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Longitudinal assessment of pragmatic and cognitive decay in healthy aging, and interplay with subjective cognitive decline and cognitive reserve

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Aging involves a general slowdown in the function of multiple cognitive areas. Longitudinal assessment of comprehension and production in pragmatic communication is lacking and whether subjective cognitive decline (SCD) and cognitive reserve (CR) interact with pragmatic competence in aging is unknown. The study sample was a small group of older adults. Pragmatic and cognitive abilities were compared at baseline and at follow up. Pragmatic comprehension and production were assessed across different expressive means. Correlations between decay in pragmatic ability and SCD and CR were tested. Pragmatic ability and comprehension, in particular, seemed to decline with age, as did naming skills, working memory, and executive functions. A correlation between SCD, CR and pragmatic ability was detected. This preliminary study on the longitudinal assessment of pragmatic decay in aging yielded novel insights into SCD and CR in healthy aging.

Keywords Healthy aging, Pragmatics, Subjective cognitive decline, Cognitive reserve, Longitudinal study

Aging involves a complex interplay of biological and psychological changes that vary across individuals and cognitive domains[1]. Age-related cognitive decline leads primarily to slower processing[2], less effective memory, such as the ability to learn and retrieve novel information[3], and less executive control[4]. Compared with younger adults, executive function (EFs) performance is lower on a range of top-down controls that drive actions into plans and adjust them toward a goal[5], such as inhibition of prepotent responses[6] and shifting between simultaneous tasks[7]. Moreover, working memory also decreases with age. This ability to hold information in a short-term memory "loop" and to manipulate it toward a goal via a central executive mechanism[8] relies on processing verbal, visual or visuospatial contents[9].

Age-related cognitive decay can be felt as self-experience of one's mental functioning, though this subjective change may not necessarily be perceived as an actual manifestation of cognitive decay. The concept of subjective cognitive decline (SCD) captures the feeling of worse performance in cognitive domains without formal neuropsychological or neurological proof[10]. The concept draws attention to cases in which this subjective perception manifests without formal evidence yet strongly anticipate the onset of objective cognitive deterioration[11]. Indeed, SCD has been often associated with the onset of mild cognitive impairment (MCI)[12,13] and Alzheimer's Disease (AD)[14,15]. SCD principally involves memory deficits such as loss of the ability to remember names, events or appointments[16]. It also affects cognitive functions besides memory, such as executive functions, attention, language, and visuospatial ability (e.g., following patterns or maps)[10,17]. Hallmarks of SCD are disorientation and difficulty with concentrating, decision-making, and planning[18]. Other markers correlated with the risk of progressive cognitive decline are SCD onset within the past 5 years and age > 60 years, confirmation by an observer, consistent (rather than episodic) manifestation over time, and seeking medical help[11].

Early signs of decay may be modulated or masked[19] by protective cognitive factors elicited by cognitively and physically stimulating activities[20]. For instance, an association exists between delayed cognitive decline and higher education level[21,22]. Similarly, the concept of cognitive reserve (CR), which encompasses a range of

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cognitive abilities developed during regular lifespan activities (e.g., education, occupation, leisure activities)[23] may explain interindividual susceptibility to an aging brain[24]. CR refers to the adaptability that helps justifying differential susceptibility of skills and day-to-day function to brain aging and pathology[25]. The concept is complex, can be seen from different angles, and disparate definitions can be used for similar terms, such as for example Resilience, Brain Reserve or Brain Maintenance[26]. In the present paper we decided to refer to the term Cognitive Reserve to reflect the label used in the questionnaire used to measure this construct in our sample. Importantly, most previous studies have applied specific proxy measures (e.g., education and occupational status) as representative indicators of CR, whereas few (e.g., Lee et al.[27]) have integrated these factors in a comprehensive evaluation of CR.

Age-related cognitive changes have been widely explored, but communication in late adulthood warrants further investigation. Previous research has focused on basic linguistic skills, such as lexical access[28], word retrieval[29], and vocabulary[30], while age-related changes in communicative-pragmatic ability have been less studied. Pragmatics refers to high-level aspects of communication (i.e., the use of language[31]), non-verbal/extralinguistic means (e.g., gestures, facial expressions, body movements) and paralinguistic cues (e.g., prosody, rhythm, speech rate) to convey meaning in a given social context[32,33].

A general age-related decline in pragmatic ability has been well documented by Zanini et al.[34] and by Daniluk and Borkowska[35] who administered Italian and Polish participants, respectively, two adapted versions of the Right Hemisphere Language Battery[36] to assess pragmatic phenomena such as metaphors, humour, and conversation. Similar results were reported by Baraldi and Domaneschi[37] who found lower pragmatic performance in a group of older adults than in younger controls, as measured with the Assessment of Pragmatic Abilities and Cognitive Substrates tool (APACS)[38]. The APACS assesses discourse ability (e.g., speech, informativeness, information flow, paralinguistic aspects, description of pictures) and pragmatic comprehension skills (e.g., narratives, recognition of non-literal meaning and humour). Similarly, other studies found age-related pragmatic difficulties with the comprehension of figurative language, such as metaphors[39,40], proverbs[41], and humour[42,43].

Furthermore, Hilviu et al.[44] used the Assessment Battery for Communication (ABaCo)[45–47] to assess pragmatic decay in three age groups across several expressive means, (linguistic, extralinguistic, paralinguistic) and pragmatic phenomena (direct and indirect communicative acts, irony, and deceit). They reported lower performance on ABaCo's extralinguistic, paralinguistic, and contextual scales by the two oldest groups (65–75 and 76–86 years). In line with these results, other studies showed that the ability to understand and produce gestures[48,49] or emotional facial expressions[50,51] declines with age. For instance, Arslan and Göksun[48] and Cocks et al.[49] found that older people do not seem to benefit from representational gestures in transient breakdowns of speech planning (e.g., conveying an abstract meaning in a picture description task), and that they are more likely to ignore gestures during a multi-modal presentation. Lastly, difficulties with emotional processing of paralinguistic aspects of communication have been documented. Older adults show poor discrimination of the affective connotation of a message through its prosody (e.g., intonation, speech rate and rhythm)[52,53].

Narrative performance involving paragrammatisms, semantic paraphasias, ambiguous referencing, and low levels of informativeness seems to wane in later adulthood[54]. Besides addressing the role of Theory of Mind (ToM) and a range of cognitive functions (e.g., EFs and memory abilities) Hilviu et al.[55] employed a micro—lexical and grammatical––and a macrolinguistic––pragmatic and discourse––approach to assess narrative skills in three age groups (20–40, 65–75, 76–86 years). They found an age-related decay in phonology, semantic retrieval, sentence complexity, coherence, cohesion, and lexical informativeness.

The majority of the studies available in the current literature, motioned above, mainly focused on a specific expressive mean, usually language, and on comprehension tasks. Few studies have provided an overall assessment of pragmatic ability in comprehension and production (e.g. Hilviu et al.[44]). What is more, despite the fair number of studies assessing pragmatic changes in late adulthood, long-term comparison using a within-individual approach (e.g., longitudinal design) is absent.

Effective cognitive functioning may interact with several aspects of communication. First, subjective perception of one's cognitive functioning often involves self-reported linguistic failures (e.g., remembering a proper name, word retrieval)[56]. Questionnaires measuring people's perception of overall cognitive functioning (i.e., SCD) have been found to correlate with language decline[57]; as language can be further broken down into several different domains, i.e., syntax, semantics and pragmatics, age-related communicative-pragmatic decline may also play a role in SCD. Nevertheless, research addressing the interaction between SCD and pragmatic competence is lacking.

Furthermore, previous studies have described relationship between pragmatic performance, especially in the discrimination of non-literal expressions, and various EFs, namely, inhibitory control[40,41], working memory and cognitive flexibility[58]. Others have noted that global cognitive functioning[35], education[34,59] and task familiarity[39] play a consistent role in effective pragmatic communication.

Similarly, cognitive reserve may correlate with performance on pragmatic tasks. A study involving patients with Parkinson's Disease[60] reported an association between the cognitive reserve index and all tasks in the comprehension section of the APACS[38]. This suggests that maintaining an active lifestyle may help counteract the decline in pragmatic ability associated with neurodegenerative conditions. In addition, given the affinity of CR profiles with the healthy controls in the study, the authors speculated that such protective effects may involve normal aging as well. In contrast, Baraldi and Domaneschi[37] found no such correlation in their group of healthy older adults, who performed worse on pragmatic tasks than the younger adult group. Nevertheless, what is remarkable that the older adults scored higher than the younger ones on CR and that overall performance on cognitive tasks was the same for both age groups. Further research is needed to explore the relationship between pragmatic ability and CR across cognitive profiles.

Study aims

The first aim of this longitudinal study was to detect a possible decline in pragmatic ability in a group of older adults between baseline and follow-up. Comprehensive pragmatic assessment of expressive means was carried out using the equivalent forms[46] of the ABaCo[47]. The equivalent forms of the ABaCo have been validated and showed good psychometric properties[45] and they assess pragmatic competence in comprehension and production across various expressive means. To the best of our knowledge, this is the first longitudinal study to employ broad assessment of pragmatic ability in healthy aging. Our hypothesis was that pragmatic performance, as assessed by ABaCo, would diminish over time.

The second aim was to investigate decline in cognitive abilities (i.e., attention, memory, executive functions), as measured by neuropsychological assessment. Our hypothesis was that higher-level cognitive functions such as inhibition, sensitivity to interference, and cognitive flexibility and working memory are affected by aging. Further aims were to explore associations between pragmatic ability and subjective perception of decline in performance (i.e., SCD). We expected to find a relationship between these domains. Finally, we wanted to investigate the interaction between cognitive reserve (i.e., CR) and the decline in pragmatic performance.

Methods

Sample

The participants were part of a larger sample of 61 individuals (34 women) involved in a research project on pragmatic and cognitive abilities in healthy aging. However, 21 individuals were inaccessible due to difficulty maintaining contact owing to COVID-19-related issues and 27 withdrew from the study for personal or health problems before the second phase of evaluation began. In addition, 1 participant was excluded because of the onset of neurological disorders during the study period. Hence, the final study sample was 12 individuals (6 women) aged 65–85 years ($M = 72.33$; $SD = 6.20$) at the beginning of the study and 69–86 years ($M = 76.8$; $SD = 4.87$) when the second evaluation phase took place. The education level was 5–19 years ($M = 12.08$; $SD = 4.76$).

All participants were Italian native speakers. Inclusion criteria for the initial phase of the study were: preserved global cognitive functioning, as determined by a cut-off score of ≥ 19.5 on the MoCA test[61] (see also Conti et al.[62] for Italian normative data), and basic linguistic skills in comprehension, as assessed with the short form of the Token Test (cut-off score ≥ 4.5)[63], and production, as assessed with the naming task of the Aachen Aphasia Test (AAT; cut-off score ≥ 108/120)[64]. These screening tests were performed also in the second phase of assessment. They were not used as cut-off measures but rather as indicators of changes in basic cognitive functioning. The scores were included in the statistical analysis. Exclusion criteria were: past or current neurological or neuropsychological disorders (e.g., epilepsy, traumatic brain injury or cerebrovascular disease), severe hearing or vision problems, diagnosis of psychiatric illness (e.g., psychosis or major depressive disorder), history of substance or alcohol abuse, and use of mood stabilizers.

The participants received an informative letter detailing the above-mentioned criteria. They were requested to withdraw from the study if any of these health conditions were present or manifested during the study period. Participation in the study was voluntary. Enrolment was conducted through flyering, collaboration with local recreative and cultural centres, and via the research group's social network. All methods and procedures were performed in accordance with the Declaration of Helsinki. The participants were asked to provide their informed written consent and told that they could withdraw the study at any time. The project was approved by the Bio-Ethical Committee of the University of Turin (Protocol no. 202174).

Procedures

The experimental design included an initial assessment (T0) and a later follow-up session (T1). Follow-up assessment was delayed due to COVID-19 restrictions. As a result, the time between T0 and T1 varied across participants longer than usual by standard procedures (range, 5 years; $M = 5.33$; $SD = 2.81$). Each assessment phase consisted of two individual sessions lasting about 1–1.5 hour each, during which pragmatic ability and cognitive functions were evaluated. During the first assessment session, cognitive reserve was measured using the Cognitive Reserve Index questionnaire (CRIq)[65]. The Multidimensional Assessment of Subjective Cognitive Decline (MASCoD)[18], a measure of SCD, was performed during the follow-up assessment (T1).

Materials

Communicative-pragmatic ability: equivalent forms of the Assessment Battery for Communication

The equivalent forms[46] of the ABaCo[45,47] were administered during each study phase to determine changes in communicative-pragmatic ability. The equivalent forms of ABaCo consist of two versions of the same test but with different items, thus ruling out the learning effect. This allows for testing and re-testing and ensures the consistent application of methodology in longitudinal studies. The items on the ABaCo include short interactions between participant and examinator and videoclips (20–25 s each) in which actors use different linguistic, extralinguistic and paralinguistic expressive means to communicate. The ability to understand the actors' communicative meaning or to produce a response to the actors' communicative act is assessed via questions about what happened in the videoclips.

Each of the equivalent forms includes 68 items and four scales (linguistic, extralinguistic, paralinguistic, context) that assess pragmatic phenomena in comprehension and production. The *linguistic* scale and the *extralinguistic* scale encompass basic speech acts (e.g., assertions, questions, commands, requests) and pragmatic phenomena such as direct and indirect communicative acts, deceit, and irony, with a focus on linguistic skills and extralinguistic means (e.g., gestures, facial expressions, body movements). The *paralinguistic* scale assesses the ability to understand and express communicative intention through prosodic cues. The *context* scale evaluates the ability to perform a communicative act appropriate for social context and to recognise the adequacy or inadequacy of a speech act according to social norms and conversational rules. Each scale allows for the analysis of specific aspects in comprehension and production. A composite score for overall comprehension and production can also be calculated. The effectiveness of the ABaCo in detecting pragmatic impairment in a variety of clinical populations[66–70] and cultural contexts[71–74] has been documented. ABaCo administration and coding procedures were conducted following the guidelines in the tool manual[47]. A detailed description of the battery is given in the Supplementary Material (Table S1).

Neuropsychological assessment
Cognitive functioning was assessed with neuropsychological tests. In each study phase, neuropsychological assessment provided for a broad evaluation of cognitive abilities (attention, memory, EFs) for comparison of performance over time.

- Attention––selective attention, visuospatial search, and alternating attention

Selective attention (i.e. the ability to focus on specific stimuli and ignore irrelevant information) and visuospatial search were assessed using Task A of the Trail Making Test (TMT – A)[75]. Trail Making Test B (TMT – B)[75] was used to measure alternating attention (i.e. the ability to manage two tasks alternately by shifting from one to the other).

- Memory––short-term verbal memory, working memory, and prose memory

Short-term verbal memory was evaluated using the Digit Span forward [76], which assesses the ability to retain a list of numbers and recall it immediately after presentation. The Digit Span backward[76] provides a measure of working memory skills (subjects must retain the strings in memory and manipulate the numbers to correctly identify the inverse order of presentation). The learning process for semantically structured verbal content (prose memory) was assessed using a story recall task (Immediate and Deferred Recall Test)[77].

- Executive functions (EFs)–inhibition, sensitivity to interference, and cognitive flexibility

Cognitive abilities in executive functioning were assessed: inhibition, sensitivity to interference, and cognitive flexibility. Subtraction of the completion times recorded for TMT – B and TMT – A (TMT – B-A)[75] returns a measure of cognitive flexibility and inhibitory control (the subject must rapidly switch tasks while suppressing irrelevant contents). In addition, the Stroop Color Word Test (SCWT)[78] was employed to evaluate inhibitory control and the ability to resist interference from conflicting instructions. The derived scores – Stroop Color Word Time (CWT) and Stroop Color Word Item (CWI) – provide information on processing speed and accuracy, respectively, on the inhibition task. A full description of the neuropsychological tests is given in the Supplementary Material (Table S2).

Multidimensional assessment of subjective cognitive decline – MASCoD
SCD was introduced in the second phase of assessment (T1) and assessed using the MASCoD[18]. Recently developed, the tool comprises various sections addressing cognitive manifestations, socio-demographic, psycho-affective, and neurological factors that correlate with SCD. We used Section A and Section B, which address risk factors associated with progressive cognitive decay, memory difficulties, and other cognitive manifestations. *Section A* includes a screening of factors which are commonly associated with SCD and increase the risk of cognitive decline, namely subjective concerns, onset of SCD within the past 5 years and over the age of 60 years, persistence of SCD over time, confirmation by an external informant, and the presence of neurological disorders or other comorbidities. *Section B* focuses on memory difficulties and other types of cognitive manifestations, such as disorientation, decision-making, and attentional problems. Both section A and Section B include a yes/no format: 1 point is assigned when a risk factor or specific manifestation is present, while 0 points are attributed when it is absent. Total score for MASCoD A + B ranges from 0 (low risk of progressive cognitive decay) to 21 (high risk of progressive cognitive decay).

Cognitive reserve
The Cognitive Reserve Index questionnaire (CRIq)[65] was administered during the first phase of assessment (T0). It consists of a global score (CRI-Global score) and three subscales: CRI-Education (years of education and training), CRI-WorkingActivity (adulthood occupations), and CRI-LeisureTime (regularly practiced cognitive stimulating activities). A summary of the CRIq coding guidelines is given in the Supplementary Material (Table S3).

Statistical analysis
Non-parametric statistical tests were employed to ensure robustness of analyses in this small study sample. We wanted to assess changes in communicative and cognitive performance over time (T1 vs. T0) and investigate their association with SCD and CR. The Wilcoxon signed-rank test was performed to determine differences in the ABaCo and the raw scores on the cognitive tasks between baseline (T0) and follow-up (T1).

Correlation analysis was performed to reveal relationships between changes in pragmatic ability and SCD (as measured with the MASCoD questionnaire) and between longitudinal changes in pragmatic ability and cognitive reserve (as measured with the CRIq). Changes in pragmatic ability were quantified as the difference between follow-up and baseline scores ($\Delta = T1 - T0$), with negative Δ scores indicating a decline in performance over time and positive Δ scores reflecting an improvement. Spearman's Rho coefficients were used to explore these associations.

ABaCo	Mean rank T0	Mean rank T1	z	p^a	r^b	95% CI for r
Overall ABaCo	.72	.70	2.43	**.015**	.70	[.21, .91]
Comprehension and production composite scores						
Comprehension	.86	.72	3.06	**.004**	.88	[.63, .97]
Production	.66	.70	.86	.338	.25	[− .38, .72]
ABaCo scales						
Linguistic scale	.76	.71	2.18	.116	.63	[.09, .88]
Extralinguistic scale	.74	.67	2.04	.082	.59	[.02, .86]
Paralinguistic scale	.75	.75	.12	.904	.03	[− .55, .60]
Context scale	.80	.60	1.22	.297	.35	[− .28, .77]

Table 1. Wilcoxon signed-rank test results for ABaCo scores at T0 and T1. [a]p-values were corrected with the FDR method. [b]Effect size (r) was calculated using the formula $r = z/\sqrt{N}$. Significant values are in bold.

Cognitive tasks	Mean rank T0	Mean rank T1	z	p^a	r^b	95% CI for r
Global cognitive functioning						
MoCA	24	23	2.14	.061	.62	[.07, .88]
Linguistic abilities						
AAT–naming	119	115	2.71	**.015**	.78	[.38, .94]
Token test	5	5	1	.387	.29	[− .34, .74]
Memory						
Span forward	7	6	1.93	.085	.56	[− .03, .86]
Span backward	6	4	2.83	**.014**	.82	[.46, .95]
Immediate and deferred recall test	11.7	12.35	.36	.722	.10	[− .50, .64]
Attention						
TMT – A	39.65	50.5	3.06	**.015**	.88	[.63, .97]
TMT – B	87	148.5	3.06	**.015**	.88	[.63, .97]
Executive functions (EFs)						
TMT – B-A	45.5	96	2.98	**.011**	.86	[.57, .96]
Stroop CWT	163.91	179.5	1.10	.374	.35	[− .36, .80]
Stroop CWI	17.5	19.5	.85	.437	.27	[− .43, .77]

Table 2. Wilcoxon signed-rank test results for cognitive test scores at T0 and T1. [a]p-values were corrected with the FDR method. [b]Effect size (r) was calculated using the formula $r = z/\sqrt{N}$. Significant values are in bold.

To address the risk of false positives due to multiple comparisons, p-values were corrected using the False Discovery Rate method (FDR)[79] for the Wilcoxon tests and the correlation analyses. This approach ranks p-values in ascending order, assigning each a rank, and applying the formula $(I/T)P$, where I represents the rank of a given p-value, T is the total number of tests conducted, and P corresponds to the desired false discovery rate threshold.

The effect size r was calculated as $r = z/\sqrt{N}$, where Z is the test statistic and N is the total number of observations. Effect size was reported for the Wilcoxon tests and the correlation analyses, with values around ± 0.10 considered small, ± 0.30 medium, and ± 0.50 large, as stated in the guidelines of Cohen[80]. Statistical analysis was performed using SPSS version 29.0.1.0 and R version 4.4.1[81].

Results

Decay in pragmatic and cognitive performance

Table 1 presents the results of the Wilcoxon signed-rank tests for pragmatic assessment with the ABaCo scales. Table 2 presents the cognitive assessments. Paired comparison revealed significant differences over time in the global ABaCo score ($z = 2.43$; $p = 0.015$; $r = 0.70$, 95% CI [0.21, 0.91]) for pragmatic ability and in the composite score for comprehension ability ($z = 3.06$; $p = 0.004$; $r = 0.88$, 95% CI [0.63, 0.97]). No difference was detected in the composite score for production ability ($z = 0.86$; $p = 0.338$; $r = 0.25$, 95% CI [− 0.38, 0.72]) nor in the ABaCo scales ($0.12 < z < 2.18$; $0.082 < p < 0.904$; $0.03 < r < 0.63$).

Paired comparison showed a significant worsening of cognitive performance on the AAT naming task ($z = 2.71$; $p = 0.015$; $r = 0.78$, 95% CI [0.38, 0.94]), on the Span backward ($z = 2.83$; $p = 0.014$; $r = 0.82$, 95% CI [0.46, 0.95]), and for all TMT scores (TMT – A: $z = 3.06$; $p = 0.015$; $r = 0.88$, 95% CI [0.63, 0.97]; TMT – B: $z = 3.06$; $p = 0.015$; $r = 0.88$, 95% CI [0.63, 0.97]; TMT – B-A: $z = 2.98$; $p = 0.011$; $r = 0.86$, 95% CI [0.57, 0.96]), while no significant differences on the other tasks were found ($0.36 < z < 2.14$; $0.061 < p < 0.722$; $0.10 < r < 0.62$).

Figures 1 and 2 illustrate the changes in pragmatic and cognitive scores, respectively, for each participant. The percentage changes in ABaCo scores, with improvement and decline indicated in a color-coded format

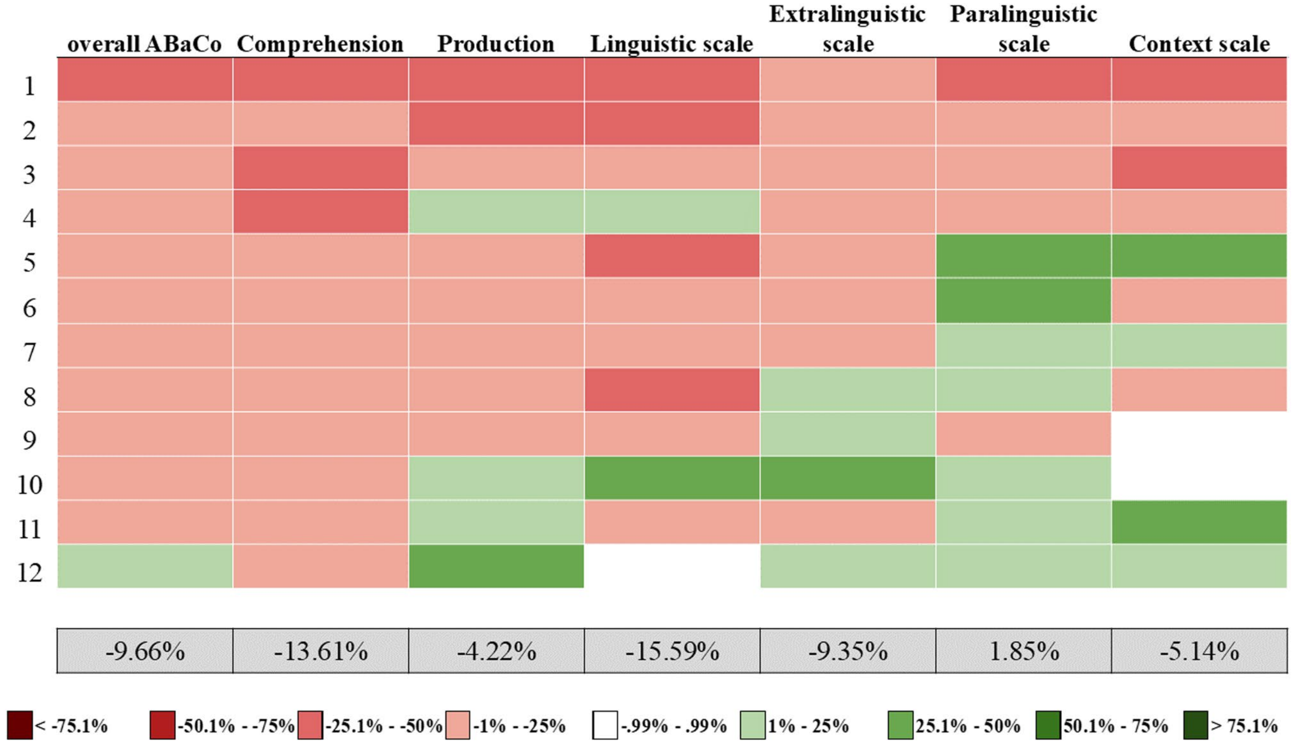

Fig. 1. Longitudinal changes in ABaCo scores.

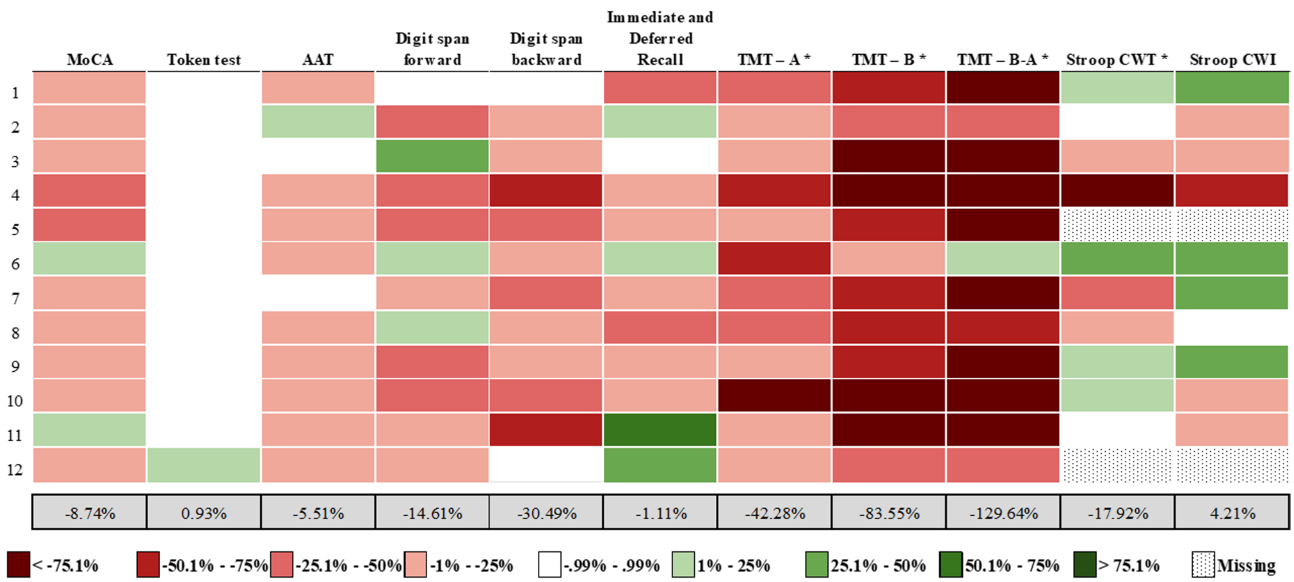

Fig. 2. Longitudinal changes in cognitive functioning.

for each participant, are shown in Fig. 1. Figure 2 shows the percentage changes in cognitive test scores and cognitive improvement or decline over time. The percentages were calculated using the formula $(\Delta/T0) \times 100$. Supplementary Materials include additional divergent bar charts illustrating the mean percentage change values for both ABaCo scores (Figure S4) and neuropsychological scores (Figure S5).

Figure 1 presents the percentage of change in performance over time according to the ABaCo scores for each participant; an increase is shown in green and a decrease in pink/red. Each row corresponds to a participant, with the case number indicated in the left margin of the figure. The bottom row, in grey, reports the overall mean percentage change values for each ABaCo score.

CRI indexes	ABaCo overall[a]	Production[a]	Comprehension[a]
CRIq-Global score	.46 [−.16, .82][b]	.59 [.02, .87][b]	−.03 [−.59, .55][b]
CRIq-Education	.06 [−.53, .61][b]	.52 [−.08, .84][b]	−.41 [−.80, .21][b]
CRIq-Working activity	.33 [−.30, .76][b]	**.59*** [.02, .87][b]	−.13 [−.66, .48][b]
CRIq-Leisure time	**.63*** [.09, .88][b]	.38 [−.25, .78][b]	.34 [−.29, .77][b]

Table 3. Spearman's Rho correlations between CRIq subscales and changes in composite scores for comprehension and production ability, and in ABaCo overall. *$p < .05$ after FDR correction. [a]Spearman rank correlation coefficients for all variables. [b]Confidence intervals computed at the 95% confidence intervals. Significant values are in bold.

Figure 2 illustrates the percentage of change in performance over time; each row corresponds to a participant. A decline is shown in darker shades of red and an increase in darker shades of green. The bottom row, in grey, reports the overall mean percentage change values for each neuropsychological test.

**Note* For the TMT and Stroop CWT tasks, higher scores represent longer completion times and thus worse performance. To maintain consistency in interpreting changes as performance deterioration, the colour scheme is inverted for these tasks and the mean percentage change values on the bottom row were sign-inverted as well.

Correlation between decay in pragmatic performance and subjective cognitive decline

Significant negative correlations were found between SCD, as measured with MASCoD A + B, and changes in pragmatic performance, as measured with Δ scores, after correcting with the FDR method. MASCoD A + B, negatively correlated with the production composite score ($r_s(10) = -0.66$, 95% CI [−0.89, −0.14], $p = 0.019$) and with the score on the linguistic scale ($r_s(10) = -0.77$, 95% CI [−0.93, −0.35], $p = 0.006$).

Correlations between decay in pragmatic performance and cognitive reserve

Table 3 presents the results of correlation analysis of the relationship between CR, as measured by the CRIq global score and subscales, and longitudinal changes in overall pragmatic performance, and the production and comprehension composite scores, as assessed with Δ scores. After applying FDR correction, we found a correlation between CRI-Leisure Time and changes in ABaCo global scores ($r_s(10) = 0.63$, 95% CI [0.09, 0.88], $p = 0.033$) and between CRI-Working Activity and changes in production composite scores ($r_s(10) = 0.59$, 95% CI [0.02, 0.87], $p = 0.046$). No other significant correlations emerged overall between CRI or its subscales and the global ABaCo scores or comprehension and production composite scores ($-0.41 < r_s < 0.59$, $0.081 < p < 0.922$). Further analysis revealed a significant correlation between the global CRI score and changes in the linguistic ABaCo scale ($r_s(10) = 0.68$, 95% CI [0.17, 0.90], $p = 0.016$), while no significant associations were found with the other ABaCo scales (extralinguistic scale: $r_s(10) = -0.13$, 95% CI [−0.66, 0.48], $p = 0.924$; paralinguistic scale: $r_s(10) = 0.04$, 95% CI [−0.55, 0.60], $p = 0.910$; context scale: $r_s(10) = 0.30$, 95% CI [−0.33, 0.75], $p = 0.676$).

Discussion

Research into age-related decline across cognitive areas has investigated processing speed[2], learning and retrieval of novel information[3], working memory[9] and executive functions[6,7], whereas pragmatic ability in late adulthood is relatively underexplored. Most research has focused principally on pragmatic comprehension, typically within linguistic formats (e.g., understanding of figurative language)[39,40], while pragmatic production has been largely neglected. Few studies have tackled a comprehensive evaluation of pragmatic ability in comprehension and production across language-mediated phenomena[34–37] and linguistic, extralinguistic, and paralinguistic expression[44].

Current data result from cross-sectional comparisons, as no study to date has used a within-person approach to explore pragmatic ability in aging. The novelty of the present study is its longitudinal design in a sample of older adults. We wanted to explore potential pragmatic decline in comprehension and production between baseline and follow-up.

Moreover, as hypothesized, our results showed a medium-to-large decrease in the ABaCo global score and a large decrease in the composite score for comprehension ability between baseline and follow-up. In contrast, we did not find the same clear effect on production ability, though the pattern of individual scores suggests a decline for most participants at the follow up assessment. Taken together, our results align with cross-sectional findings[44] and show that communicative-pragmatic ability becomes less effective with advancing age, especially when it comes to comprehension. Similarly, Baraldi and Domaneschi[37] reported lower APACS pragmatic comprehension composite scores for older adults than for younger ones[38] on a mixture of various comprehension tasks, including narratives, non-literal expressions, and humour. The age effect on the production composite score was, instead, less evident, which derives from a semi-structured interview and picture description tasks.

We observed no significant difference in the scores on each ABaCo scale separately (linguistic, extralinguistic, paralinguistic, context). Several factors account for this discrepancy. First, there is the small study sample. The wide confidence intervals reflect great variability, it is likely that a larger sample could have provided more precise estimates of the effects sizes. Moreover, differently from previous studies, and for the first time, we employed longitudinal comparisons.

From a qualitative perspective, however, a fair number of participants performed worse at the second evaluation compared to the first: 9 out of 12 participants scored worse on the linguistic scale and 8 out of 12 on the extralinguistic scale. Despite the lack of statistically significant group-level changes, the mean percentage changes indicated a performance decrease of approximately 9% to 16% on those scales. This could indicate a general decrease in the use of linguistic and in extralinguistic means (e.g., gestures, facial expressions, body movements). This observation is shared by previous studies that found an impact of age on extralinguistic modality, particularly gestures[49] and facial expression[82]. In addition, our qualitative data are in line with those reported by Hilviu et al.[44], who showed that older participants performed worse than younger ones on the ABaCo extralinguistic scale.

In contrast and, again, from a qualitative perspective, 7 out of 12 participants showed an improvement in the paralinguistic scale scores over time, and the mean changes show an increase of approximately 2%. A possible explanation is that, unlike linguistic and extralinguistic means, paralinguistic ability follows a more heterogeneous trajectory in late adulthood, with elements such as intonation of an utterance according to a specific emotion potentially benefitting from aging[83]. Finally, there was greater variation among participants on the context scale, with no clear trend across single-case performance between baseline and follow up assessment. However, the mean change scores revealed a 5% decrease in participants' performance. Note that since the context scale contains fewer items than the other ABaCo scales, this may make it more sensitive to fluctuations. It is also noteworthy that we could rely on the use of the equivalent forms of the ABaCo[46], which consist of items of identical difficulty but different content. These features, which are often missing in many neuropsychological tasks, make it possible to exclude learning effect when performing the assessment multiple times, while providing a comprehensive and accurate evaluation of pragmatic ability, taking into account several expressive means, i.e., linguistic, extralinguistic and paralinguistic in addition to the sensitivity to context. In addition to their applicability and usefulness in longitudinal studies, equivalent forms can be successfully used as assessment tools administered before and after training programs to verify their effectiveness. In the specific case of ABaCo, this has been successfully conducted to test the efficacy and specificity of pragmatic training in adults with traumatic brain injury[84] and schizophrenia[85,86], in adolescents on the autism spectrum[87] and also in healthy older people[88]. In addition, the performance of a group of patients with traumatic brain injury, tested before and after an enhancement pragmatic program on the equivalent forms of ABaCo and on the Communication Activities of Daily Living (CADL-2)[89], showed a positive significant correlation, testifying the convergent content validity of the tools[90].

A second aim of the study was to determine potential decay in cognitive performance. Data on cognitive functioning in attention, memory skills, and EFs were collected by neuropsychological assessment during each phase of the study. Screening tests yielded information on changes in basic cognitive abilities, namely, global cognitive functioning, i.e., MoCA[61], naming (AAT)[64], and linguistic comprehension (Token Test–short form)[63]. We observed a negative medium-to-large difference in the basic cognitive skills of naming over time, as assessed with the AAT. In contrast, no statistically significant difference in basic language comprehension or global cognitive functioning, as measured by the Token Test and the MoCA test, respectively, was found between baseline and follow-up evaluation. These findings are not surprising, as these screening tools assess basic cognitive functions, which are generally preserved in aging, particularly within a relatively short time period. Naming skills may be more vulnerable to age-related decline, however, as reported by previous studies showing a general slowing in linguistic production compared with comprehension[91].

We found a large age-related effect on the ability to store verbal information (i.e., digits) in the short-term memory loop and to manipulate it in inverse order, as assessed with the Digit Span backward, which involves working memory skills. Likewise, Braver and West[92] reported that the most robust indicators of memory decline are complex span tasks, such as the backward Digit Span, which require top-down controls rather than mere storage of information in short-term memory. Indeed, we found no such clear age effect on short-term memory for either unrelated verbal content (i.e., digits), as assessed with the forward mode of the Digit Span, or semantically structured verbal content (i.e., prose memory), as assessed on the Immediate and Deferred recall task.

A robust decrease in attentional domains was noted, especially in selective attention and visuospatial search (TMT – A) and alternating attention (TMT – B). In addition, cognitive flexibility and inhibition worsened over time, as indicated by higher TMT – B-A scores with a large effect size. This suggests that a decrease in executive functioning (TMT – B-A) rather than a general impairment in basic attentional functions (e.g., visuospatial processing for TMT – A) may underlie the overall worse performance on the task. This could manifest as greater difficulty with shifting between tasks, slower updating, and less effective inhibition of irrelevant responses[5]. We found no difference in the derived scores of the Stroop Color Word Test, namely CWI and CWT, which return a measure of accuracy and processing speed, respectively, on tasks involving inhibitory control and resistance to interference. Furthermore, we observed greater fluctuation across individual performance on this test. This was unexpected, as previous studies seemed to agree that aging affects the ability to inhibit intrusive responses and to suppress irrelevant information[93], with higher sensitivity to the Stroop effect[94]. However, a more recent study suggested that age-related effects may be more clearly detectable in later stages of life[95] beyond the age range of our sample. In addition, these earlier studies made cross-sectional comparisons across lifespan, which may be more sensitive to age-related effects.

Another study aim was to explore the association between cognitive and pragmatic decay and an individual's self-experience of such changes, namely SCD. Subjective manifestations of decline are strongly related to various cognitive domains (memory, EFs, language)[96], however, an association between SCD and pragmatic ability has never been investigated before. In our exploratory findings, we observed a negative correlation between the MASCoD A + B scores[18] and the changes in the composite score for pragmatic production ability but not between the global ABaCo score and the comprehension composite score. The confidence interval indicates that the true strength of this association is likely to be at least small-to-moderate, despite the relatively small sample size. Individuals with higher MASCoD scores may notice lesser ability to express themselves clearly, with poor integration of multiple expressive means (e.g., tone of voice, gestures, gaze, linguistic contents), and to organize their thoughts during conversation according to their communicative meaning. Moreover, a greater involvement of production than comprehension ability in SCD may be explained by the different degree of external confirmation, which is one of the strongest predictors of SCD. Indeed, ineffective production skills are more likely to be reported or confirmed by an external partner in comments and feedback rather than comprehension skills, for which an individual privately establishes an incorrect representation. Further studies with a larger number of participants may reveal a correlation between SCD and pragmatic comprehension.

Furthermore, we found a medium-to-large negative correlation between MASCoD A + B and lower performance scores on the ABaCo linguistic scale. This is not surprising since language is the most commonly used expressive means, and age-related issues in this domain could impact subjective experience in adapting to daily living and social interactions. In addition, SCD has been linked to linguistic difficulties and older adults frequently self-report constraints in basic linguistic abilities, (e.g., word finding, remembering names)[97]. It is plausible that subjective language decline could extend to pragmatic decline, with less ability to convey and interpret a speech act in relation to contextual cues. In sum, besides the standard cognitive abilities usually investigated, communicative-pragmatic ability may influence the overall private perception of one's cognitive functioning. Hence, given the predictive role of SCD in the onset of age-related neurodegenerative conditions[98], a decline in pragmatic ability in older age may serve as a sensitive marker for early signs of cognitive decline, especially in the absence of neuropsychological evidence. It is noteworthy that while our results are consistent with the notion that linguistic-communicative ability may shape subjective experiences of cognitive functioning, no conclusions about causality or directionality can be drawn from correlational analyses alone. On the other hand, the limited sample size did not allow to apply regression models or multivariate analyses, Further studies with larger samples and tracking of both subjective and objective changes will be essential to clarify the nature and direction of this relationship.

Finally, we explored the relationship between the decay in pragmatic ability and CR, namely, an individual's ability to cope with an aging brain, which relies on a range of lifespan experiences[23]. The current literature lacks converging evidence on this topic[37,60] and the definition itself of this concept is matter of huge groupwork (see Stern et al.[25,26]). We found a significant negative correlation between CRI-Leisure Activities and changes in the ABaCo global score. This means that participants who regularly attended recreational and cultural events experienced less pragmatic decline over time. This observation is shared by Lee et al.[27], who reported that lifelong leisure activities (e.g., reading the newspapers, going to the cinema or the theatre, physical activity) may play a greater protective role against early cognitive decline than other cognitive reserve components. Since most of such recreational activities often take place within a social context and involve conversational interactions, they could help counter age-related decline by enhancing communicative-pragmatic ability. Moreover, we found that CRI-Working Activities correlated with changes in the production composite score. This is in line with studies that showed a relationship between work complexity and protection against cognitive decline[99]. Finally, our findings suggest a negative correlation between CR total score and the ABaCo linguistic scale. This is not surprising, given the supremacy of language over other expressive means, in which cognitive stimulating activities tend to preserve our ability to communicate via language more effectively than via other modalities, such as gestures or tone of voice. Similarly, Champagne-Lavau et al.[100] and Daniluk & Burkowska[59] found a link between education and linguistic comprehension (metaphors and humoristic expressions) in late adulthood. Since studies on this topic are scarce, further research is needed to draw conclusions on the link between CR and pragmatic ability. It is noteworthy that although these correlations reached statistical significance, the wide confidence intervals indicate uncertainty in effect magnitude, especially for CRI-Working Activities. These findings should thus be interpreted as preliminary signals that warrant further investigation in larger samples, to analyse the variable of interests, i.e., the impact of education, occupation and leisure time separately and from different angles.

The present study is the first, preliminary, attempt to report longitudinal assessment of pragmatic ability in aging, and as such represents a novel contribution to the current literature. Compared with cross-sectional studies, longitudinal studies provide a more accurate measure of individual trajectories, while reducing the impact of external factors (e.g., interindividual differences and cohort effects). In addition, this is the first study to address the relationship between pragmatic ability and SCD, as measured using the MASCoD questionnaire, which makes a valuable contribution to the conceptualization of SCD and implications for its early detection.

Despite its merits, the study has some limitations. Many of the participants who took part in the initial phase of the study were later excluded for various reasons: drop-out, difficulty with maintaining contact, and onset of neurological disorders. The final sample size was therefore reduced, and this necessarily leads to some level of caution when interpreting the results. The reduced sample may have contributed to the observed fluctuations and to the absence of significant differences over time, particularly when breaking down the analysis in overall performance, i.e., the ABaCo global score in sub-components, i.e., ABaCo scales. In addition, due to the limited sample size, any regression model aimed to better understand the correlations analysis or to take into account the variability between T0 and T1 would have been inappropriate. Future studies should aim to replicate these findings in larger samples in order to enhance variability, enable more robust comparisons and perform more complex analysis.

A final consideration concerning our results is isolation and social distancing, experienced especially by older adults during the COVID-19 pandemic, which could have had an impact on cognitive functioning and mental health[101]. For instance, Amanzio et al.[102] reported a decline in cognitive performance, particularly regarding attention and EFs, in healthy elderlies during lockdowns. There's little to no evidence on pragmatic impairment due to the pandemic and its consequences, but Cummings[103] argued that the Long COVID condition and its "brain fog" (i.e. cognitive and linguistic difficulties) could have caused the disruption of pragmatic and discourse skills. Although our study did not directly investigate the role of the pandemic and lockdowns on participants, it is reasonable to assume that communicative-pragmatic ability, like other cognitive functions, may have been influenced by the imposed social restrictions and reduced engagement, as well as from COVID-19 itself.

Conclusion

Communicative-pragmatic ability may become less effective with advancing age, ensuing in miscommunication and frustration during conversation and social isolation and loss of positive social experiences. Besides cognitive functioning (e.g., attention, memory, EFs), assessment of pragmatic competence in healthy aging is essential for gaining a better understanding of how well an individual adapts to a given social context, with regard to communicative and more general cognitive achievements.

Longitudinal studies can have a crucial role in this research area, as they provide long-term trajectories of individual functioning. While previous studies have made only cross-sectional comparisons to assess pragmatic ability across the lifespan, the present study opens new insights into the assessment of communicative-pragmatic ability in healthy aging by adopting a within-person approach to evaluating comprehension and production ability. Our findings, to be intended as preliminary due to the limited sample size, still have the merit to enrich the current literature by expanding on an individual's background of cognitive resources and subjective awareness. The present study opens the path to the possibility to establish new procedures in clinical settings able to detect early stages of cognitive decline. Even considering the explorative nature of the study, this has crucial implications for targeted prevention and enhancing programs in pragmatic ability.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available for privacy or ethical restrictions; however, data will be available from the corresponding author (ilaria.gabbatore@unito.it) on reasonable request.

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I.G and F.M.B.: conceptualization of the study and funding acquisition. R.C.: Investigation and data curation. G.V.: formal analysis. All authors contributed to the writing of the original draft.

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Declarations

Competing interests
The authors declare no competing interests.

Ethical approval and informed consent

All methods and procedures were performed in accordance with the Declaration of Helsinki. The participants were asked to provide their informed written consent and told that they could withdraw the study at any time. The project was approved by the Bio-Ethical Committee of the University of Turin (Protocol no. 202174).

Consent for publication
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Additional information

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