request.

References

- Agostoni, G., Bambini, V., Bechi, M., Buonocore, M., Spangaro, M., Repaci, F., Cocchi, F., Bianchi, L., Guglielmino, C., Sapienza, J., Cavallaro, R., & Bosia, M. (2021). Communicative-pragmatic abilities mediate the relationship between cognition and daily functioning in schizophrenia. *Neuropsychology*, 35(1), 42–56. <https://doi.org/10.1037/NEU0000664>
- Agrela, N., Santos, M. E., & Guerreiro, S. (2020). Transcultural translation and adaptation of the Assessment Battery for Communication (ABaCo) for the Portuguese population. *Revista CEFAC*, 22(3), Article e15319. <https://doi.org/10.1590/1982-0216/202022315319>
- Andrews-Hanna, J. R., Snyder, A. Z., Vincent, J. L., Lustig, C., Head, D., Raichle, M. E. E., & Buckner, R. L. (2007). Disruption of large-scale brain systems in advanced aging. *Neuron*, 56(5), 924–935. <https://doi.org/10.1016/J.NEURON.2007.10.038/ATTACHMENT/344BADAD-EEFA-41B2-8C84-270374F788D5/MMC1.PDF>
- Angeleri, R., Bara, B. G., Bosco, F. M., Colle, L., & Sacco, K. (2015). *Batteria per l'Assessment della Comunicazione (ABaCo)*. Firenze: Giunti OS Organizzazioni Speciali.
- Angeleri, R., Bosco, F. M., Gabbatore, I., Bara, B. G., & Sacco, K. (2012). Assessment battery for communication (ABaCo): Normative data. *Behavior Research Methods*, 44(3), 845–861. <https://doi.org/10.3758/s13428-011-0174-9>
- Angeleri, R., Gabbatore, I., Merlini, A., & Sacco, F. M. (2026). Assessment Battery for Communication (ABaCo): An Extension of Normative Data to Elderly Individuals. *Journal of Psycholinguistic Research*, 55(4), 74. <https://doi.org/10.1007/s10936-026-10264-7>
- Arbuthnott, K., & Frank, J. (2000). Trail making test, part B as a measure of executive control: Validation using a set-switching paradigm. *Journal of Clinical and Experimental Neuropsychology*, 22(4), 518–528. [https://doi.org/10.1076/1380-3395\(200008\)22:4](https://doi.org/10.1076/1380-3395(200008)22:4)
- Bambini, V., Agostoni, G., Buonocore, M., Tonini, E., Bechi, M., Ferri, I., Sapienza, J., Martini, F., Cuoco, F., Cocchi, F., Bischetti, L., Cavallaro, R., & Bosia, M. (2022). It is time to address language disorders in schizophrenia: A RCT on the efficacy of a novel training targeting the pragmatics of communication (PragmaCom). *Journal of Communication Disorders*, 97, Article 106196. <https://doi.org/10.1016/J.JCOMDIS.2022.106196>
- Bambini, V., Arcara, G., Bechi, M., Buonocore, M., Cavallaro, R., & Bosia, M. (2016). The communicative impairment as a core feature of schizophrenia: Frequency of pragmatic deficit, cognitive substrates, and relation with quality of life. *Comprehensive Psychiatry*, 71, 106–120. <https://doi.org/10.1016/j.comppsy.2016.08.012>
- Bambini, V., Tonini, E., Ceccato, I., Lecce, S., Marocchini, E., & Cavallini, E. (2020). How to improve social communication in aging: Pragmatic and cognitive interventions. *Brain and Language*, 211, Article 104864. <https://doi.org/10.1016/j.bandl.2020.104864>
- Bambini, V., Van Looy, L., Demiddele, K., & Schaecken, W. (2021). What is the contribution of executive functions to communicative-pragmatic skills? Insights from aging and different types of pragmatic inference. *Cognitive Processing*, 22(3), 435–452. <https://doi.org/10.1007/S10339-021-01021-W>
- Bara, B. G. (2010). *Cognitive pragmatics*. MIT Press.
- Baraldi, M. A., & Domaneschi, F. (2024). Pragmatic skills in late adulthood. *Journal of Psycholinguistic Research*, 53(2), 1–34. <https://doi.org/10.1007/S10936-024-10061-0/TABLES/10>
- Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 42(2), 241–251. <https://doi.org/10.1017/S0021963001006643>
- Barulli, D., & Stern, Y. (2018). Cognitive reserve: Theory, measurement, and evidence. In *APA handbook of dementia* (pp. 357–368). <https://doi.org/10.1037/0000076-018>
- Benichov, J., Cox, L. C., Tun, P. A., & Wingfield, A. (2012). Word recognition within a linguistic context: Effects of age, hearing acuity, verbal ability, and cognitive function. *Ear and Hearing*, 33(2), 250–256. <https://doi.org/10.1097/AUD.0B013E31822F680F>
- Bibby, H., & McDonald, S. (2005). Theory of mind after traumatic brain injury. *Neuropsychologia*, 43(1), 99–114. <https://doi.org/10.1016/j.neuropsychologia.2004.04.027>
- Bischetti, L., Ceccato, I., Lecce, S., Cavallini, E., & Bambini, V. (2023). Pragmatics and theory of mind in older adults' humor comprehension. *Current Psychology*, 42(19), 16191–16207. <https://doi.org/10.1007/S12144-019-00295-W/TABLES/4>
- Bloom, P., & German, T. P. (2000). Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*, 77(1), B25–B31. [https://doi.org/10.1016/S0010-0277\(00\)00096-2](https://doi.org/10.1016/S0010-0277(00)00096-2)
- Borella, E., Carretti, B., Riboldi, F., & De Beni, R. (2010). Working memory training in older adults: Evidence of transfer and maintenance effects. *Psychology and Aging*, 25(4), 767–778. <https://doi.org/10.1037/A0020683>
- Bosco, F. M., & Angeleri, R. (2012). Communicative impairment after traumatic brain injury: Evidence and pathways to recovery. In *Brain Injury - Functional aspects, rehabilitation and prevention* (p. 226). <https://doi.org/10.5772/27975>
- Bosco, F. M., Angeleri, R., Zuffranieri, M., Bara, B. G., & Sacco, K. (2012). Assessment battery for communication: Development of two equivalent forms. *Journal of Communication Disorders*, 45(4), 290–303. <https://doi.org/10.1016/j.jcomdis.2012.03.002>
- Bosco, F. M., Berardinelli, L., & Parola, A. (2019). The ability of patients with schizophrenia to comprehend and produce sincere, deceitful and ironic communicative intentions: The role of theory of mind and executive functions. *Frontiers in Psychology*, 10, Article 827. <https://doi.org/10.3389/fpsyg.2019.00827>
- Bosco, F. M., & Gabbatore, I. (2017). Sincere, deceitful, and ironic communicative acts and the role of the theory of mind in childhood. *Frontiers in Psychology*, 8, Article 21. <https://doi.org/10.3389/fpsyg.2017.00021>
- Bosco, F. M., & Gabbatore, I. (2025). Pragmatica cognitiva: dalla teoria al trattamento clinico. *Sistemi Intelligenti*, XXXVII(1/2025), 69–88. <https://doi.org/10.1422/115209>
- Bosco, F. M., Gabbatore, I., Angeleri, R., Zettin, M., & Parola, A. (2018). Do executive function and theory of mind predict pragmatic abilities following traumatic brain injury? An analysis of sincere, deceitful and ironic communicative acts. *Journal of Communication Disorders*, 75, 102–117. <https://doi.org/10.1016/j.jcomdis.2018.05.002>
- Bosco, F. M., Gabbatore, I., Gastaldo, L., & Sacco, K. (2016). Communicative-Pragmatic Treatment in Schizophrenia: A Pilot Study. *Frontiers in Psychology*, 7, 166. <https://doi.org/10.3389/fpsyg.2016.00166>
- Bosco, F. M., Parola, A., Angeleri, R., Galetto, V., Zettin, M., & Gabbatore, I. (2018). Improvement of communication skills after traumatic brain injury: The efficacy of the cognitive pragmatic treatment program using the Communicative Activities of Daily Living. *Archives of Clinical Neuropsychology*, 33(7), 875–888. <https://doi.org/10.1093/arclin/acy041>
- Bosco, F. M., Parola, A., Sacco, K., Zettin, M., & Angeleri, R. (2017). Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions. *Brain and Language*, 168, 73–83. <https://doi.org/10.1016/j.bandl.2017.01.007>

- Bosco, F. M., Parola, A., Valentini, M. C., & Morese, R. (2017). Neural correlates underlying the comprehension of deceitful and ironic communicative intentions. *Cortex*, 94, 73–86. <https://doi.org/10.1016/j.cortex.2017.06.010>
- Bosco, F. M., Tirassa, M., & Gabbatore, I. (2018). Why pragmatics and theory of mind do not (completely) overlap. *Frontiers in Psychology*, 9, 1–7. <https://doi.org/10.3389/fpsyg.2018.01453>
- Bottiroli, S., Cavallini, E., Ceccato, I., Vecchi, T., & Lecce, S. (2016). Theory of mind in aging: Comparing cognitive and affective components in the faux pas test. *Archives of Gerontology and Geriatrics*, 62, 152–162. <https://doi.org/10.1016/j.archger.2015.09.009>
- Brugnolo, A., De Carli, F., Accardo, J., Amore, M., Bosia, L. E., Bruzzaniti, C., ... Girtler, N. (2016). An updated Italian normative dataset for the Stroop color word test (SCWT). *Neurological Sciences*, 37(3), 365–372. <https://doi.org/10.1007/S10072-015-2428-2/TABLES/5>
- Buckner, R. L. (2004). Memory and executive function in aging and AD: Multiple factors that cause decline and reserve factors that compensate. *Neuron*, 44(1), 195–208. <https://doi.org/10.1016/J.NEURON.2004.09.006/ASSET/4BEE662D-0A34-42A3-A1B3-93FF4E804D3E/MAIN.ASSETS/GR8.JPG>
- Burke, D. M., & Shafto, M. A. (2004). Aging and language production. *Current Directions in Psychological Science*, 13(1), 21–24.
- Cavallini, E., Bianco, F., Bottiroli, S., Rosi, A., Vecchi, T., & Lecce, S. (2015). Training for generalization in theory of mind: A study with older adults. *Frontiers in Psychology*, 6. <https://doi.org/10.3389/FPSYG.2015.01123>
- Champagne-Lavau, M., Monetta, L., & Moreau, N. (2012). Impact of educational level on metaphor processing in older adults. *Revue Française de Linguistique Appliquée*, 2, 89–100.
- Christensen, H., Korten, A. E., Jorm, A. F., Henderson, A. S., Jacomb, P. A., Rodgers, B., & Mackinnon, A. J. (1997). Education and decline in cognitive performance: Compensatory but not protective. *International Journal of Geriatric Psychiatry*, 12(3), 323–330. [https://doi.org/10.1002/\(SICI\)1099-1166\(199703\)12:3](https://doi.org/10.1002/(SICI)1099-1166(199703)12:3)
- Conti, S., Bonazzi, S., Laiacina, M., Masina, M., & Coralli, M. V. (2015). Montreal Cognitive Assessment (MoCA) - Italian version: Regression-based norms and equivalent scores. *Neurological Sciences*, 36(2), 209–214. <https://doi.org/10.1007/s10072-014-1921-3>
- Cova, I., Nicotra, A., Maestri, G., Canevelli, M., Pantoni, L., & Pomati, S. (2022). Translations and cultural adaptations of the Montreal Cognitive Assessment: A systematic and qualitative review. *Neurological Sciences*, 43(1), 113–124. <https://doi.org/10.1007/s10072-021-05716-y>
- D'Ortenzio, S., Gabbatore, I., Petriglia, F., Gasparotto, G., Vegna, G., Marini, A., & Bosco, F. M. (2026). Is narrative enhancement possible in healthy aging? A preliminary investigation into the effects of advanced training activities. *Journal of Psycholinguistic Research* (Under Review - 2nd round).
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, 19(4), 450–466. [https://doi.org/10.1016/S0022-5371\(80\)90312-6](https://doi.org/10.1016/S0022-5371(80)90312-6)
- Daniluk, B., & Borkowska, A. R. (2020). Pragmatic aspects of verbal communication in elderly people: A study of Polish seniors. *International Journal of Language & Communication Disorders*, 55(4), 493–505. <https://doi.org/10.1111/1460-6984.12532>
- Davis, B., Guendouzi, J., Savage, M., Blackburn, W., & Williams, M. (2024). Politeness strategies in response to prompted directives in the preliminary English version of the ABAcO battery. *Journal of Interactional Research in Communication Disorders*, 6(2), 115–129. <https://doi.org/10.1558/JIRCD.V7I1.26755>
- De Renzi, E., & Vignolo, L. A. (1962). The token test: A sensitive test to detect receptive disturbances in aphasics. *Brain*, 85(4), 665–678. <https://doi.org/10.1093/brain/85.4.665>
- De Vellis, R. F. (1991). *Scale development: Theory and applications*. Thousand Oaks, CA: Sage.
- Diamond, A. (2013). Executive functions. *Annual Review of Psychology*. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Dordević, M., Glumbićs, N., & Brojčin, B. (2016). Paralinguistic abilities of adults with intellectual disability. *Research in Developmental Disabilities*, 48, 211–219. <https://doi.org/10.1016/j.ridd.2015.11.001>
- D'Ortenzio, S., Petriglia, F., Gasparotto, G., Andreetta, S., Gobbo, M., & Marini, A. (2025). Aging, cognitive efficiency, and lifelong learning: Impacts on simple and complex sentence production during storytelling. *Brain Sciences*, 15, Article 1120. <https://doi.org/10.3390/brainsci15101120>
- Fittipaldi, S., Legaz, A., Maito, M., Hernandez, H., Altschuler, F., Canziani, V., ... Ibanez, A. (2024). Heterogeneous factors influence social cognition across diverse settings in brain health and age-related diseases. *Nature Mental Health*, 2(1), 63–75. <https://doi.org/10.1038/s44220-023-00164-3>
- Fjell, A. M., Sneve, M. H., Grydeland, H., Storsve, A. B., & Walhovd, K. B. (2017). The disconnected brain and executive function decline in aging. *Cerebral Cortex*, 27(3), 2303–2317. <https://doi.org/10.1093/CERCOR/BHW082>
- Frau, F., Cerami, C., Dodich, A., Bosia, M., & Bambini, V. (2024). Weighing the role of social cognition and executive functioning in pragmatics in the schizophrenia spectrum: A systematic review and meta-analysis. *Brain and Language*, 252, Article 105403. <https://doi.org/10.1016/J.BANDL.2024.105403>
- Gabbatore, I., Angeleri, R., Bosco, F. M., Cossa, F. M., Bara, B. G., & Sacco, K. (2014). Assessment of communicative abilities in aphasic patients. *Minerva Psichiatrica*, 55, 45–55.
- Gabbatore, I., Bosco, F. M., Geda, E., Gastaldo, L., Duca, S., Costa, T., ... Sacco, K. (2017). Cognitive pragmatic rehabilitation program in schizophrenia: A single case fMRI study. *Neural Plasticity*, 2017(1), Article 1612078. <https://doi.org/10.1155/2017/1612078>
- Gabbatore, I., Bosco, F. M., Mäkinen, L., Ebeling, H., Hurtig, T., & Loukusa, S. (2019). Investigating pragmatic abilities in young Finnish adults using the Assessment Battery for Communication. *Intercultural Pragmatics*, 16(1), 27–56. <https://doi.org/10.1515/IP-2019-0002/MACHINEREADABLECITATION/RIS>
- Gabbatore, I., Bosco, F. M., & Tirassa, M. (2024). What are they all doing in that restaurant? Perspectives on the use of theory of mind. *Frontiers in Psychology*, 15, Article 1507298.
- Gabbatore, I., Conterio, R., Vegna, G., & Bosco, F. M. (2025). Longitudinal assessment of pragmatic and cognitive decay in healthy aging, and interplay with subjective cognitive decline and cognitive reserve. *Scientific Reports*, 15(1), Article 30835.
- Gabbatore, I., Sacco, K., Angeleri, R., Zettin, M., Bara, B. G., & Bosco, F. M. (2015). Cognitive pragmatic treatment: A rehabilitative program for traumatic brain injury individuals. *Journal of Head Trauma Rehabilitation*. <https://doi.org/10.1097/HTR.0000000000000087>
- Gabbatore, I., Vegna, G., Hilviu, D., Merlini, A., & Bosco, F. M. (2026). Enhancing pragmatic communication in healthy aging: A preliminary investigation of the long-term effects of the Advanced Cognitive Pragmatic Treatment. *Journal of Psycholinguistic Research* (in press. Accepted for publication on July 17, 2026).
- Gertel, V. H., Zhang, H., & Diaz, M. T. (2020). Stronger right hemisphere functional connectivity supports executive aspects of language in older adults. *Brain and Language*, 206, Article 104771. <https://doi.org/10.1016/J.BANDL.2020.104771>
- Happé, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, 24(2), 129–154. <https://doi.org/10.1007/BF02172093>
- Henry, J. D., Phillips, L. H., Ruffman, T., & Bailey, P. E. (2013). A meta-analytic review of age differences in theory of mind. *Psychology and Aging*, 28(3), 826–839. <https://doi.org/10.1037/A0030677>
- Henry, J. D., von Hippel, W., & Baynes, K. (2009). Social inappropriateness, executive control, and aging. *Psychology and Aging*, 24(1), 239–244. <https://doi.org/10.1037/A0013423>
- Hilviu, D., Gabbatore, I., Parola, A., & Bosco, F. M. (2022). A cross-sectional study to assess pragmatic strengths and weaknesses in healthy ageing. *BMC Geriatrics*, 22, Article 699. <https://doi.org/10.1186/S12877-022-03304-Z>
- Hilviu, D., Parola, A., Bosco, F. M., Marini, A., & Gabbatore, I. (2025). Grandpa, tell me a story! Narrative ability in healthy aging and its relationship with cognitive functions and Theory of Mind. *Language, Cognition and Neuroscience*, 40(1), 103–121. <https://doi.org/10.1080/23273798.2024.2401027>
- Hippel, W. v. (2007). Aging, executive functioning, and social control. *Current Directions in Psychological Science*. <https://doi.org/10.1111/J.1467-8721.2007.00512.X>
- Holland, A. L., Frattali, C., & Fromm, D. (1999). *Communication activities of daily living: CADL-2*. Austin, TX: Pro-Ed.
- Holler, J., & Levinson, S. C. (2019). Multimodal language processing in human communication. *Trends in Cognitive Sciences*, 23(8), 639–652. <https://doi.org/10.1016/J.TICS.2019.05.006>
- Honan, C. A., McDonald, S., Gowland, A., Fisher, A., & Randall, R. K. (2015). Deficits in comprehension of speech acts after TBI: The role of theory of mind and executive function. *Brain and Language*, 150, 69–79. <https://doi.org/10.1016/j.bandl.2015.08.007>
- Huber, W., Poeck, K., & Willmes, K. (1983). The Aachen aphasia test. *Advances in Neurology*, 42, 291–303.
- Hyter, Y. D. (2017). Pragmatic assessment and intervention in children. *Perspectives in Pragmatics, Philosophy and Psychology*, 11, 493–526. https://doi.org/10.1007/978-3-319-47489-2_19
- Idowu, M. I., & Szameitat, A. J. (2023). Executive function abilities in cognitively healthy young and older adults—A cross-sectional study. *Frontiers in Aging Neuroscience*, 15, Article 976915. <https://doi.org/10.3389/FNAGI.2023.976915>
- Kasher, A. (1991). On the pragmatic modules: A lecture. *Journal of Pragmatics*, 16(5), 381–397. [https://doi.org/10.1016/0378-2166\(91\)90132-H](https://doi.org/10.1016/0378-2166(91)90132-H)
- Katsos, N., & Andrés-Roqueta, C. (2021). Where next for pragmatics and mind reading? A situation-based view (response to Kissine). *Language*, 97(3), e184–e197.
- Kissine, M. (2021). Autism, constructionism, and nativism. *Language*, 97(3), e139–e160. <https://doi.org/10.1135/LAN.2021.0055>
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33, 159–174.
- Levinson, S. C. (1983). *Pragmatics*. Cambridge University Press.
- López-Martínez, Á., Santiago-Ramajo, S., Caracul, A., Valls-Serrano, C., Hornos, M. J., & Rodríguez-Fórtiz, M. J. (2011). Game of gifts purchase: Computer-based training of executive functions for the elderly. In 2011 IEEE 1st International Conference on Serious Games and Applications for Health, SeGAH 2011. <https://doi.org/10.1109/SeGAH.2011.6165448>
- Marini, A., Galetto, V., Zampieri, E., Vorano, L., Zettin, M., & Carlomagnò, S. (2011). Narrative language in traumatic brain injury. *Neuropsychologia*, 49(10), 2904–2910. <https://doi.org/10.1016/j.neuropsychologia.2011.06.017>
- Marini, A., Petriglia, F., D'Ortenzio, S., Bosco, F. M., & Gasparotto, G. (2025). Unveiling the dynamics of discourse production in healthy aging and its connection to cognitive skills. *Discourse Processes*, 62(6–7), 479–501. <https://doi.org/10.1080/0163853X.2025.2507548>
- Marini, A., Petriglia, F., D'Ortenzio, S., Gabbatore, I., & Gasparotto, G. (2026). Cognitive reserve effects on discourse production processing in healthy aging. *Journal of Neurolinguistics*. Article 101315. <https://doi.org/10.1016/j.jneuroling.2026.101315>
- Marini, A., Petriglia, F., Gasparotto, G., D'Ortenzio, S., Andreetta, S., & Gobbo, M. (2026). Standardization of the MultiLevel discourse analysis (MLA) and identification of data-driven age bands for research on language in healthy aging.

- Journal of Neurolinguistics*, 79, Article 101343. <https://doi.org/10.1016/j.jneuroling.2026.101343>
- Mather, M. (2010). Aging and cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, 1(3), 346–362. <https://doi.org/10.1002/WCS.64>
- Mitchell, R. L. C., & Kingston, R. A. (2014). Age-related decline in emotional prosody discrimination. *Experimental Psychology*, 61(3), 215–223. <https://doi.org/10.1027/1618-3169/A000241>
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>
- Montemurro, S., Jarema, G., & Mondini, S. (2021). Cognitive reserve and language processing demand in healthy older adults. *Language, Cognition and Neuroscience*, 36(6), 758–772. <https://doi.org/10.1080/23273798.2021.1896012>
- Montemurro, S., Mondini, S., Signorini, M., Marchetto, A., Bambini, V., & Arcara, G. (2019). Pragmatic language disorder in Parkinson’s disease and the potential effect of cognitive reserve. *Frontiers in Psychology*, 10, Article 1220. <https://doi.org/10.3389/fpsyg.2019.01220>
- Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., ... Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, 53(4), 695–699. <https://doi.org/10.1111/J.1532-5415.2005.53221.X>
- Nelson, H. E. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, 12(4), 313–324. [https://doi.org/10.1016/S0010-9452\(76\)80035-4](https://doi.org/10.1016/S0010-9452(76)80035-4)
- Nucci, M., Mapelli, D., & Mondini, S. (2013). Cognitive Reserve Index questionnaire (CRIq): A new instrument for measuring cognitive reserve. *Aging Clinical and Experimental Research*, 24(3), 218–226. <https://doi.org/10.1007/BF03654795>
- Nunnally, J. (1978). *Psychometric theory*. New York: McGraw-Hill.
- O’Driscoll, C., & Shaikh, M. (2017). Cross-cultural applicability of the Montreal Cognitive Assessment (MoCA): A systematic review. *Journal of Alzheimer’s Disease*, 58(3), 789–801. <https://doi.org/10.3233/JAD-161042>
- Orbelo, D. M., Testa, J. A., & Ross, E. D. (2003). Age-related impairments in comprehending affective prosody with comparison to brain-damaged subjects. *Journal of Geriatric Psychiatry and Neurology*, 16(1), 44–52. <https://doi.org/10.1177/0891988702250565>
- Parola, A., Berardinelli, L., & Bosco, F. M. (2018). Cognitive abilities and theory of mind in explaining communicative-pragmatic disorders in patients with schizophrenia. *Psychiatry Research*, 260, 144–151. <https://doi.org/10.1016/j.psychres.2017.11.051>
- Parola, A., & Bosco, F. M. (2018). Rehabilitation of communicative-pragmatic ability and ageing. In *Rehabilitation medicine for elderly patients* (pp. 357–360). Cham: Springer.
- Parola, A., & Bosco, F. M. (2022). An eye-tracking investigation of the cognitive processes involved in the comprehension of simple and complex communicative acts. *Quarterly Journal of Experimental Psychology*, 75(10), 1976–1995. <https://doi.org/10.1177/17470218221079629>
- Parola, A., Bosco, F. M., Gabbatore, I., Galetto, V., Zettin, M., & Marini, A. (2019). The impact of the Cognitive Pragmatic Treatment on the pragmatic and informative skills of individuals with traumatic brain injury (TBI). *Journal of Neurolinguistics*, 51, 53–62. <https://doi.org/10.1016/j.jneuroling.2018.12.003>
- Parola, A., Gabbatore, I., Berardinelli, L., Salvini, R., & Bosco, F. M. (2021). Multimodal assessment of communicative-pragmatic features in schizophrenia: A machine learning approach. *NPJ Schizophrenia*, 7(1), 1–9. <https://doi.org/10.1038/s41537-021-00153-4>
- Parola, A., Gabbatore, I., Bosco, F. M., Bara, B. G., Cossa, F. M., Gindri, P., & Sacco, K. (2016). Assessment of pragmatic impairment in right hemisphere damage. *Journal of Neurolinguistics*, 39, 10–25. <https://doi.org/10.1016/j.jneuroling.2015.12.003>
- Parola, A., Salvini, R., Gabbatore, I., Colle, L., Berardinelli, L., & Bosco, F. M. (2020). Pragmatics, theory of mind and executive functions in schizophrenia: Disentangling the puzzle using machine learning. *PLoS One*, 15(3). <https://doi.org/10.1371/JOURNAL.PONE.0229603>
- Petriglia, F., Gasparotto, G., D’Ortenzio, S., Gabbatore, I., & Marini, A. (2025). Assessing lexical diversity and informativeness across the adult lifespan: A comprehensive investigation. *Research Methods in Applied Linguistics*, 4, Article 100276. <https://doi.org/10.1016/j.rmal.2025.100276>
- Petriglia, F., Marini, A., Gabbatore, I., & Bosco, F. M. (2025). Pragmatic and narrative decline in healthy aging: A multilevel assessment of their interplay. *Journal of Communication Disorders*, 118, Article 106593. <https://doi.org/10.1016/j.jcomdis.2025.106593>
- Pickup, G. J. (2008). Relationship between theory of mind and executive function in schizophrenia: A systematic review. *Psychopathology*, 41(4), 206–213. <https://doi.org/10.1159/000125554>
- Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, 1(4), 515–526. <https://doi.org/10.1017/S0140525X00076512>
- Raimo, S., Cropano, M., Roldán-Tapia, M. D., Ammendola, L., Malangone, D., & Santangelo, G. (2022). Cognitive and affective theory of mind across adulthood. *Brain Sciences*, 12(7), 899. <https://doi.org/10.3390/BRANS12070899>
- Reitan, R. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, 8, 271–276. <https://doi.org/10.2466/PMS.8.7.271-276>
- Rowley, D. A., Rogish, M., Alexander, T., & Riggs, K. J. (2017). Cognitive correlates of pragmatic language comprehension in adult traumatic brain injury: A systematic review and meta-analyses. *Brain Injury*, 31(12), 1564–1574. <https://doi.org/10.1080/02699052.2017.1341645>
- Royle, P., Steinhauer, K., Dessureault, É., Herbay, A. C., & Brambati, S. M. (2019). Aging and language: Maintenance of morphological representations in older adults. *Frontiers in Communication*, 4, Article 387223. <https://doi.org/10.3389/FCOMM.2019.00016/BIBTEX>
- Sacco, K., Angeleri, R., Bosco, F. M., Colle, L., Mate, D., & Bara, B. G. (2008). Assessment Battery for Communication—ABaCo: A new instrument for the evaluation of pragmatic abilities. *Journal of Cognitive Science*, 9, 111–157.
- Sacco, K., Gabbatore, I., Geda, E., Duca, S., Cauda, F., Bara, B. G., & Bosco, F. M. (2016). Rehabilitation of communicative abilities in patients with a history of TBI: Behavioral improvements and cerebral changes in resting-state activity. *Frontiers in Behavioral Neuroscience*, 10. <https://doi.org/10.3389/fnbeh.2016.00048>
- Schubotz, L., Holler, J., Drijvers, L., & Özyürek, A. (2021). Aging and working memory modulate the ability to benefit from visible speech and iconic gestures during speech-in-noise comprehension. *Psychological Research*, 85(5), 1997–2011. <https://doi.org/10.1007/S00426-020-01363-8/FIGURES/3>
- Spinnler, H., & Tognoni, G. (1987). Standardizzazione e taratura italiana di test neuropsicologici. *Italian Journal of Neurological Sciences*, 6(8), 8–119.
- Staekenborg, S. S., Kelly, N., Schuur, J., Koster, P., Scherder, E., Tielkes, C. E. M., ... Claus, J. J. (2020). Education as proxy for cognitive reserve in a large elderly memory clinic: “Window of benefit”. *Journal of Alzheimer’s Disease*, 76(2), 671–679. <https://doi.org/10.3233/JAD-191332>
- Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, 47(10), 2015–2028. <https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2009.03.004>
- Stern, Y., Arenaza-Urquijo, E. M., Bartés-Faz, D., Belleville, S., Cantillon, M., Chetelat, G., ... Van Loenhoud, A. C. (2020). Whitepaper: Defining and investigating cognitive reserve, brain reserve, and brain maintenance. *Alzheimer’s & Dementia*, 16(9), 1305–1311. <https://doi.org/10.1016/J.JALZ.2018.07.219>
- Sullivan, K., Zaitchik, D., & Tager-Flusberg, H. (1994). Preschoolers can attribute second-order beliefs. *Developmental Psychology*, 30, 395–402. <https://doi.org/10.1037/0012-1649.30.3.395>
- Tomasi, D., & Volkow, N. D. (2011). Aging and functional brain networks. *Molecular Psychiatry*, 17(5), 549–558. <https://doi.org/10.1038/mp.2011.81>
- Valiengo, L. d. C. L., Stella, F., & Forlenza, O. V. (2016). Mood disorders in the elderly: Prevalence, functional impact, and management challenges. *Neuropsychiatric Disease and Treatment*, 12, 2105–2114. <https://doi.org/10.2147/NDT.S94643>
- Wang, M. Y., Chang, C. Y., & Su, S. Y. (2011). What’s cooking? -Cognitive training of executive function in the elderly. *Frontiers in Psychology*, 2, Article 228. <https://doi.org/10.3389/fpsyg.2011.00228>
- Wechsler, D. (1997). In *WAIS-III/WMS-III technical manual*. San Antonio, TX: The Psychological Corporation.
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children’s understanding of deception. *Cognition*, 13(1), 103–128. [https://doi.org/10.1016/0010-0277\(83\)90004-5](https://doi.org/10.1016/0010-0277(83)90004-5)