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The Cognitive Assessment Interview (CAI): Association with neuropsychological scores and real-life functioning in a large sample of Italian subjects with schizophrenia

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ABSTRACT

Introduction: The Cognitive Assessment Interview (CAI) is an interview-based scale developed to measure cognitive impairment and its impact on functioning in subjects with schizophrenia (SCZ). Previous studies demonstrated good psychometric properties of the CAI. However, only relatively small samples of SCZ were investigated. This study aimed to determine in a large sample of SCZ (N = 580) the relationships of the Italian Version of the CAI with measures of cognitive performance and functional capacity and real-life functioning, using state-of-the-art instruments.

Methods: Intraclass correlation coefficients (ICCs) and Cronbach's alpha were calculated to examine the CAI's inter-rater reliability and internal consistency. Pearson's correlation coefficients were used to evaluate relationships between CAI global and domain composite scores with neurocognition, social cognition, functional capacity, and functioning.

Results: The inter-rater reliability and internal consistency were good to excellent. The CAI global composite score showed a strong correlation with the MATRICS Consensus Cognitive Battery (MCCB) composite score ($r = -0.50$) and moderate/strong associations with measures of functional capacity ($-0.46 < r < -0.52$) and real-life functioning ($-0.30 < r < -0.51$). Finally, CAI composite social cognition score correlated moderately with the Facial Emotion Identification Test ($r = -0.31$) and two subscales of the Awareness of Social Inference Test ($-0.32 < r < -0.34$).

Conclusions: The study suggests that CAI is a valid co-primary measure for clinical trials and a suitable instrument to screen impairment in neurocognitive and social cognitive domains and its impact on functioning in SCZ in everyday clinical practice.

Abbreviations: CAI, The Cognitive Assessment Interview; CGI-CogS, Clinical Global Impression of Cognition in Schizophrenia; FDA, Food and Drug Administration; FEIT, Facial Emotion Identification Test; FEP, first-episode psychosis; ICCs, intraclass correlation coefficients; MATRICS, Measurement and Treatment Research to Improve Cognition in Schizophrenia; MCCB, MATRICS Consensus Cognitive Battery; MSCEIT, Mayer-Salovey-Caruso Emotional Intelligence Test; SCID-I-P, Structured Clinical Interview for DSM-IV-Patient version; SCoRS, Schizophrenia Cognition Rating Scale; SCZ, subjects with schizophrenia; SLOF, Specific Level of Functioning Scale; TASIT, The Awareness of Social Inference Test; ToM, theory of mind; UCSD, University of California San Diego (UCSD); UPSA-B, University of California San Diego Performance-based Skills Assessment (UPSA-B).

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1. Introduction

The impairment in different domains of cognition represents a core feature of schizophrenia, detected in all the phases of the disorder, independently of the severity of symptoms, in the premorbid and prodromal states, as well as, in an attenuated form, in non-affected relatives of subjects with schizophrenia (Bleuler, 1950; Kraepelin, 1989; Heinrichs and Zakzanis, 1998; Sitskoorn et al., 2004; Mesholam-Gately et al., 2009; Reichenberg, 2010; Bora et al., 2014; Fatouros-Bergman et al., 2014; McCleery et al., 2014; Lee et al., 2015; Grimes et al., 2017; Mucci et al., 2018; Barch, 2019; Reed et al., 2019; Reichenberg et al., 2019; Zhang et al., 2019; Kotov et al., 2020; Menon, 2020). This impairment impacts the real-life functioning more than negative and positive symptoms (Kurtz et al., 2010; Harvey and Strassnig, 2012; Galderisi et al., 2014; Galderisi et al., 2016; Green et al., 2019; Harvey and Strassnig, 2019; Galderisi et al., 2020; Mucci et al., 2021). According to the current conceptualization, cognitive impairment in subjects with schizophrenia includes deficits in seven domains: speed of processing, attention/vigilance, working memory, verbal learning and memory, visuospatial learning and memory, reasoning and problem solving and social cognition (Green et al., 2004; Green et al., 2019; Green et al., 2020). In order to assess all these domains, a comprehensive consensus cognitive battery, the NIMH-Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) Consensus Cognitive Battery (MCCB) was developed (Green et al., 2004; Nuechterlein et al., 2008). This is a performance-based instrument and is now regarded as the gold standard battery to detect cognitive impairment in subjects with schizophrenia.

However, the U.S. Food and Drug Administration (FDA) indicated also the need to integrate and complement primary measures of cognitive impairment, obtained by assessing performance on neuropsychological tests, with co-primary measures, obtained using interview-based instruments (Durand et al., 2015). These instruments have been developed to measure the impact on functioning of the cognitive impairment and might be useful in both clinical trials and routine practice to help patients and clinicians to appraise the clinical meaning of cognitive impairment or its changes over time or following pharmacological or psychosocial treatments (Green et al., 2008; Buchanan et al., 2011; Green et al., 2011; Keefe et al., 2015; Bowie, 2019; Davidson, 2019; Falkai and Schmitt, 2019; Keefe, 2019; Melle, 2019; Sahakian and Savulich, 2019; Glenthoj et al., 2020). As a matter of fact, neuropsychological test scores and their changes over time do not have an immediate meaning to patients and carers and do not directly convey any information concerning the impact of patients' cognitive deficits on real-life functioning. Thus, interview-based instruments have different advantages: they are more practical and easier to use in routine clinical context than performance-based instruments; they provide a self-evaluation of cognitive impairment by patients, as well as a clinically meaningful evaluation by informants and clinicians, thus increasing motivation of patients to adhere to clinical trials or cognitive rehabilitation interventions and motivation of clinicians to prescribe these interventions (Keefe et al., 2006a; Palumbo et al., 2019; Ventura et al., 2013). Therefore, assessing cognitive functioning through a clinical interview might be more practical and might enable the examination of the impact of cognition on daily functioning in a way that can be comprehensible for doctors, patients and carers (Ventura et al., 2013).

Within this frame, the MATRICS Initiative tested, alongside performance-based instruments, also interview-based cognitive instruments as co-primary measures. Two co-primary measures, the Schizophrenia Cognition Rating Scale (SCoRS) (Keefe et al., 2006a) and the Clinical Global Impression of Cognition in Schizophrenia (CGI-CogS) (Ventura et al., 2008) were evaluated, showing good psychometric properties, and were regarded as a valid co-primary measure as intended by the MATRICS Initiative (they were associated with the composite score of MCCB, with measures of functional capacity and functioning) (Green et al., 2008; Green et al., 2011; Keefe et al., 2006a). However, a study focusing on the validity of the SCoRS demonstrated that the pattern of correlations between SCoRS and functioning varied in different samples; in particular, the relationship with functioning was found only in clinically stable patients, but not in recently hospitalized ones, suggesting a limited value of the SCoRS in acute phases (Vita et al., 2013). In addition, other limitations of these co-primary measures included the following: 1) the instruments were able to evaluate cognitive impairment, but they appeared to grasp a single general factor of cognition without a specific sensitivity towards the individual functions; 2) from an Item-response theory analysis carried out on the 21 items of the SCoRS and on the 20 of the CGI-CogS it emerged that only 10 to 12 items were necessary to achieve an accurate estimate of the neuropsychological deficits (Reise et al., 2011). Therefore, in order to shorten the administration-time of interview-based instruments, the Cognitive Assessment Interview (CAI), a semi-structured interview, was developed by experts within the MATRICS Initiative, using both CGI-CogS and SCoRS as "parent instruments". CAI is a second-generation co-primary measure which originates from the above-mentioned scales, through an Item-response analysis, and consists of 10 items that investigate 6 of the 7 impaired domains in subjects with schizophrenia (as for the visuospatial learning and memory domain no question was deemed appropriate) (Ventura et al., 2010). CAI showed good psychometric properties in terms of reliability, internal consistency, administration time (15–30 min) and did not demonstrate practice effects, making it a reliable instrument in detecting changes over time (Ventura et al., 2010; Ventura et al., 2013; Ventura et al., 2016; Palumbo et al., 2019). In addition, it was found to be associated with measures of neurocognition (assessed with the MCCB composite score or the total score derived from the Screen for Cognitive Impairment in Psychiatry), functional capacity and everyday functioning (Ventura et al., 2010; Ventura et al., 2013; Sánchez-Torres et al., 2016; Ventura et al., 2016) and to be able, more than objective measures, to reflect the impact of cognitive impairment on the daily functioning of subjects with schizophrenia (Ventura et al., 2010; Ventura et al., 2013; Sanchez-Torres et al., 2016; Sánchez-Torres et al., 2016; Ventura et al., 2016).

CAI is the only interview that includes an item to assess social cognition. In our knowledge, only two studies provided information about the association of CAI scores with measures of social cognition (Bosgelmez et al., 2015; Sanchez-Torres et al., 2016). Social cognition is a complex, multidimensional construct, recently conceptualized as composed by four domains: emotional processing, theory of mind (ToM), social perception and attributional style/bias (Pinkham et al., 2014; Green et al., 2019). A unified battery assessing all social cognition domains is not available, while validated instruments, with modest to good psychometric properties, are available and assess emotional processing and ToM (Pinkham et al., 2014; Pinkham et al., 2016; Pinkham et al., 2018; Galderisi et al., 2014; Galderisi et al., 2020; Mucci et al., 2021; Rocca et al., 2016). Alongside these performance-based instruments for social cognition, an interview-based social cognition measure has also been developed, the Observable Social Cognition Rating Scale, showing a strong association with outcome (Healey et al., 2015; Silberstein et al., 2018).

The study by Sanchez-Torres et al. (Sanchez-Torres et al., 2016) was carried out in 122 Spanish subjects with psychosis, of which 56 subjects with a first-episode psychosis (FEP) and 66 with a chronic psychosis (non-FEP). The authors evaluated the association between CAI global scores and the social cognition assessed using the emotion management branch of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) (Mayer et al., 2003), a test included within the MCCB, which evaluates the emotional regulation, a subdomain of the emotional processing of social cognition. This study demonstrated that CAI global scores did not correlate with the scores of the MSCEIT in non-FEP, while negative moderate correlations were found in FEP. However, in this study only a subdomain of social cognition was included in the assessment of social cognition, and no specific correlations between CAI social cognition scores and other aspects of social cognition (for instance, ToM)

were investigated. Instead, the study by Bosgelmez et al. (2015) evaluated the correlations between CAI social cognition domain and different aspects of social cognition. In a sample of 95 Turkish clinically stable subjects with schizophrenia, the authors found that the composite score of the CAI social cognition domain showed a moderate negative correlation with the score of the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001), a test which assesses theory of mind, and a weak negative correlation with the score of the Facial Emotion Identification Test (FEIT) (Kerr and Neale, 1993), which assesses emotional processing.

However, only relatively small samples of subjects with schizophrenia have been included in the above-mentioned studies. Therefore, it remains to be proven that CAI psychometric properties hold in large and representative clinical samples, and to collect more evidence about sensitivity of CAI to capture not only impairment in neurocognition but also in social cognition.

1.1. Aims and hypotheses

The aims of the present study, carried out in a large sample of stabilized subjects with schizophrenia, recruited within a national multicenter study, were: a) to confirm the inter-rater reliability and the internal consistency of the CAI Italian version (Palumbo et al., 2019) in a multicenter study involving a large sample of subjects with schizophrenia; b) to test the construct validity evaluating the associations between the CAI composite global score with the MCCB composite score, measures of social cognition (ToM and emotion processing), functional capacity and real-life functioning, according to the previous literature on the topic (Green et al., 2008; Green et al., 2011; Keefe et al., 2006a); c) to evaluate correlations between the composite scores of CAI domains and the corresponding MCCB domains; d) to explore correlations between the composite score of CAI social cognition domain with measures of social cognition (ToM and emotion processing).

We hypothesized that CAI would show good psychometric properties, in terms of inter-rater reliability, internal consistency and convergent validity in identifying the severity of cognitive impairment (with respect to a standard cognitive battery, the MCCB), as well as strong relationships with functional capacity and real-life functioning domains, thus representing a valid co-primary measure that should be used to complement the cognitive assessment with neuropsychological tests.

2. Methods

2.1. Study participants

The present work was part of the multicenter 4-year follow-up study on the variables that influence real life functioning of people diagnosed with schizophrenia carried out by the Italian Network for Research on Psychosis (Galderisi et al., 2020; Mucci et al., 2021). Study participants were recruited from those living in the community and attending the outpatient units of the 24 Italian university psychiatric clinics and/or community mental health departments. All patients included in the baseline study (Galderisi et al., 2014) who agreed to participate in the follow-up were enrolled. Recruitment took place from March 2016 to December 2017. The inclusion criterion was a diagnosis of schizophrenia according to DSM-IV, confirmed by the Structured Clinical Interview for DSM-IV-Patient version (SCID-I-P) (First et al., 2002). Exclusion criteria were: a) history of head trauma with loss of consciousness in the 4-year interval between baseline and follow-up; b) progressive cognitive deterioration possibly due to dementia or other neurological illness diagnosed in the last 4 years; c) a history of alcohol and/or substance abuse in the last 6 months; d) current pregnancy or lactation; e) inability to provide an informed consent; f) treatment modifications and/or hospitalization due to symptom exacerbation in the last 3 months.

All participants provided a written informed consent for participation after receiving a comprehensive explanation of the study procedures and goals.

The study has been conducted in accordance with the principles of the Declaration of Helsinki (59th World Medical Association General Assembly; October 2008). Approval of the study protocol was obtained from the Ethics Committees of the participating centers.

2.2. Assessment instruments

2.2.1. Psychopathological assessment

The Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) was used to assess positive and disorganization symptom severity. The scores for the factor "positive symptoms" were calculated based on the consensus 5-factor solution proposed by Wallwork et al. (2012). "Disorganization" was assessed using the PANSS item P2, to avoid overlap with cognitive impairment (Galderisi et al., 2020). Negative symptoms were assessed using the Brief Negative Symptom Scale (BNSS) (Kirkpatrick et al., 2011), which includes five negative symptom domains: anhedonia, asociality, avolition, blunted affect and alogia. We used the two-factor model of the BNSS: "Expressive deficit domain" (sum of the subscales blunted affect and alogia) and "Experiential domain" (sum of the subscales anhedonia, asociality and avolition).

2.2.2. Performance-based cognitive assessment

Cognitive functions were assessed using the MCCB (Kern et al., 2008; Nuechterlein et al., 2008) that includes tests for the assessment of seven cognitive domains: speed of processing, attention/vigilance, working memory, verbal learning and memory, visuospatial learning and memory, reasoning and problem solving and social cognition. Standardized T-scores corrected for age and gender using Italian normative data (Mucci et al., 2018) were used in the analyses. T-scores had an average of 50 and a standard deviation of 10.

2.2.3. Interview-based cognitive assessment

The CAI (Ventura et al., 2010) is a semi-structured interview developed by shortening and modifying the CGI-Cogs (Keefe et al., 2006a) and the SCoRS (Ventura et al., 2008) scales. It includes 10 items investigating 6 cognitive domains derived from the MATRICS Initiative (speed of processing, attention/vigilance, working memory, verbal learning and memory, reasoning and problem solving and social cognition). For each item, a score is assigned from 1 to 7, with higher scores reflecting greater impairment. It is possible to assign a "N/A" or "not applicable" or "not available" score, for instance if the participant interrupts the interview or if only limited information is available. To assign the score, the clinician rates the extent to which the cognitive dysfunction impacts on functioning expected in the workplace, school or in the social environment, avoiding the influence on cognitive functioning of other symptoms of the disorder. The interview should be administered to the patient (patient interview) and to an informant, for instance a caregiver or someone who knows patient's daily functioning (informant interview). The scores obtained from the two interviews, patient and informant interviews, must be separate. Patient's interview scores reflect the judgment of the clinician exclusively based on patient's interview, while informant's interview scores reflect only the clinical judgment based on the patient's deficit reported during the informant's interview. In addition, the clinician assigns for all the items a composite score, which reflects his/her judgment obtained by integrating all sources of information (patient and informant). At the end of the interview, the global severity of cognitive impairment, rated from 1 to 7, which reflects the patient's overall cognitive impairment, should be rated or scored. As for the 10 items, also for the global score, there are three separate scores (one based on the patient interview, one on the informant interview, and one on the composite scores). In the present paper we used the Italian version of the CAI (Palumbo et al., 2019) and we focused only on the composite scores for global and domain scores.

2.2.4. Social cognition assessment

The assessment of social cognition partly included in the MCCB MSCEIT (Mayer et al., 2003) managing emotion section (MSCEIT-ME) was integrated by the FEIT (Kerr and Neale, 1993) and The Awareness of Social Inference Test (TASIT) (McDonald et al., 2006).

FEIT is a facial emotion recognition test which consists in identifying the correct emotion (joy, anger, fear, disgust, surprise, sadness or neutral) represented in a specific photo. A total of 55 photos are presented randomly (Kerr and Neale, 1993).

TASIT (McDonald et al., 2006) consists of seven scales (positive emotions, negative emotions, sincere, simple sarcasm, paradoxical sarcasm, sarcasm enriched and lie), organized into 59 videos divided in three sections (TASIT 1–3): TASIT 1 "The Emotion Evaluation Test", which explores emotional processing; TASIT 2 "Social Inference-Minimal" and TASIT 3 "Social Inference-Enriched", which explore theory of mind.

The total scores of MSCEIT, FEIT and TASIT were obtained by summing the number of correct answers to the individual items.

2.2.5. Functional capacity assessment

Functional capacity was evaluated by the brief version of the University of California San Diego (UCSD) Performance-based Skills Assessment (UPSA-B) (Mausbach et al., 2007), a performance-based instrument that assesses "financial skills" (counting money and paying bills) and "communication skills" (to dial a telephone number for emergency or reschedule an appointment by telephone). The total score, ranging from 0 (worst functional capacity) to 100 (best functional capacity), was obtained as the sum of the two domains.

2.2.6. Real-life functioning assessment

Real-life functioning was assessed using the Specific Level of Functioning Scale (SLOF) (Sabbag et al., 2012; Mucci et al., 2014), a hybrid instrument that examines several aspects of functioning. This measure is based on key caregiver's judgment on behavior and functioning of patients and consists of 43 items exploring six domains: physical efficiency, skills in self-care, interpersonal relationships, social acceptability, everyday life skills (e.g., shopping, using public transportation), and working skills. For this scale, the higher the total score, the better the overall functioning of the subject. In the present study, three subscales of the SLOF were used: "Interpersonal relationships", "Everyday life skills" and "Working skills", which are the most informative for patients affected by schizophrenia (Rocca et al., 2018).

2.3. Training of the raters and inter-rater reliability assessment

For the training of the raters and in order to assess inter-rater reliability, the coordinating center (Department of Psychiatry, University of Campania "Luigi Vanvitelli") recorded 6 interviews to subjects with schizophrenia (who were not recruited for the study) and their non-affected parents. Initially, two videos were shown to the raters and used for the training, and successively 4 videos were used for the inter-rater agreement evaluation. Raters were 24 research staff members, one from each of the 24 Italian university psychiatric clinics.

2.4. Statistical analyses

Intraclass correlation coefficients (ICCs) and Cronbach's alpha were calculated in order to examine inter-rater reliability and internal consistency, respectively.

Pearson's correlation coefficients were used to explore the following correlations: 1) correlations between the CAI composite global score with the MCCB composite score, measures of social cognition (ToM and emotion processing), functional capacity and real-life functioning; 2) correlations between the composite scores of CAI domains and the corresponding MCCB domains; 3) correlations between the composite score of CAI social cognition domain with FEIT and TASIT scores; 4) correlations between the MCCB composite score, functional capacity and real-life functioning; 5) correlations between the MCCB social cognition domain with FEIT and TASIT scores.

Given the large number of cases, correlations were interpreted taking into account the absolute value of the correlation coefficient rather than its significance. In fact, for sample sizes > 200, even a correlation coefficient of 0.10 is significant at $p < .01$, but has no clinical significance. Correlation coefficients between 0.10 and 0.29 in absolute value were interpreted as indicative of weak linear correlation, from 0.30 to 0.49 as moderate correlation, from 0.50 to 1 as strong correlation (Cohen, 1992). Statistical analyses were carried out using IBM SPSS, version 21. The significance level for all correlation analyses was set to $p < .0004$ (p corrected for multiple tests).

2.5. Additional analyses

Additional control analyses are reported within the supplementary materials and include the following: 1) associations between CAI composite scores and demographic characteristics of the sample (age and gender); 2) correlations among the MCCB domain scores; 3) correlations of psychopathology scores with CAI and MCCB; 4) regression analyses with the MCCB composite score as dependent variable and UPSA and CAI as independent predictors.

3. Results

3.1. Demographic and clinical characteristics

The sample was composed by 580 subjects with a diagnosis of schizophrenia according to the DSM-IV criteria. The demographic and clinical characteristics of the sample are described in Table 1.

Table 1
Descriptive statistics.

	Total N = 580	
	N	%
Males	401	69.1
Females	179	30.9

	Total N = 580	
	Mean	SD
Age (years)	46.61	10.11
Education in years	11.79	3.40
CAI composite global score	3.39	1.36
MCCB composite score	30.97	12.63
FEIT	37.35	8.58
TASIT-1 "Emotion Evaluation"	20.41	4.91
TASIT-2 "Social inference-minimal"	38.69	10.60
TASIT-3 "Social inference-enriched"	38.82	10.11
UPSA – B Financial ability	34.24	15.30
UPSA – B Communication ability	31.15	14.56
UPSA – B total score	65.92	27.11
SLOF – Interpersonal relationships	22	6.38
SLOF – Everyday life skills	40.12	9.57
SLOF – Working skills	19.95	6.52
PANSS Positive Factor	8.47	4.30
PANSS Disorganization item (P2)	2.46	1.44
BNSS Experiential domain	18.60	9.80
BNSS Expressive deficit domain	12.10	7.71

CAI = Cognitive Assessment Interview; MCCB = MATRICS Consensus Cognitive Battery; FEIT = Facial Emotion Identification Test; TASIT = The Awareness of Social Inference Test; UPSA – B = University of California, San Diego, Performance-Based Skills Assessment – Brief; SLOF = Specific Level of Functioning Scale; PANSS = Positive and Negative Syndrome Scale; BNSS = Brief Negative Symptom Scale.

3.2. Inter-rater reliability and internal consistency

The results showed a good to excellent inter-rater reliability, according to criteria of Cicchetti, 1994. In particular, the ICCs were as follows: 0.835 (Working Memory item 1 – composite score), 0.841 (Working Memory item 2 – composite score), 0.748 (Attention and Vigilance item 3 - composite score), 0.747 (Attention and Vigilance item 4 - composite score), 0.745 (Verbal Memory and Learning item 5 - composite score), 0.772 (Verbal Memory and Learning item 6 - composite score), 0.703 (Reasoning and Problem Solving item 7 - composite score), 0.627 (Reasoning and Problem-Solving item 8 – composite score), 0.676 (Speed of Processing item 9 - composite score), 0.645 (Social Cognition item 10 - composite score).

The coefficient alpha for the CAI composite scores (0.952) was very high, indicating an excellent internal consistency.

3.3. Correlations between CAI composite global score, MCCB composite score, social cognition, functional capacity and real-life functioning

A strong negative correlation between the CAI composite global score and the MCCB composite score was observed ($r = -0.500$, $p = 7.49 \times 10^{-32}$). A negative correlation coefficient means that impairment on the CAI is associated with impairment on the MCCB or social cognition tests, in fact cognitive impairment is indicated by high scores on the CAI and low scores on the MCCB and social cognition tests (FEIT, TASIT and MSCEIT). The CAI composite global score showed a moderate correlation with the FEIT ($r = -0.323$, $p = 1.05 \times 10^{-13}$), TASIT-1 "Emotion Evaluation Test" ($r = -0.396$, $p = 1.65 \times 10^{-21}$) and with the TASIT-2 "Social Inference-minimal" ($r = -0.310$, $p = 3.06 \times 10^{-13}$).

The CAI composite global score showed moderate to strong correlations with the UPSA-B scores "financial ability" ($r = -0.456$, $p = 9.50 \times 10^{-32}$), "communication" ($r = -0.501$, $p = 4.45 \times 10^{-39}$) and total score ($r = -0.516$, $p = 1.30 \times 10^{-41}$), and moderate to strong correlations with the SLOF subscales Working skills ($r = -0.487$, $p = 1.26 \times 10^{-36}$), Everyday life skills ($r = -0.507$, $p = 5.82 \times 10^{-40}$) and Interpersonal relationships ($r = -0.303$, $p = 4.77 \times 10^{-14}$).

Similarly, the MCCB composite score showed moderate to strong correlations with the UPSA-B scores "financial ability" ($r = 0.552$, $p = 4.50 \times 10^{-41}$), "communication" ($r = 0.484$, $p = 1.47 \times 10^{-30}$) and total score ($r = 0.569$, $p = 5.09 \times 10^{-44}$) and moderate correlations with the SLOF subscales Working skills ($r = 0.440$, $p = 5.03 \times 10^{-25}$) and Everyday life skills ($r = 0.451$, $p = 2.27 \times 10^{-26}$). A weak correlation was observed between the MCCB composite score and the SLOF subscale Interpersonal Relationships ($r = 0.244$, $p = 3.33 \times 10^{-8}$).

All these results are shown in Table 2.

No significant difference was found between the correlations of CAI with functional capacity or SLOF subscales and correlations of MCCB with the same measures, except for the correlation with UPSA-B scores "financial ability" (z score = −2.078, p = .004). However, the statistical significance of this last result did not survive correction for multiple tests.

Interestingly, both CAI composite global score and MCCB composite score had the same pattern of correlations with measures of real-life functioning. In particular, stronger correlations were found for both CAI and MCCB with the SLOF subscales Everyday Life Skills and Working Skills, while weaker correlations were found with SLOF subscale Interpersonal Relationships.

3.4. Correlations between composite scores of CAI domains and corresponding MCCB domains

The correlations between the composite scores of CAI domains and the corresponding MCCB domains are shown in Table 3.

The composite scores of CAI domains working memory ($r = -0.480$, $p = 8.46 \times 10^{-30}$), verbal learning and memory ($r = -0.408$, $p = 3.55 \times 10^{-21}$), and speed of processing ($r = -0.444$, $p = 4.09 \times 10^{-25}$) showed moderate negative correlations with the MCCB composite score and with the corresponding MCCB domains (working memory $r = -0.412$, $p = 4.85 \times 10^{-25}$; verbal learning and memory $r = -0.368$, $p = 5.87 \times 10^{-20}$; speed of processing $r = -0.385$, $p = 9.28 \times 10^{-32}$).

In addition, CAI working memory correlated with verbal learning and speed of processing domains of the MCCB at magnitudes that approximated the correlation with MCCB working memory scores. Similarly, CAI speed of processing scores correlated with working memory and verbal learning scores of the MCCB at magnitudes that approximated the correlation with MCCB speed of processing scores.

CAI attention and vigilance showed a moderate correlation with the MCCB composite score ($r = -0.478$, $p = 1.57 \times 10^{-29}$) and with the corresponding MCCB domain ($r = -0.317$, $p = 1.17 \times 10^{-13}$); however, the latter correlation was weaker than the correlation between CAI attention and vigilance and other MCCB domains (working memory, verbal learning and memory and speed of processing). CAI social cognition ($r = -0.407$, $p = 5.43 \times 10^{-21}$) and reasoning and problem-solving domains ($r = -0.491$, $p = 2.71 \times 10^{-31}$) showed a moderate correlation with the MCCB composite score and a weak correlation with the corresponding MCCB domains (social cognition $r = -0.203$, $p = 2.20 \times 10^{-6}$; reasoning and problem-solving domains $r = -0.279$, $p = 1.17 \times 10^{-11}$). However, the latter correlations were weaker than those with other MCCB domains.

This pattern of results is probably due to the strong cross-correlations of MCCB domains in subjects with schizophrenia as reported in the Supplementary materials (Table S2). In particular, as reported in Table S2 the MCCB working memory domain scores were strongly associated with the MCCB verbal learning and memory, speed of processing and reasoning and problem solving domain scores. Furthermore, MCCB speed of processing domain scores were strongly associated with MCCB working memory, verbal learning and memory and reasoning and problem solving domain scores.

Table 2
Pearson correlations between CAI composite global score and MCCB composite score with social cognition, functional capacity and real-life functioning.

	CAI composite global score	MCCB composite score
MCCB composite score	**−0.500****	1
FEIT Total score	**−0.323****	**0.429****
TASIT-1 "Emotion processing"	**−0.396****	**0.552****
TASIT-2 "Social inference-minimal"	**−0.310****	**0.464****
TASIT-3 "Social inference-enriched"	−0.250**	**0.412****
UPSA-B financial ability	**−0.456****	**0.552****
UPSA-B communication ability	**−0.501****	**0.484****
UPSA-B total score	**−0.516****	**0.569****
SLOF Interpersonal relationship	**−0.303****	0.244**
SLOF Everyday life skills	**−0.507****	**0.451****
SLOF Working skills	**−0.487****	**0.440****

CAI = Cognitive Assessment Interview; MCCB = MATRICS Consensus Cognitive Battery; UPSA – B = University of California, San Diego, Performance-Based Skills Assessment – Brief; SLOF = Specific Level of Functioning; FEIT = Facial Emotion Identification Test; TASIT = The Awareness of Social Inference Test.
Negative correlation coefficients mean that impairment on the CAI is associated with impairment on the MCCB, in fact cognitive impairment is indicated by high scores on the CAI and low scores on the MCCB.
In boldface moderate to strong correlations ($r > 0.30$); **$p < 0.0004$ (p value threshold corrected for multiple tests).

3.5. Correlations between the composite score of CAI social cognition domain and MCCB social cognition domain with FEIT and TASIT

The composite score of the CAI social cognition domain showed moderate negative correlations with FEIT ($r = -0.313$, $p = 5.99 \times 10^{-13}$) and with TASIT-1 "The Emotion Evaluation Test" ($r = -0.339$, $p = 7.40 \times 10^{-16}$) and TASIT 2 "Social Inference-Minimal" ($r = -0.317$, p

Table 3
Pearson correlations between composite scores of CAI domains and MCCB domains.

	MCCB WM	MCCB A/V	MCCB VL	MCCB SC	MCCB R & PS	MCCB SoP	MCCB Comp
CAI WM	**−0.412****	**−0.330**	**−0.384**	−0.131	−0.273	**−0.366**	**−0.480**
CAI A/V	**−0.368**	**−0.317****	**−0.382**	−0.167	−0.244	**−0.380**	**−0.478**
CAI VL	**−0.337**	−0.282	**−0.368****	−0.115	−0.213	**−0.318**	**−0.408**
CAI SC	**−0.337**	−0.235	**−0.311**	−0.203**	−0.211	**−0.352**	**−0.407**
CAI R & PS	**−0.373**	−0.298	**−0.379**	−0.193	−0.279**	**−0.421**	**−0.491**
CAI SoP	**−0.355**	−0.239	**−0.345**	−0.189	−0.261	**−0.385****	**−0.444**
CAI Global	**−0.387**	**−0.316**	**−0.379**	−0.171	−0.270	**−0.404**	**−0.500****

CAI = Cognitive Assessment Interview; MCCB = MATRICS Consensus Cognitive Battery; WM = working memory; A/V = attention/vigilance; VL = verbal learning and memory; SC = social cognition; R & PS = reasoning and problem solving; SoP = speed of processing; Comp = composite score.
Negative correlation coefficients mean that impairment on the CAI is associated with impairment on the MCCB, in fact cognitive impairment is indicated by high scores on the CAI and low scores on the MCCB.
In boldface moderate to strong correlations ($r > 0.30$); **$p < 0.0004$ (p value threshold corrected for multiple tests).

$= 9.59 \times 10^{-14}$) (Table 4).

MCCB social cognition domain showed moderate correlations with FEIT ($r = 0.304$, $p = 4.92 \times 10^{-12}$), TASIT-1 "The Emotion Evaluation Test" ($r = 0.300$, $p = 1.98 \times 10^{-12}$), TASIT 2 "Social Inference-Minimal" ($r = 0.355$, $p = 6.58 \times 10^{-17}$) and TASIT 3 "Social Inference-enriched" ($r = 0.348$, $p = 3.22 \times 10^{-16}$) (Table 4).

Interestingly, both the composite score of the CAI social cognition domain and MCCB social cognition domain had the same pattern of correlations with measures of social cognition, since we did not observe any statistical differences in correlation coefficients (all $p > .05$).

4. Discussion

Our study demonstrated that CAI showed good psychometric properties, in this large sample of community dwelling subjects with chronic schizophrenia, in terms of inter-rater reliability, internal consistency, convergent validity and relationship with functional capacity and real-life functioning. Thus, the CAI is a valid co-primary measure that can be used to capture the impact of cognitive impairment on real-life functioning in subjects with schizophrenia.

4.1. CAI inter-rater reliability and internal consistency

The 10 CAI items showed a good to excellent inter-rater reliability and internal consistency, in line with psychometric properties reported in previous studies (Ventura et al., 2010; Ventura et al., 2013; Bosgelmez et al., 2015; Sánchez-Torres et al., 2016; Palumbo et al., 2019). The high reliability of the instrument suggests that the CAI can be used in clinical trials to capture the cognitive functioning of the participant through a brief clinical interview.

Table 4
Pearson correlations between the composite score of CAI social cognition domain and MCCB social cognition domain, with FEIT and TASIT.

	CAI social cognition domain	MCCB social cognition domain
FEIT Total score	**−0.313****	**0.304****
TASIT-1 "Emotion processing"	**−0.339****	**0.300****
TASIT-2 "Social inference-minimal"	**−0.317****	**0.355****
TASIT-3 "Social inference-enriched"	−0.297**	**0.348****

CAI = Cognitive Assessment Interview; MCCB = MATRICS Consensus Cognitive Battery; FEIT = Facial Emotion Identification Test; TASIT = The Awareness of Social Inference Test.
Negative correlation coefficients mean that impairment on the CAI is associated with impairment on the social cognition tests, in fact cognitive impairment is indicated by high scores on the CAI and low scores on the FEIT and TASIT tests.
In boldface moderate correlations (>0.30 up to 0.49); **$p < 0.0004$ (p value threshold corrected for multiple tests).

4.2. CAI convergent validity and relationship with functional capacity and real-life functioning

According to the previous literature on the topic (Green et al., 2008; Green et al., 2011; Keefe et al., 2006a), the construct validity of the CAI was examined testing its correlation with global cognitive performance, using the MCCB composite score.

In line with the findings of previous CAI validation studies (Ventura et al., 2013; Sanchez-Torres et al., 2016; Sánchez-Torres et al., 2016; Ventura et al., 2016), the CAI global composite score showed a strong correlation with the MCCB composite score, suggesting that CAI may be a valid co-primary measure to assess cognitive functioning in subjects with schizophrenia.

Furthermore, consistently to what has been demonstrated for performance-based instruments (Mucci et al., 2018) in our study we found an impact of the age on CAI measures, since, as expected, cognitive functions declined significantly with age on all domains. This finding supports the validity of the CAI in capturing the severity of cognitive impairment.

In addition, the CAI global composite score was moderately/strongly associated with functional capacity and real-life functioning, in line with previous findings (Ventura et al., 2013; Bosgelmez et al., 2015; Sanchez-Torres et al., 2016; Ventura et al., 2016). Our findings add to this evidence also demonstrating the same pattern of correlations with measures of real-life functioning as those found for the MCCB scores. In particular, stronger correlations were found with the SLOF subscales Everyday Life Skills and Working Skills, and weaker correlations with the SLOF subscale Interpersonal Relationships.

Overall, these data suggest that the CAI might be used in clinical practice for an easy, reliable and accurate assessment of cognitive impairment and its impact on functioning.

Our study adds to the existing literature in demonstrating that CAI has a moderate to strong relationship with both objective measures of cognitive impairment and with measures of functional outcome, thus improving the demonstration of the validity of the CAI as a co-primary measure. In particular, the CAI represents a valid interview-based co-primary measure, that might be used to integrate objective performance-based measures of cognitive impairment (e.g., the MCCB).

4.3. Is the CAI able to grasp the impairment in different cognitive domains?

In our study, analyses of correlations between composite scores of the CAI domains and the corresponding MCCB domains demonstrated that CAI domains working memory, verbal learning and memory, and speed of processing showed good convergent validity with the same domains assessed by the MCCB. However, we have to point out that CAI

working memory correlated with verbal learning and speed of processing domains of the MCCB at magnitudes that approximate the correlation with MCCB working memory scores. Similarly, CAI speed of processing scores correlated with working memory and verbal learning scores of the MCCB at magnitudes that approximate the correlation with MCCB speed of processing scores. This pattern of correlations should be explained in the light of the strong inter-correlations between different MCCB domains, that we found in our sample, according to results of previous studies (Burton et al., 2013; Keefe et al., 2006b). In addition, Reise et al. (2011) demonstrated that interview-based assessment of cognition (e.g., SCoRS and CGI-Cogs) was able to grasp a single dimension of cognitive deficits in subjects with schizophrenia, definable as a global cognitive factor.

CAI attention and vigilance and reasoning and problem-solving domains did not show a strong association with the corresponding domains measured using the MCCB. These domains of the CAI appear to be more associated with other domains of the MCCB (working memory, verbal learning and memory and speed of processing). Since the CAI is a co-primary measure that assesses how the impairment in cognitive domains impacts the real-life functioning in subjects with schizophrenia, these results might be due to the fact that attention and vigilance and reasoning and problem-solving domains might be less associated with the functioning. As regard to social cognition, we performed additional analyses using FEIT and TASIT since the MSCEIT captures only the emotional intelligence subdomain, while it is possible that CAI is able to grasp other aspects of social cognition.

4.4. Is the CAI able to capture the patient's social cognition ability?

In order to evaluate the ability of the CAI to grasp different aspects of social cognition, in our study we performed correlation analyses between CAI and measures of emotional processing and theory of mind, assessed using FEIT and TASIT. We found that the CAI composite global score and the CAI composite social cognition score showed the same trend of results. In particular, both scores showed a moderate correlation with FEIT and TASIT subscales, except for the TASIT-3 "social inference-enriched". Interestingly, correlations of CAI social cognition domain with measures of social cognition were similar to those found between MCCB social cognition domain and the same measures of social cognition, supporting the ability of this interview in capturing deficits in social cognition.

These results are in line with the findings of the study by Bosgelmez et al. (2015) that evaluated the correlations between CAI social cognition domain and measures of emotional processing and theory of mind, assessed respectively through the FEIT and the Reading the Mind in the Eyes Test. In this study (Bosgelmez et al., 2015), in a sample of 95 Turkish clinically stable subjects with schizophrenia, the authors found that the composite score of the CAI social cognition domain showed a moderate negative correlation with the score of the Reading the Mind in the Eyes Test, a test which assesses theory of mind, and a weak negative correlation with the score of the Facial Emotion Identification Test, which assesses emotional processing. Instead, an inadequate convergent validity was found between CAI composite social cognition score and MSCEIT score, in line with the findings of Sanchez-Torres et al. (Sanchez-Torres et al., 2016).

Overall, our results, in line with previous literature, indicate that the domain of social cognition investigated by the MSCEIT-ME is not captured by the CAI, which might grasp other aspects of social cognition, such as emotional processing and theory of mind, those assessed with FEIT and TASIT.

Some limitations of the present study should be taken into account. First of all, the lack of multivariate analysis might limit the generalizability of present results. The fact that the CAI correlates moderately with social cognition, in particular with emotional processing and theory of mind, might to some extent be due to the absence of the evaluation of other aspects of social cognition, such as social perception and attributional bias. In addition, the study did not investigate the CAI sensitivity to change, since it was not the primary aim of the "parent" study, and the CAI was only added to the follow-up assessments. Finally, further studies carrying out factor analyses to investigate the existence of different factors within the CAI are encouraged in order to better understand whether CAI factors are associated with similar MCCB factors.

5. Conclusions

In conclusion, our large, multicenter study confirmed the psychometric properties of the CAI and demonstrated that this instrument can be a valid co-primary measure to assess impairment in neurocognitive and social cognitive domains and how this impairment impacts the real-life functioning in subjects with schizophrenia. These data suggested the possible use of the CAI in clinical trials, as a valid co-primary measure that could complement the cognitive assessment with neuropsychological tests over time or following pharmacological or psychosocial treatments, to provide measures with greater face validity to patients and carers than neuropsychological scores. Furthermore, this instrument might be used in routine clinical context as a screening instrument of patient's overall cognitive impairment in a rapid and suitable way. In addition, the instrument might provide information concerning the patient's perception of the impact of her/his cognitive impairment on functional outcome, thus improving the patient's insight on cognitive dysfunctions and, consequently, the patient's motivation to engage in cognitive rehabilitation programs, aimed at ameliorating functional outcome.

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CRediT authorship contribution statement

The project idea was initiated by AM, SG, JV, GMG and DP, involving a collaboration with LG, AP, PB, PR, AR, AB, PRu, MM. GMG and DP performed the analyses of the data and wrote the first draft of the manuscript. All Authors were responsible for the interpretation of the analyses, contributed to critically revising the content, and approved the final manuscript for submission to Schizophrenia Research.

Declaration of competing interest

The authors have declared that there are no conflicts of interest in relation to the subject of this study.

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Appendix A. Supplementary data

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