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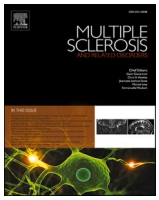

Dynamic emotion recognition and authenticity detection in multiple sclerosis: preliminary cognitive, behavioral, and neuroimaging evidence

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ABSTRACT

Background: Facial emotion recognition (FER) is affected in multiple sclerosis (MS), impacting interpersonal functioning. Standard FER tests utilize static/posed stimuli, lacking in ecological validity. In this pilot study, we used the Emotion Authenticity Recognition (EAR) test, featuring both genuine/posed dynamic expressions, to assess FER in an MS sample, also investigating behavioral/neuroimaging correlates.

Methods: A group of 54 MS patients (36 F; age = 41.4 ± 11.0, education = 14.7 ± 2.8) and a matched age/sex/education sample of 54 healthy controls (HCs) completed the EAR test, which provides two indices: Emotion Recognition (ER) and Emotion Authenticity (EA). Associations were explored with clinical/neuropsychological/self-report/MRI data. Structural 3T-MRI was analyzed using Voxel-Based Morphometry (VBM) for regional gray matter volumes.

Results: No significant differences were found with standard t-tests for ER and EA between MS and HCs. Bayesian independent t-tests revealed moderate evidence for no group difference in ER (BF10 = 0.210, % error = 0.029) and anecdotal evidence in favor of the null hypothesis for EA (BF10 = 0.658, % error = 0.017).

In MS, ER correlated with age (r = -0.50, p < 0.001), disease duration (R = -0.30, $p = 0.030$), education (R = 0.34, $p = 0.012$), and with domain-specific/global cognitive functioning (all r indexes among 0.3 - 0.5). EA was lower in patients with severe cognitive impairment (r = 0.47, $p < 0.001$) and associated with empathy (R = 0.29, p = 0.037).

ER was associated with bilateral widespread cortical regions and cerebellum, while EA with fronto-temporal cortices and amygdala.

Conclusions: Despite no statistically significant differences observed compared to HCs, EAR in MS reflected age, cognition, and brain damage: this test captures subtle alterations, underscoring the value of dynamic and genuineness-based measures in MS assessment. These preliminary findings warrant further investigation into emotion-cognition interactions in MS.

1. Introduction

Multiple Sclerosis (MS) is a chronic immune-mediated disease characterized by inflammatory and neurodegenerative processes (Calabrese et al., 2015; Filippi et al., 2018), and is the most common neurological cause of disability in young adults (Browne et al., 2014; Koch et al., 2010). Physical manifestations in MS are common but are not enough to fully explain the complex symptomatology of MS, which includes many of the so-called “invisible symptoms”. This definition reflects not only the external invisibility of these symptoms to others but also the difficulty in assessing them in clinical practice due to time constraints and the lack of objective and reliable tools (Lakin et al., 2021). The invisible symptoms include physical and mental fatigue (the most common symptom, affecting up to 95% of patients) (Fisk et al., 1994; Kobelt et al., 2017; Penner, 2016; Khan et al., 2014), mood changes, and cognitive deficits.

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Cognitive difficulties affect a large proportion of individuals with MS, with prevalence estimates reaching 80%, varying according to disease subtype, assessment criteria, and neuropsychological measures applied (Chiaravalloti & DeLuca, 2008; Portaccio & Amato, 2022). Cognitive dysfunctions have been described as the most common and, at the same time, the most disabling symptom contributing to disability in MS patients (Benedict et al., 2020). These symptoms can emerge at any point during the clinical course of MS (Amato et al., 2019) and are present even in the early stages of the disease, including in those who do not fulfil the criteria for severe cognitive impairment (Pitteri et al., 2019). Cognitive deficits worsen over the course of the disease, even when physical disability is minimal (Benedict & Zivadinov, 2011), and they have a profound impact on the quality of life of patients and their caregivers, negatively affecting psychosocial well-being, interpersonal skills, work abilities, and the management of daily activities (Kalb et al., 2018; Sumowski et al., 2018; Benedict et al., 2020).

Neuropsychological assessment of MS patients primarily involves traditional paper-and-pencil tests, which are used to investigate the cognitive domains most affected in this population. Due to the heterogeneity and multifactorial nature of the disorder, multiple cognitive domains are typically impaired in MS patients. Specifically, difficulties are observed in the following areas: information processing speed, verbal and visuospatial memory and learning, attention, executive functions, and social cognition (DeLuca et al., 2020).

In the 2013 revision of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5), the domain of social cognition was introduced as one of the six key neurocognitive domains (alongside learning and memory, complex attention, language, perceptual-motor function, and executive functions). Interest in the concept of social cognition has grown significantly over the past 20 years. Social cognition refers to the processing of information about people and social situations; it includes all the core mental operations underlying social interactions and the processes needed to establish and maintain interpersonal relationships (Dulau et al., 2017; Roelofs et al., 2017). Social cognition is a multidimensional domain comprising three main subcomponents: facial emotion recognition, theory of mind, and empathy (Chalah & Ayache, 2017). Facial emotion recognition involves identifying human emotions from facial expressions (Niedenthal & Brauer, 2012). Theory of Mind (ToM) is defined as the ability to infer the intentions, dispositions, and beliefs of other persons (Green et al., 2008). Empathy refers to the capacity to feel and understand what another person is experiencing (Bellet & Maloney, 1991).

Many studies demonstrated alterations in social cognition in MS, although this domain has received less attention than traditional cognitive domains. Specifically, all three abovementioned core components of social cognition - facial emotion recognition, theory of mind, and empathy - can be impaired in individuals with MS (Bora et al., 2016; Cotter et al., 2016), regardless of clinical phenotype, physical disability, or disease duration (Dulau et al., 2017; Henry et al., 2017; Neuhaus et al., 2018; Lin et al., 2021). Although associations between social cognition and other cognitive domains in MS have been reported (Dulau et al., 2017; Ciampi et al., 2018; van der Hiele et al., 2020; Henry et al., 2011; Kraemer et al., 2013; Raimo et al., 2017; Berneiser et al., 2014; Cecchetto et al., 2014; Ouellet et al., 2010), deficits in social cognition have also been found in patients classified as "cognitively preserved" based on comprehensive neuropsychological assessments (Pitteri et al., 2019). These deficits tend to remain stable over time, as demonstrated in a 3-year longitudinal study (Ziccardi et al., 2021), suggesting that this domain may be relatively independent of other cognitive processes (Neuhaus et al., 2018; Golde et al., 2020). Furthermore, impairments in facial emotion recognition and theory of mind have been found since the time of diagnosis, indicating that these difficulties emerge in the very early stages of the disease. Newly diagnosed MS patients perform significantly worse than healthy controls on social cognition tasks, with performance levels comparable to those of patients with longer disease duration, further supporting the early onset and persistence of these deficits (Ziccardi et al., 2024). These impairments may lead to the deterioration of patients' social environments and a consequent reduction in their quality of life (Phillips et al., 2011; Czekóová et al., 2019; Isernia et al., 2019). Moreover, they are also associated with emotional distress (e.g., depression and anxiety) and fatigue, both common symptoms in this patient population (Ziccardi et al., 2021).

These difficulties are mirrored in specific neuroimaging profiles: social cognitive deficits in MS patients are particularly associated with damage to the amygdala, including both cortical lesions and volume reduction in this region (Batista et al., 2017; Chalah & Ayache, 2017; Pitteri et al., 2019; Ziccardi et al., 2021). Additionally, performance on social cognition tests is significantly linked to the insular and medial frontal cortices (Labbe et al., 2021), as well as to the cingulate, orbitofrontal, and temporal cortices (Chalah & Ayache, 2017). Functional MRI studies have shown a significant correlation between social cognition and altered resting-state functional connectivity among specific brain regions, such as the amygdala, fusiform gyrus, and lateral occipital cortex (Golde et al., 2020; Labbe et al., 2020), as well as within key brain networks including the default mode network, the executive network, and the limbic-paralimbic network (Bisecco et al., 2020; Isernia et al., 2022). Importantly, these alterations are already evident at the onset of the disease: at diagnosis, MS patients who perform worse on social cognition tests are also those with more pronounced gray matter damage in the limbic regions, the basal ganglia, and the occipital lobe. Specifically, facial emotion recognition has been described as associated with amygdala and caudate volumes; theory of mind with the lingual gyrus, cuneus, cingulate, putamen, pallidum, and amygdala; and empathy with the cuneus and putamen (Ziccardi et al., 2024).

The present study aims to deepen the understanding of social cognition abilities in patients with MS through the administration of the innovative Emotion Authenticity Recognition (EAR) test (Scarpazza et al., 2025), which is designed to evaluate the recognition ability of both the type and authenticity of facial emotions using dynamic stimuli. The test will be administered to a group of patients with MS and a matched group of healthy controls. Additionally, the study will investigate the association between EAR scores and both overall cognitive functioning and self-reported psychological profile, obtained through a comprehensive neuropsychological evaluation. Finally, the associations with cortical brain volumetry, measured via high-field (3Tesla) MRI, will also be examined.

2. Materials and methods

This study complies with the Preferred Evaluation of Cognitive And Neuropsychological Studies (PECANS) guidelines (Costa et al., 2025). The completed PECANS checklist is provided in the Supplementary Materials (see Supplementary Materials 1).

2.1. Participants

For the present study, patients with a diagnosis of clinically definite MS and healthy controls matched for gender, age, and education were recruited.

Inclusion criteria were: i) clinically definite MS diagnosis according to the most recent criteria (Thompson et al., 2018); ii) < 9 months between the neuropsychological evaluation and the social cognition protocol; iii) < 9 months between the MRI and the social cognition protocol; iv) no clinical relapses between the social cognition protocol and the MRI nor between the social cognition protocol and the neuropsychological evaluation.

Exclusion criteria were: i) concurrent neurological diseases (other than MS); ii) psychiatric disorders; iii) visual and/or motor impairments that could affect the execution of the social cognition protocol or the neuropsychological evaluation; iv) substance abuse, and v) inability to provide informed consent.

All patients are followed at the Regional Center of High

Specialization for Research and Treatment of Multiple Sclerosis, belonging to the University Hospital of Verona (Italy), and were included in this study between February 14 and April 30, 2024. During this time frame, patients underwent a testing protocol for the evaluation of facial emotion recognition (which will be detailed below). These patients also completed, close to the social cognition protocol, an extensive neuropsychological evaluation, a high-field (3 Tesla) magnetic resonance imaging (MRI) exam, and a neurological examination, including physical disability assessment via the EDSS scale (Kurtzke, 1983), whose data were retrospectively collected. Informed consent was collected, and the local ethics committee approved the study (A.O.U.I. Verona, protocol no. 66418).

2.2. Experimental protocol – Facial emotion recognition

The project aimed to investigate facial emotion recognition in MS patients through an innovative test: the Emotion Authenticity Recognition test (EAR; Scarpazza et al., 2025).

The EAR consists of 60 short videos selected from the Padova Emotional Dataset of Facial Expressions (PEDFE; Miolla et al., 2023), a validated dataset containing dynamic facial expressions related to six emotions: happiness, anger, fear, sadness, surprise, and disgust. The emotional expressions displayed could be genuine (i.e., authentically generated using an experimental procedure) or posed (i.e., simulated, produced by asking the subject to portray a specific emotion without direct emotional elicitation).

The 60 videos selected from the PEDFE and included in the EAR comprise 10 stimuli for each of the six emotions, with five showing genuine emotional states and five showing posed emotional states (including a total of 30 genuine and 30 posed emotional expressions). The EAR test was built by selecting from the 1458 PEDFE stimuli (Miolla et al., 2023) those with the highest accuracy in emotion recognition and genuineness to achieve a ceiling effect to avoid potential ambiguities. The selected stimuli averaged about 3 seconds in length.

During the experimental procedure, patients were asked to watch the short videos displaying genuine or posed emotions and then identify which of the six emotions was expressed and whether the emotion shown was genuine or posed. The participants answered verbally. One point was given for each correct answer. Two global indices were obtained: an emotion recognition index (ER) and an emotion authenticity index (EA). The maximum score for each index was 60. We also calculated specific indices: one for correct recognition of each single emotion (the maximum score for each of the 6 emotion was 10, which together compose the ER global index) and one for the correct identification of authenticity in genuine and simulate stimuli (the maximum score for each of the two condition was 30, which together compose the EA global index) (Fig. 1).

Raw scores for the ER and EA indices were calculated according to the Italian validation (Scarpazza et al., 2025) and used in the analyses explained below. The test duration was approximately 10 to 15 minutes. Participants were tested in a quiet room by a single experimenter.

2.3. Neuropsychological assessment

All MS patients underwent an extensive neuropsychological evaluation close with the experimental protocol and MRI, according to the inclusion criteria, using the Brief Repeatable Battery of Neuropsychological Tests (BRB-NT; Amato et al., 2006) along with other complementary tests to complete the cognitive profile, including the Stroop Test (ST; Caffarra et al., 2002), Trail Making Test (TMT; Siciliano et al., 2019), phonemic, semantic, and alternating verbal fluency (VF; Costa et al., 2014), Modified Five Point Test (Cattelani et al., 2011), and the Brief Visuospatial Memory Test-Revised (BVMT-R; Goretti et al., 2014).

Raw scores were adjusted for age, education, and gender based on Italian normative data for each test. Corrected scores below the cut-off (5th percentile) were classified as altered. MS patients were classified into three groups based on their performances in all neuropsychological tests administered, using a conservative criterion (Ziccardi et al., 2024): "cognitively normal" (CN, 0 subtests below the clinical cut-off), and "cognitively impaired" (CI, at least one test below the clinical cut-off), further subdivided into "mildly impaired" (mCI, up to 2 subtests below the clinical cut-off) or "severely impaired" (sCI, at least 3 failed subtests).

A global cognitive functioning index and three domain-specific cognitive functioning indices (memory, MEM; attention and processing speed, ATT/IPS; executive functions, EF) were calculated by averaging the z-scores of all tests (global cognitive function) and tests within each specific domain (domain-specific cognitive function) (Ziccardi et al., 2024).

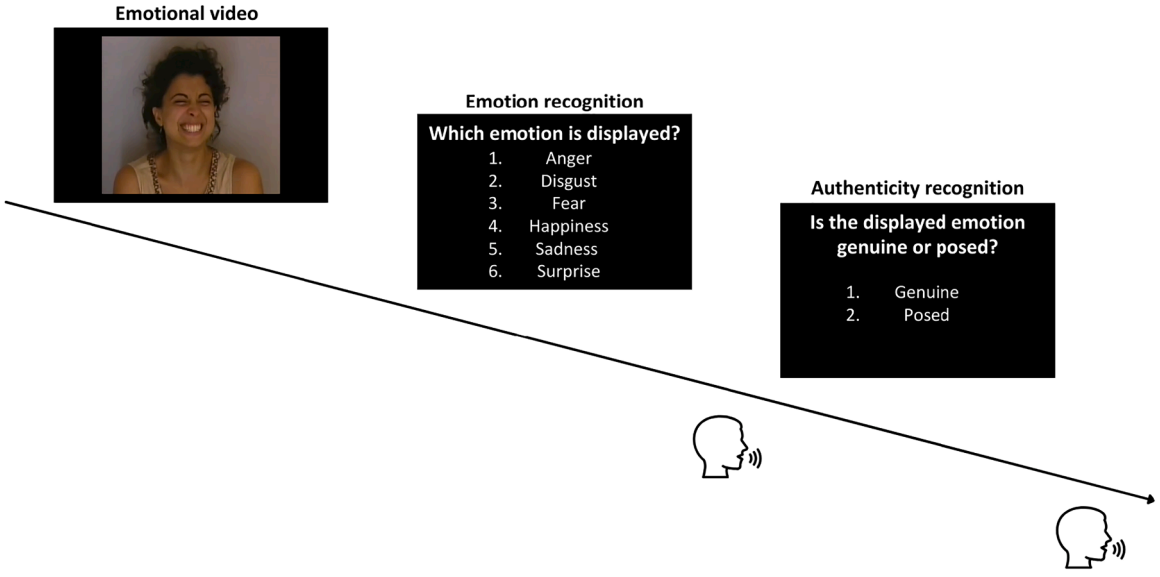

Fig. 1. Example of a dynamic stimulus from the Emotion Authenticity Recognition (EAR) task.
The Fig. depicts the EAR test procedure, in which a video of a facial expression is used to assess both Emotion recognition (i.e., type of emotion) and Authenticity recognition (i.e., whether the emotion is genuine or posed).

2.4. Self-report questionnaires

For the assessment of emotional status (i.e., depression, anxiety, and stress), all patients completed the Depression, Anxiety, and Stress Scale-21 (DASS-21; Bottesi et al., 2015).

Additional questionnaires were administered to evaluate the psychological profile of patients: specifically, for anxiety the State-Trait Anxiety Inventory (STAI-Y2; Spielberger et al., 1983), for impulsivity the Barratt Impulsiveness Scale (BIS-11; Fossati et al., 2001), for personality the Behavioral Inhibition System/Behavioral Activation System (BIS/BAS; Leone et al., 2002), for empathy the Interpersonal Reactivity Index (IRI; Maddaluno et al., 2022), and for alexithymia the Toronto Alexithymia Scale-20 (TAS-20; Bressi et al., 1996).

2.5. Behavioral statistical analyses

Statistical analyses were performed using SPSS software (SPSS Inc., Chicago, IL, USA, version 24).

The normality of the data distribution was tested using the Shapiro-Wilk test, and either Pearson or Spearman was used accordingly. A comparison between MS patients and HCs on EAR results was primarily performed, with a Bayesian approach in case of null results.

To evaluate the association between social cognition protocol results and clinical, cognitive, and psychological outcomes, correlation analyses were performed using Pearson or Spearman tests, as appropriate, and subgroup comparisons based on clinical/cognitive status were carried out using t-tests or Mann-Whitney tests, depending on normality, or with analysis of variance (ANOVA) with Bonferroni correction.

Results are reported as mean ± SD for continuous variables and median [interquartile range, IQR] for discrete variables.

A *p-value* < 0.05 was considered statistically significant.

2.6. MRI acquisition and analysis

MS patients also underwent high-field MRI (3.0 T) (Philips Medical Systems, Best, Netherlands) concurrent with the neuropsychological evaluation and social cognition protocol.

The following image set was acquired: 3D T1-weighted sequences with fast field echo, repetition time (TR) / echo time (TE) = 8.4 / 3.7 ms, voxel size = 1×1×1 mm^3, matrix = 256 × 256.

Voxel-Based Morphometry (VBM) analysis using the software Statistical Parametric Mapping (SPM) and a standard processing analysis was conducted on the T1 sequences to characterize differences in regional volume and tissue concentration (Scarpazza et al., 2015). We did not control for lesion count.

After performing a correlation analysis between grey matter volume (GMV) and EAR performance, excluding the influence of age, gender, and total intracranial volume ($p < 0.001$ uncorrected), we performed follow-up analyses on the regions identified to further explore the relationship between GMV in these regions and EAR performance. This involved extracting GMV from the peak voxels in each MS individual and performing correlation analysis using Jamovi (https://www.jamovi.org) to quantify the strength of the identified correlations. Statistical inferences were made at $p < 0.05$ FWE corrected.

3. Results

Fifty-four MS patients (36 females, 66.6%; age mean±standard deviation (SD) = 41.4 ± 11.0 years; education mean ± SD = 14.7 ± 2.8 years) and 54 HCs matched for gender, age, and education (36 females; age mean ± SD = 41.0 ± 11.0 years, education mean ± SD = 14.7 ± 3) were included in the study.

All patients were under treatment with disease-modifying therapy for MS: 6 MS patients (12.5%) were under low efficacy DMT (all with dimethyl fumarate), while 48 MS patients (87.5%) were under high efficacy DMT (14 with cladribine, 12 with natalizumab, 7 with ocrelizumab, 6 with ofatumumab, 6 with ozanimod, 3 with siponimod).

Complete clinical and demographic results are presented in Table 1.

3.1. Facial emotion recognition protocol

MS patients and HCs obtained the following scores at the EAR test: MS: ER index = 50.9 ± 4.7, EA index = 52.1 ± 4.9; HCs: ER index = 50.6 ± 5.9, EA index = 50.6 ± 5.0. A t-test comparison for ER and EA showed no significant differences between MS and HCs (ER: $p = 0.80$, pBonf = 1.0; EA: $p = 0.11$, pBonf = 0.22). Results are graphically represented in Fig. 2. To determine whether the absence of a significant group effect could be interpreted as evidence favoring the null effect of the group, Bayesian independent t-tests were performed; the t-test revealed moderate evidence for no group difference in ER (BF10 = 0.210, % error = 0.029) supporting the absence of group difference, and anecdotal evidence in favor of the null hypothesis for EA (BF10 = 0.658, % error = 0.017), meaning that the data are not strong enough to draw firm conclusions.

No statistically significant differences emerged between MS patients and HCs considering the recognition of each specific emotion (all $p > 0.05$) and in the identification of authenticity between genuine and simulate emotions (genuine: p = 0.45; simulate: p = 0.11).

3.2. Association with demographic and clinical data

Statistically significant correlations were found between the ER index and age (r = -0.50, $p < 0.001$), education level ($R = 0.34$, $p = 0.012$), and disease duration both from onset and diagnosis (from onset: R = -0.30, $p = 0.030$; from diagnosis: R = -0.27, $p = 0.049$). No significant associations emerged between the EA index and demographic/clinical data.

3.3. Association with neuropsychological data

Patients included in the current study can be classified as follows according to their cognitive status: 30 patients were cognitively normal (55.6%), and 24 patients were cognitively impaired (44.4%), subdivided into 16 mildly cognitively impaired patients (29.6%) and 8 severely cognitively impaired patients (14.8%). Given the small subgroup sizes, especially for sCI patients, analyses performed should be considered as exploratory.

Regarding the classification of cognitive status based on specific cognitive domains: 9 patients (16.7%) showed alterations in the

Table 1
Clinical and demographic results of MS patients included in the study.

	MS patients (n=54)	HCs (n=54)	p-value
Gender (F/M)	36/18	36/18	n.s.
Age (mean±SD), years	41.4±11.0	41.0 ±11.0	n.s.
Education (mean±SD), years	14.7±2.8	14.7 ±3.0	n.s.
Clinical MS course (RRMS/SPMS/PPMS)	50/3/1	/	/
EDSS (median [IQR])	2.0 [2.0]	/	/
Disease duration from onset (mean±SD)	9.2±7.9	/	/
Disease duration from diagnosis (mean±SD)	7.3±7.2	/	/
DMT (low efficacy/high efficacy)	6/48	/	/
Months between neuropsychological assessment and experimental protocol (mean±SD) [range]	2.5±2.7 [0-8]	/	/
Months between neuropsychological assessment and MRI (mean±SD) [range]	2.0±2.5 [0-8]	/	/

MS = multiple sclerosis; HCs = healthy controls; F = females; M = males; L = left; R = right; RRMS = relapsing-remitting MS; SPMS = secondary progressive MS; PPMS = primary progressive MS; EDSS = Expanded Disability Status Scale; DMT = disease-modifying treatment; NPS = neuropsychological evaluation; MRI = magnetic resonance imaging.

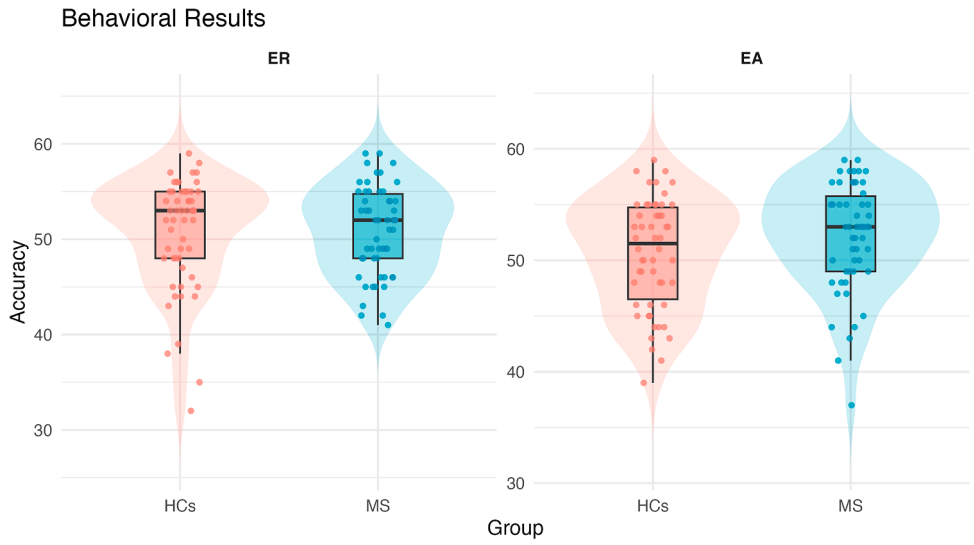

Fig. 2. ER and EA behavioral results in the MS and HCs groups.
ER = Emotion Recognition; EA = Emotion Authenticity; HCs = Healthy Controls; MS = Multiple Sclerosis.

memory domain (MEM), 15 (27.8%) in the attention/information processing speed domain (ATT/IPS), and 12 (22.2%) in the executive function domain (EF).

Interestingly, patients with severe cognitive impairment have a worse performance at the EA task (M ± SD = 47.5 ± 6.2) compared with patients without cognitive impairment (M ± SD = 52.7±4.1, $p = 0.018$) and with mild cognitive impairment (M ± SD = 54.4 ± 3.6, $p = 0.003$). No significant results were found for the ER index.

Considering the raw scores of individual neuropsychological tests and the z-scores of individual cognitive domains and global level, statistically significant correlations were found between the ER index and the Word List Generation test ($r = 0.28$, $p = 0.042$), Stroop Test ($r = -0.29$, $p = 0.035$), Semantic Verbal Fluency ($r = 0.32$, $p = 0.039$), Atlernate Verbal Fluency ($r = 0.44$, $p = 0.004$), Brief Visuospatial Memory Test ($r = 0.49$, $p = 0.004$), the MEM ($r = 0.41$, $p = 0.002$) and ATT/IPS domains ($r = 0.45$, $p = 0.001$), and the global cognitive functioning index ($r = 0.47$, $p < 0.001$). No significant associations with cognitive data were found for the EA index.

All results obtained by patients in the neuropsychological assessment, regarding cognitive tests, are reported in Table 2.

Regarding the relationship with self-report questionnaires, a statistically significant correlation emerged between the EA index and the IRI questionnaire for the total score ($R = 0.29$, $p = 0.037$) and the personal distress subscale (raw score: $R = 0.28$, $p = 0.045$; adjusted score: $R = 0.30$, $p = 0.029$). In contrast, the ER index showed significant correlations with the STAI-Y2 ($R = 0.30$, $p = 0.030$), BIS/BAS (BIS total; $r = 0.38$, $p = 0.005$), and BIS-11 subscales of cognitive complexity ($r = -0.33$, $p = 0.017$) and cognitive instability ($R = 0.31$, $p = 0.027$).

All results obtained by patients in the neuropsychological assessment, regarding self-administered questionnaires, are reported in Table 3.

3.4. Association with neuroradiological data – VBM

VBM results are reported in Fig. 3.

The ER index was found to be significantly positively correlated with the right superior and middle temporal gyrus (coordinates 46, -57, 9, $r = 0.41$, $p = 0.003$; STG: 69, -32, 3, $r = 0.51$, $p < 0.001$) (Fig. 4, upper panel). Negative correlations were found between GMV and ER index in the left middle frontal gyrus (MFG: -34, 30, 32, $r = -0.53$, $p < 0.001$), left cuneus (-9, -78, 26, $r = -0.41$, $p = 0.003$) and precuneus (-12, -62, 54, $r = -0.41$, $p = 0.003$) and the left cerebellar culmen (-36, -40, -38, $r = -0.40$, $p = 0.003$) (Fig. 4, middle panel).

The EA index showed a significant positive correlation with the right temporal pole / amygdala (TP / a coordinates 45, 16, -36, $r = 0.44$; $p < 0.001$) and with the right inferior frontal gyrus (50, 28, 16, $r = 0.37$, $p = 0.008$). Negative correlations between EA index and GMV in the right fusiform gyrus (40, -30, -16, $r = -0.59$, $p < 0.001$), the right precentral gyrus (48, -3, 50, $r = -0.44$, $p = 0.001$) and the left superior temporal gyrus (-42, -3, -20, $r = -0.37$, $p = 0.008$) were also observed (Fig. 4, lower panel).

4. Discussion

This work aimed to deepen the understanding of aspects related to the domain of social cognition in patients with MS, about which the literature is highly heterogeneous, through the use of an innovative assessment protocol: the EAR test (Scarpazza et al., 2025). The EAR enables the assessment of both emotion type recognition (ER) and emotion authenticity recognition (EA) using dynamic, ecologically valid facial stimuli. We highlight that about 45% of the MS patients included in this work showed evidence of global cognitive impairment, a prevalence consistent with that reported in the literature (Benedict et al., 2020; DeLuca et al., 2020). Patients in our sample exhibited greater executive and attentional difficulties (27-28%) and, in a lower proportion, memory difficulties (17%), which also aligns with the literature (Rao et al., 1991; Guimarães and Sá, 2012; Ziccardi et al., 2024).

At the group level, no significant differences emerged between MS patients and healthy controls on either ER or EA. These findings are consistent with previous studies evaluating emotion recognition performance (Jehna et al., 2011; Pinto et al., 2012; Pitteri et al., 2019; Crivelli et al., 2021), despite other studies demonstrating a significantly lower performance in MS compared to controls (Henry et al., 2011; Raimo et al., 2017; Neuhaus et al., 2018). However, to delve further into this, we also applied a Bayesian approach to determine whether no significant group effect could be considered as evidence in favor of the null effect of the group. For ER, the analysis revealed moderate evidence supporting the absence of group differences, suggesting that the ability to recognize the type of emotion is likely preserved in MS. In contrast, for EA, only anecdotal evidence in favor of the null hypothesis was found, indicating that while no differences emerged, the evidence is too weak to draw firm conclusions. Taken together, this pattern suggests that while basic ER remains largely intact, the ability to discern authenticity may be influenced by the limited sample size and its heterogeneity, then deserves further investigation in larger samples to understand whether it represents a more fragile and nuanced aspect of

Table 2
Neuropsychological results of MS patients included in the study.

Global cognitive status and functioning	CN/mCI/sCI (n) 30/16/8	z-score (M±SD) 0.4 ± 0.6
Cognitive domains	**Preserved/Impaired**	**z-score (M ±SD)**
MEM	45/9	0.5 ± 0.9
ATT/IPS	39/15	0.07 ± 0.7
EF	42/12	0.6 ± 0.7
Neuropsychological tests	**Raw score (mean ±SD)**	**z-score (M ±SD)**
SRT-LTS	54.7 ± 15.6	0.7 ± 1.7
SRT-CLTR	48.0 ± 18.5	0.5 ± 1.2
SRT-D	9.6 ± 2.3	0.3 ± 1.0
SPART-I	23.3 ± 4.1	0.5 ± 0.8
SPART-D	7.8 ± 1.9	0.3 ± 0.8
SDMT	55.0 ± 11.0	0.4 ± 1.1
PASAT-3	42.7 ± 11.7	-0.2 ± 1.0
PASAT-2	33.5 ± 10.3	-0.2 ± 0.8
WLG	27.6 ± 5.6	0.1 ± 1.0
ST-EIT	13.6 ± 5.6	NA
ST-EIE	0.4 ± 1.5	NA
TMT-A time (errors)	27.6 ± 8.6 (0.3 ± 0.4)	0.5 ± 0.3 (NA)
TMT-B time (errors)	76.9 ± 23.7 (0.4 ± 0.7)	0.4 ± 0.3 (NA)
PVF	42.5 ± 0.7	0.9 ± 1.1
SVF	57.7 ± 8.5	1.7 ± 0.9
AVF	40.4 ± 10.1	1.1 ± 0.9
SIVF	0.8 ± 0.2	0.3 ± 0.8
MFPT-UDs	35.1 ± 9.3	0.1 ± 1.1
MFPT-CSs	14.3 ± 11.4	1.0 ± 1.6
MFPT-ErrInd	7.3 ± 7.3	0.04 ± 1.0
BVMT-R	27.2 ± 5.9	0.1 ± 0.9

MS = multiple sclerosis; CN = cognitively normal; mCI = mildly cognitively impaired; sCI = severely cognitively impaired; MEM = memory; ATT/IPS = attention/information processing speed; EF = executive functions; SRT-LTS = Selective Reminding Test—Long-Term Storage; SRT-CLTR = Selective Reminding Test—Consistent Long-Term Retrieval; SRT-D = Selective Reminding Test—Delayed; SPART-I = Spatial Recall Test—Immediate; SPART-D = Spatial Recall Test—Delayed; SDMT = Symbol Digit Modalities Test; PASAT-3 = Paced Auditory Serial Addition Test—3 seconds; PASAT-2 = Paced Auditory Serial Addition Test—2 seconds; WLG = Word List Generation; ST-EIT = Stroop Test — Effect Interference Time; ST-EIE = Stroop Test — Effect Interference Error; TMT-A = Trail Making Test—A version; TMT-B = Trail Making Test—B version; PVF = Phonemic Verbal Fluency; SVF = Semantic Verbal Fluency; AVF = Alternate Verbal Fluency; SIVF = Shifting Index Verbal Fluency; MFPT-UDs = Modified Five Point Test—Unique Designs; MFPT-CSs = Modified Five Point Test—Cumulative Strategies; BVMT-R = Brief Visuospatial Memory Test-Revised; NA = not available.

Table 3
Self-report questionnaire results of MS patients included in the study.

Questionnaires	Raw score (M±SD)	Corrected score (M±SD)
IRI		
Perspective taking	18.6±4.6	17.9±4.5
Fantasy	13.1±4.5	12.4±4.4
Empathic concern	20.2±4.4	19.7±4.5
Personal distress	10.3±5.3	10.4±5.3
Total	64.4±11.9	62.8±11.3
DASS-21		
Depression	3.1±3.3	/
Anxiety	2.4±2.8	/
Stress	6.4±3.8	/
Total	11.9±8.6	/
STAI-Y2		
Trait	39.1±12.0	/
State	38.5±12.4	/
BIS-11		
Attention	10.0±2.2	/
Motor	12.2±2.7	/
Self-control	12.4±2.6	/
Cognitive complexity	11.9±2.6	/
Perseverance	6.4±1.6	/
Cognitive instability	5.7±1.7	/
Attentional impulsivity	15.7±3.1	/
Motor impulsivity	18.6±3.5	/
Non-planning impulsivity	24.3±4.4	/
Total	58.6±8.3	/
BIS/BAS		
BAS reward responsiveness	19.4±3.0	/
BAS drive	11.6±3.3	/
BAS fun seeking	9.3±3.1	/
BIS total	23.0±5.1	/
BAS total	40.3±7.8	/
TAS-20		
Difficulty identifying feelings	14.9±6.3	/
Difficulty describing feelings	12.8±4.8	/
Externally-oriented thinking	18.3±4.4	/
Total	46.0±12.0	/

IRI = Interpersonal Reactivity Index; DASS-21 = Depression, Anxiety, and Stress Scale-21; STAI-Y2 = State-Trait Anxiety Inventory-Y2; BIS-11 = Barratt Impulsiveness Scale-11; BIS/BAS = Behavioral Inhibition System/Behavioral Activation System; TAS-20 = Toronto Alexithymia Scale-20.

social cognition in MS. Importantly, this absence of informative group-level evidence does not argue against the relevance of EA; rather, it suggests that any potential effects may depend on individual differences within the MS group, therefore subsequent analyses focused on correlations and potential moderating variables are important.

Regarding the ability to recognize emotion type (ER), no significant differences emerged when comparing MS patients divided by global cognitive status. This result has also been observed in previous works (Neuhaus et al., 2018; Pitteri et al., 2019; Ziccardi et al., 2024), contrasting other works in which cognition and social cognition were associated (Dulau et al., 2017; Henry et al., 2017), even though this association resulted in inconsistent findings (Cotter et al., 2016). This evidence suggests that emotional recognition performance could also be impaired in patients without cognitive impairment. However, when cognition was treated as a continuum rather than a dichotomy (deficit/no deficit), stronger associations emerged: ER performance correlated positively with global cognitive status, as well as with memory, attention/processing speed, and executive functions. (i.e., semantic and alternating fluency, visuospatial memory, and inhibition of automatic responses). These significant correlations suggest the importance of efficient cognitive functioning, especially in memory, attention, and executive domains, for correctly recognizing which emotion a person is displaying. These results are consistent with the literature demonstrating that social cognition performance parallels good functioning on traditional neuropsychological tests measuring classic cognitive domains (Ouellet et al., 2010; Berneiser et al., 2014; Cecchetto et al., 2014).

Additionally, an association emerged between ER and some clinical and demographic parameters: as expected, patients with the highest scores were those with greater brain/cognitive reserve (younger age and higher education) and lower MS impact and exposition (shorter time since diagnosis). These findings align with prior published studies (Cotter et al., 2016; Ziccardi et al., 2021). Correlations were also found between ER and self-report questionnaire results: patients with a better ability in recognizing facial emotions reported higher trait anxiety, greater cognitive instability, lower cognitive complexity, and more effective behavioral inhibitory control. The anxiety result contrasts with some recent studies on the association between social cognition and emotional state in MS patients (Genova et al., 2020; Ziccardi et al., 2021), while, to our knowledge, no studies have yet explored the relationship between impulsivity (measured by BIS-11) and social cognition in MS. No association emerged with the questionnaire assessing subjective empathy.

Regarding the ability to recognize the genuineness of facial emotional stimuli (EA), MS patients showed a generally good performance, though not homogeneously distributed: most patients scored

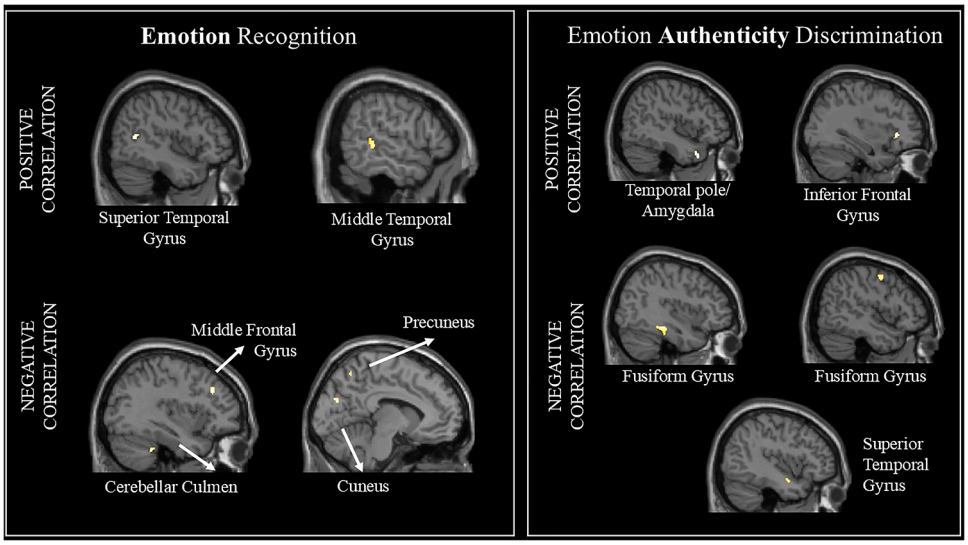

Fig. 3. VBM results.
Significant results were found for emotion recognition and emotion authenticity discrimination, considering both positive and negative correlations with VBM data.

very high (ceiling effect), probably due to the nature of the test, which was expressly designed for this purpose to avoid potential ambiguity. From a descriptive perspective, MS patients scored higher on the EA index than on the ER index; this is opposite to findings in healthy subjects both in the EAR test standardization and original validation study (Scarpazza et al., 2025; Miolla et al., 2023), as well as in the current sample of HCs.

Performance reflected traditional cognitive status classification: patients with severe cognitive impairment scored significantly lower on EA compared to both cognitively preserved patients and those with mild impairment, although this result should be confirmed due to their limited prevalence. However, no specific associations emerged with individual cognitive domains or test scores. This pattern contrasts sharply with that found for ER. The apparent dissociation between categorical and dimensional analyses warrants clarification. EA showed a significant effect of cognitive status at the group level, driven by lower performance in the sCI subgroup, yet it did not correlate with continuous cognitive measures. This pattern is consistent with a non-linear or threshold-like relationship, whereby EA remains relatively stable across preserved cognitive functioning but declines once a critical level of impairment is reached. Restricted variability and ceiling effects in the CN and mCI groups, together with the small size of the sCI subgroup, may further limit the detection of linear associations.

By contrast, ER did not differ across cognitive-status groups, suggesting relative preservation at the categorical level. However, its significant associations with individual cognitive tests and domain/global indices indicate a graded relationship with cognition when examined dimensionally. Together, these findings suggest that EA and ER capture partially distinct aspects of social–emotional processing, with differential sensitivity to categorical versus continuous cognitive variation.

Correlations emerged between EA and self-report questionnaire results, particularly empathy (measured through the IRI): MS patients who were more accurate in detecting the genuineness of emotions also reported higher empathy both globally and specifically regarding discomfort felt when witnessing others' negative experiences. A similar association was found in the test validation study on healthy subjects (Scarpazza et al., 2025). Unlike emotional type recognition, genuineness recognition ability was not associated with clinical or demographic parameters in our study. This absence of significant associations is informative and suggests that genuineness recognition may rely on social-cognitive mechanisms that are relatively independent of disease severity or basic demographic factors. Whereas emotional type recognition involves the decoding of salient affective cues, genuineness recognition may depend on more integrative or higher-order inferential processes that are not adequately captured by standard clinical measures. Alternatively, individual differences in this ability may be driven by factors not assessed here, motivating subsequent analyses focusing on correlational approaches and potential moderating variables.

From a behavioral standpoint, interpreting these findings may involve a form of dual emotional bias: on one hand, MS patients may have a high positive emotional bias toward themselves (other studies have reported high self-reported empathy in MS patients, Ziccardi et al., 2024); on the other hand, they may have a negative emotional bias toward others, making them more skeptical about what they see. Thus, healthy controls may tend to trust others more and consequently make more errors in genuineness recognition. Additionally, the disease might have increased emotional awareness and sensitivity in patients. These are preliminary conclusions from this pilot study and require confirmation in future research.

Considering MRI data, we used Voxel-Based Morphometry (VBM). ER skills showed an association with a widespread brain pattern, including cortical regions across all four lobes: frontal involvement included the middle frontal gyrus; temporal involvement included the superior and middle temporal gyri; parietal involvement included the precuneus region; occipital involvement included the cuneus. Previous literature on the neural bases of social cognition performance reflects wide heterogeneity. Frontal regions have been previously associated with ER in the literature (Adolphs, 2003; Wilde et al., 2005; Beauchamp & Anderson, 2010), including studies in MS patients (Krause et al., 2009; Labbe et al., 2020); this association likely reflects the role of these areas in executive functions (Henry et al., 2022), consistent with significant findings in this project. Temporal regions play a primary role in the visual recognition of emotions (Metternich et al., 2024), especially the temporal gyri (Uono et al., 2017). Parietal regions, especially the superior parietal lobule and precuneus, are also described as key for facial emotion recognition (Sarkheil et al., 2013; Orlando et al., 2023; Cavanna & Trimble, 2006). Emotion recognition from faces also involves brain cortices belonging to the occipital lobe (Sabatinelli et al., 2011; Xu et al., 2021). Moreover, we additionally also found a significant association between ER and the cerebellar culmen: this is in line with a vast stream of research highlighting cerebellum as a “social hub in the brain”, in terms of one of the most important regions with predominant role in emotion perception and understanding social action sequences (Sokolov et al., 2018; Van Overwalle et al., 2020; Turrini & Avenanti, 2024).

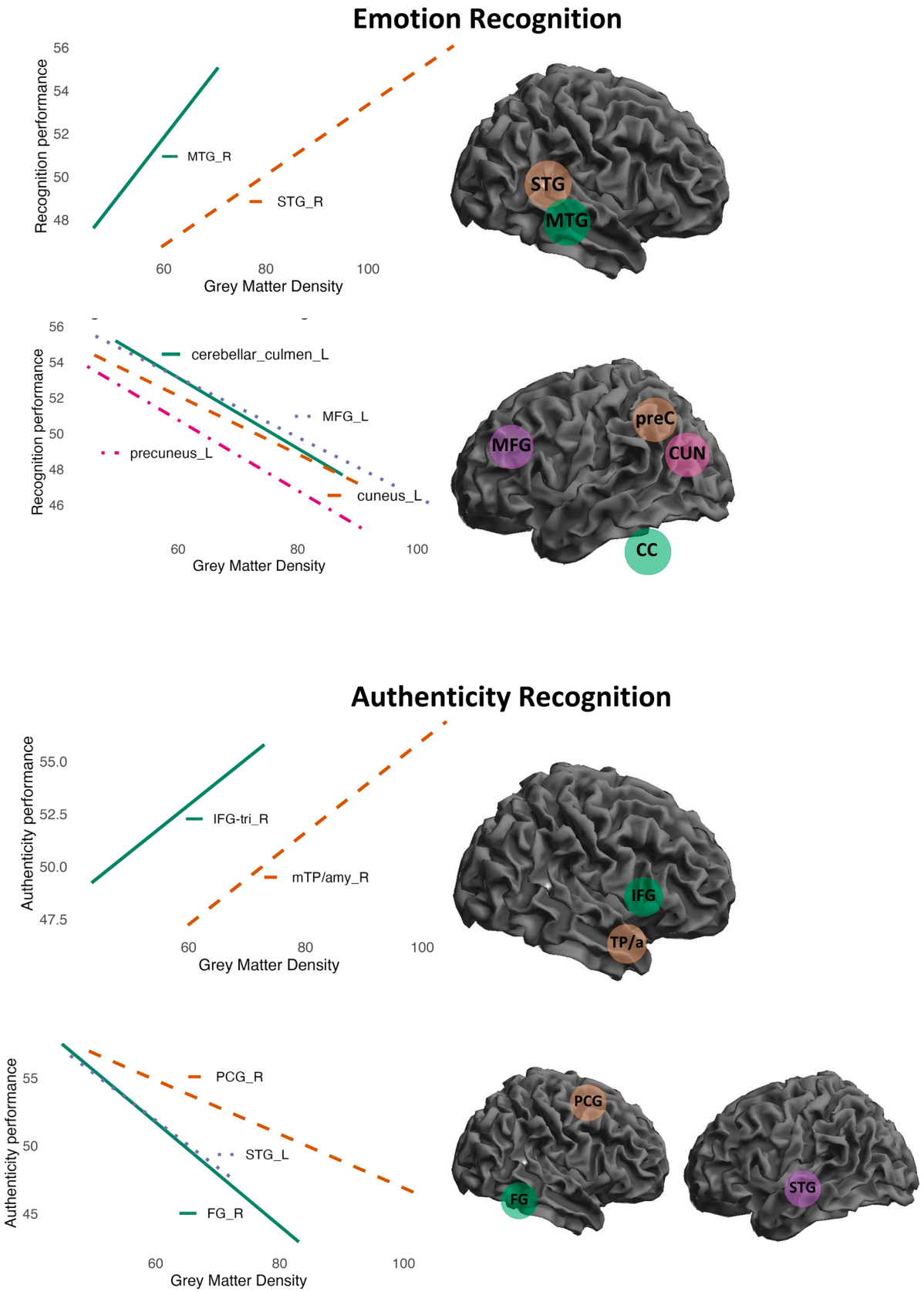

Fig. 4. Significant association between VBM data and both ER/EA.
Upper panel: correlations between Emotion Recognition score and GMV in the brain regions emerged at VBM. Lower panel: correlations between the Emotion Authenticity score and GMV in the brain regions emerged at VBM.
STG = superior temporal gyrus; MTG = middle temporal gyrus; MFG = middle frontal gyrus; preC = precuneus; CUN = cuneus; CC = cerebellar culmen; IFG = inferior frontal gyrus; TP/a = temporal pole/amygdala; PCG = precentral gyrus; FG = fusiform gyrus.

Literature on the neural basis of visually discriminating the genuineness of facial emotions is sparse, especially in MS, where this protocol has not been applied before for this purpose. However, among significant areas emerged in our results there are key regions for emotional content processing (amygdala, fusiform gyrus, inferior frontal gyrus, superior temporal gyrus, precentral gyrus, temporal pole; Adolphs, 2003; Kawasaki et al., 2012; Uono et al., 2016; Goodkind et al., 2012; Seo et al., 2014; Olson et al., 2007; Batista et al., 2017; Chalah & Ayache, 2017; Pitteri et al., 2019; Ziccardi et al., 2021; Golde et al., 2020; Labbe et al., 2020) and also predictive processing during social cognition tasks (Costa et. al. 2024).

This work is a pilot study; its results are thus preliminary, and several limitations must be acknowledged. Indeed, the majority of the patients included were presented with a very mild disability (both physical and cognitive), except for a minimal proportion of progressive patients. This led to two main drawbacks. First, the current results could not be generalised to the whole MS population. Second, although we were able to provide preliminary evidence on these specific alterations, supporting results with behavioural processes and neural correlates.

Moreover, it was not possible to include a control group that also underwent MRI scans and complete neuropsychological assessments, in addition to the experimental protocol; therefore, it is unclear whether findings are MS-specific. Future studies should include a control group with both behavioral and imaging data to provide a broader understanding of the observed phenomenon. Also, future validation studies should be conducted using the EAR test. Furthermore, this study was designed with a cross-sectional approach: it would be of great interest to verify how performance on the administered protocols would evolve in a longitudinal follow-up perspective, to deepen the knowledge on evolution over time and the causal association between cognitive and social cognitive functioning. Finally, future research should deepen these aspects by encouraging collaboration among multiple MS centres to allow for the generalization of the results through a multicentric project.

Data sharing statement

Deidentified data will be shared on request from a qualified investigator.

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CRediT authorship contribution statement

Stefano Ziccardi: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Rachele Pezzetta:** Writing – review & editing, Visualization, Methodology, Formal analysis. **Alexa Schincariol:** Writing – review & editing, Visualization, Methodology, Formal analysis. **Francesco Guarnaccia:** Writing – review & editing, Investigation. **Agnese Tamanti:** Writing – review & editing, Investigation. **Damiano Marastoni:** Writing – review & editing, Investigation. **Massimiliano Calabrese:** Writing – review & editing, Investigation. **Cristina Scarpazza:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

All authors declare no specific competing interest related to this research.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.msard.2026.107155.

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