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How emotion regulation shapes facial emotion recognition in younger and older adults

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ABSTRACT

Facial emotion recognition and emotion regulation both undergo systematic changes with age, yet these domains have rarely been studied together. The present study examined how habitual emotion regulation strategies—cognitive reappraisal and expressive suppression—relate to facial emotion recognition in younger and older adults. We compared 76 older adults ($\geq$ 65 years; $M = 83.74$ years) and 64 younger adults (18–30 years; $M = 22$ years), all cognitively unimpaired and clinically pre-screened. By design, the older sample was restricted to individuals with preserved global cognition (MoCA $\geq$ 26) in order to isolate emotional from cognitive contributions to age-related recognition differences. Participants completed a forced-choice identification task with six high-intensity basic emotions (happiness, sadness, anger, disgust, surprise, fear) and the Emotion Regulation Questionnaire (ERQ). Older adults showed reduced recognition accuracy across all emotions except happiness, with the largest decrements for sadness, anger, surprise, and fear, and reported higher expressive suppression and comparable cognitive reappraisal relative to younger adults. Linear mixed-effects models showed that age differences in recognition were not attenuated by adjusting for regulation strategies, sex, education or depressive symptoms. Critically, the functional coupling between regulation and recognition differed qualitatively across age groups: in older adults, cognitive reappraisal predicted overall recognition while suppression did not; in younger adults, the pattern reversed. This double dissociation suggests an age-dependent reconfiguration of the functional links between regulation and perception, evident in cognitively preserved older adults and therefore not reducible to global cognitive decline.

Introduction

Emotions are fundamental to human adaptation, organising perception, guiding action selection, and scaffolding social interaction. A cornerstone of successful social functioning is emotion perception—the ability to accurately decode affective states from nonverbal cues, particularly facial expressions. This capacity enables rapid inferences about others' internal states and behavioural intentions, supporting adaptive interpersonal behaviour (Adolphs, 2002). At the same time, how individuals regulate their own emotional experiences may shape how they perceive and interpret emotions in others. Despite robust literatures documenting age-related changes in both facial emotion recognition and emotion regulation, these two domains have remained largely disconnected, leaving a critical gap in our understanding of socioemotional ageing.

Age-related differences in facial emotion recognition

A substantial body of research has established that facial emotion recognition shows reliable age-related decline, although the nature and extent of the deficits remain debated. Three meta-analyses anchor this literature. Ruffman et al. (2008) synthesised 28 studies ($N = 1667$) and reported reduced recognition accuracy in older adults for anger, sadness, and fear across multiple modalities, while disgust appeared relatively preserved. The authors proposed a neuropsychological model linking these deficits to age-related frontal and temporal volume

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reductions rather than to general cognitive decline or motivational bias. Gonçalves et al. (2018) updated this evidence with 24 post-2008 studies ($N = 2168$) and reported that older adults were less accurate at identifying anger, sadness, fear, surprise, and even happiness, challenging accounts based solely on positivity bias. Most recently, Hayes et al. (2020) conducted the largest meta-analysis to date (102 datasets, $N = 10{,}526$) and showed that task characteristics moderate observed age effects: the largest deficits emerged for anger, fear, and sadness with static photographs, while dynamic stimuli produced more uniform moderate deficits. Hayes et al. also revealed that the widely cited preservation of disgust recognition was largely an artefact of the Pictures of Facial Affect stimulus set; with other stimulus formats, older adults showed disgust impairments comparable to those for other negative emotions.

Mechanistic accounts of these age-related deficits invoke multiple contributing factors. Some evidence points to perceptual and attentional differences: Sullivan et al. (2007) found that older adults fixate less on the eye region and more on the mouth when viewing emotional faces—a pattern that reduces information intake for anger, fear, and sadness, which rely heavily on eye-region cues. However, attentional scanning differences cannot fully explain age-related decline. Abbruzzese et al. (2019) demonstrated that fear recognition deficits in older adults were unrelated to cognitive function or visual exploration strategies, suggesting domain-specific neurobiological origins. Hamlin et al. (2024) showed that age remained a unique predictor of social cognition performance even after controlling for emotion reactivity, reinforcing the argument that emotion recognition deficits reflect more than general cognitive decline. Taken together, these findings suggest that normal ageing produces gradual, emotion-specific declines in facial affect recognition, concentrated particularly on negative emotions, with neural substrates likely involving progressive frontolimbic network changes (Ruffman et al., 2008).

Age-related changes in emotion regulation

In apparent contrast to declining perceptual abilities, research on emotion regulation reveals a paradoxical developmental trajectory characterised by maintained or even improved regulatory functioning with age. The Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) measures individual differences in two widely studied strategies: cognitive reappraisal (an antecedent-focused strategy involving reinterpreting the meaning of emotion-eliciting situations) and expressive suppression (a response-focused strategy involving inhibiting outward emotional displays). Foundational work by John and Gross (2004) demonstrated that, from early to later adulthood, Western adults show increasing cognitive reappraisal use and decreasing expressive suppression use, accompanied by higher subjective well-being. This developmental shift has been interpreted through Socioemotional Selectivity Theory (SST; Carstensen, 1992, 2006), which proposes that as perceived time horizons shrink, older adults prioritise emotionally meaningful goals through proactive emotion regulation, including cognitive reappraisal and attentional deployment toward positive stimuli. In a landmark 10-year experience-sampling study, Carstensen et al. (2011) confirmed that ageing is associated with more positive emotional experience and greater emotional stability, supporting the SST framework (Mather & Carstensen, 2005; Reed & Carstensen, 2012).

Important nuances qualify this optimistic portrait. The Strength and Vulnerability Integration (SAVI) model (Charles, 2010) proposes that ageing brings both regulatory expertise and physiological vulnerabilities; when stressors are chronic and inescapable, age advantages in regulation can disappear or reverse. The Selection, Optimization, and Compensation with Emotion Regulation (SOC-ER) framework (Urry & Gross, 2010) further suggests that older adults strategically shift toward less cognitively demanding regulatory strategies as executive resources decline. Shiota and Levenson (2009) showed that older adults were less successful at detached (cognitively demanding) reappraisal but equally or more successful at positive reappraisal. Opitz et al. (2012) confirmed this neurally, reporting reduced prefrontal activation during cognitive reappraisal in older adults. Opitz et al. (2014) further demonstrated that fluid cognitive ability predicted reappraisal success regardless of age, supporting a cognitive resource account. Together, these findings indicate that the relationship between ageing and emotion regulation is more complex than simple improvement, with regulatory success depending on strategy type and available cognitive resources.

The regulation–recognition interface and the cognitive-versus-emotional ambiguity

Despite strong theoretical reasons to expect that emotion regulation strategies and emotion recognition abilities should interact, these two domains have remained empirically disconnected in the ageing literature. Gross's process model of emotion regulation (Gross, 1998, 2015) explicitly positions emotion perception as the first stage of the regulatory process—identification of emotional stimuli is a prerequisite for regulation—suggesting that habitual regulation strategies might reciprocally shape perceptual processing of emotional information. Empirical evidence from younger adults indicates that regulation strategies carry cognitive costs that could affect emotion processing. Richards and Gross (2000) showed that expressive suppression during emotional films impaired memory for event details, attributed to attentional resource diversion toward self-monitoring of expressive behaviour, while reappraisal produced no such impairment. Butler et al. (2003) demonstrated that suppression disrupts social interaction in both the suppressor and their interaction partner, effects that could plausibly extend to impaired processing of others' emotional expressions. Petrican et al. (2015) found that habitual suppressors showed altered neural processing of non-verbal affective cues, potentially reflecting compensation for emotionally impoverished social environments. More recently, Sommer and Schlegel (2025) demonstrated a three-way interaction between cognitive emotion regulation, emotion recognition ability, and social outcomes in naturalistic interactions—one of the first direct demonstrations that regulation and recognition interact in real social contexts.

A central methodological challenge in research on age-related changes in facial emotion recognition is the difficulty of disentangling specifically emotional contributions from broader cognitive decline. Age groups commonly compared in this literature differ not only in regulatory and emotional functioning, but also in attention, processing speed, working memory, and other cognitive domains relevant to face processing (Henry et al., 2016; Ruffman et al., 2008). When older samples include individuals with mild cognitive impairment or even subclinical cognitive decline, observed recognition deficits become ambiguous between two interpretations: a specifically emotional change associated with ageing, or a more general cognitive deficit that incidentally affects emotion recognition. To address this ambiguity, the present study deliberately restricted recruitment of older adults to those with preserved global cognitive functioning (MoCA $\geq$ 26), substantially above the standard cut-off for mild cognitive impairment screening. This inclusion criterion was central to the design rather than a generic exclusion: by sampling cognitively high-functioning older adults, we sought to isolate emotional and regulatory contributions to recognition from contributions of global cognitive decline. Any age-related recognition deficits emerging in this sample cannot plausibly be attributed to global cognitive impairment and are therefore informative about specifically emotional or socio-cognitive ageing.

Yet, despite the theoretical relevance of this question, no published study has directly examined whether ERQ-measured cognitive reappraisal and expressive suppression predict facial emotion recognition accuracy in cognitively preserved older adults. This gap is striking given that both processes draw on overlapping frontolimbic neural architecture. Lesion and neuroimaging research in stroke and traumatic brain injury populations has revealed that emotion recognition relies on a distributed network including occipitotemporal neocortex, amygdala, orbitofrontal cortex, and right frontoparietal regions (Adolphs, 2002; Dal Monte et al., 2013), while emotion regulation maps to an overlapping but distinguishable network centred on left ventrolateral prefrontal cortex and connected subcortical regions (Joutsa et al., 2022). Both ageing and focal brain injury produce deficits in these overlapping networks: normal ageing produces gradual, modest declines concentrated on negative emotions (Ruffman et al., 2008), whereas stroke produces acute, severe, and often global impairments (Yuvaraj et al., 2013). This convergence highlights frontotemporal network integrity as critical for both regulation and recognition, but the functional interaction between these capacities in healthy ageing remains unexplored.

The present study

The present study addresses this gap by examining the relationship between habitual emotion regulation strategies (measured via the ERQ) and facial emotion recognition performance in younger and older adults, using an extreme-groups age-comparative design. We pursued three specific objectives. First, we characterised age-related differences in facial emotion recognition across six basic emotions (happiness, sadness, anger, disgust, surprise, fear) using a standardised forced-choice identification task. Based on meta-analytic evidence (Hayes et al., 2020; Ruffman et al., 2008), we hypothesised that older adults would show reduced overall accuracy, with emotion-specific deficits most pronounced for anger, fear, and sadness. Second, we examined age-related differences in ERQ-measured cognitive reappraisal and expressive suppression. Following the developmental literature (John & Gross, 2004), we expected older adults to report higher reappraisal and lower suppression than younger adults, although the executive resource account (Opitz et al., 2014; Urry & Gross, 2010) allows for the alternative possibility of reduced reappraisal due to declining cognitive capacity. Third, and most critically, we tested whether emotion regulation strategies modulate emotion recognition performance in an emotion-specific manner. Drawing on the process model of emotion regulation (Gross, 2015) and evidence that suppression depletes cognitive resources (Richards & Gross, 2000), we hypothesised that expressive suppression would be associated with reduced recognition accuracy, particularly for negative emotions requiring greater cognitive effort to decode. Conversely, we expected that cognitive reappraisal—indexing flexible, adaptive regulatory capacity—might facilitate emotion recognition through enhanced attentional engagement with emotional stimuli. By restricting the older sample to cognitively preserved participants and by adjusting for sex, education, and depressive symptoms, the design allows us to test whether regulation–recognition associations operate independently of global cognitive decline, of demographic confounds, and of subclinical mood factors.

Methods

Participants and design

A total of 140 cognitively unimpaired adults participated in this age-comparative, cross-sectional study. Participants were allocated to two age groups: a younger adult group ($n = 64$; 44 women, 68.8%; aged 18–30 years, $M = 22.00$, $SD = 3.30$) recruited as university student volunteers, and an older adult group ($n = 76$; 40 women, 52.6%; aged 70–97 years (inclusion criterion ≥ 65 years), $M = 83.74$, $SD = 7.68$) recruited from a tertiary university hospital. We employed an extreme-groups design (younger vs. older adults) rather than a continuous lifespan sampling approach in order to maximise statistical power for detecting age-related effects on facial emotion recognition; we acknowledge that this design does not provide direct evidence about the trajectory of these effects across middle adulthood, which constitutes an important target for future research and is discussed in the *Limitations* section.

The two groups were comparable in years of formal education ($M = 14.06$, $SD = 2.57$ vs. $M = 13.58$, $SD = 2.53$; $p = .265$). The proportion of women differed marginally between groups ($\chi^2(1) = 3.76$, $p = .052$); given that this difference approached conventional significance and that prior literature has reported sex-related variability in facial emotion processing, sex was included as a covariate in the primary mixed-effects models, and an exploratory Sex × Group × Emotion analysis is reported in the *Sensitivity analyses* subsection. As expected, younger adults scored higher on the Montreal Cognitive Assessment (MoCA; $M = 29.94$, $SD = 0.24$) than older adults ($M = 26.84$, $SD = 1.05$; $p < .001$); however, both groups performed at or above the standard screening cut-off (≥ 26), consistent with preserved global cognition. Younger adults reported slightly lower depressive symptoms on the Beck Depression Inventory–II (BDI-II; $M = 2.69$, $SD = 3.16$ vs. $M = 3.89$, $SD = 2.81$; $p = .019$), although both groups scored well below the clinical threshold (see Table 1).

Inclusion and exclusion criteria

Inclusion criteria were chosen to align the sample with the design rationale of disentangling emotional from cognitive contributions to age-related recognition differences. Both groups were required to show: (a) age within the specified range; (b) preserved global cognitive functioning, operationalised as MoCA ≥ 26 (selecting older adults clearly above the conventional screening cut-off for mild cognitive impairment); (c) absence of clinically significant depressive symptomatology, operationalised as BDI-II ≤ 15; and (d) self-reported ability to perform the visual identification task, with prescribed corrective lenses or hearing aids worn during testing where applicable. The MoCA inclusion criterion was central to the study rationale: by restricting the older sample to cognitively preserved individuals, we ensured that any observed age-related deficits in facial emotion recognition could not be attributed to global cognitive decline. Exclusion criteria included prior diagnosis of psychiatric or neurological disorders, current use of psychotropic medication, and any uncorrected sensory deficit reported at recruitment that could compromise task performance.

Recruitment and pre-screening

Older adults were recruited consecutively from the outpatient services of a tertiary university hospital and were pre-screened by the referring hospital physician, who applied the inclusion and exclusion criteria above prior to study referral. This medical pre-screening ensured a clinically curated sample of cognitively preserved older adults but, by design, restricts representativeness: the older sample is therefore best characterised as a cognitively high-functioning, hospital-recruited subgroup rather than a population-representative sample of community-dwelling older adults. Younger adults were recruited as student volunteers from the university community.

Sample size and compensation

The sample size was determined by participant availability within the recruitment period. Post-hoc statistical power was estimated for the primary three-way interaction (Group × Emotion × ERQ subscale) and is reported in the *Statistical analysis* subsection. Participants did not receive any financial or material compensation for their participation.

Ethics and data protection

The study protocol was approved by the institutional ethics committee on 31 January 2023 (full reference details provided in the title page). The study was conducted in accordance with the Declaration of Helsinki (1964 and subsequent amendments) and with the recommendations of the International Committee of Medical Journal Editors (ICMJE). All participants provided written informed consent prior to enrolment, after a plain-language explanation of the study aims, the voluntary nature of participation, the absence of compensation, and the

Table 1
Sample characteristics by age group.

Variable	Older (n = 76) M (SD) or n	Younger (n = 64) M (SD) or n	Older range	Younger range	Test	p
Age (years)	83.74 (7.68)	22.00 (3.30)	70–97	19–28	t(138) = 63.46	< 0.001
Education (years)	13.58 (2.53)	14.06 (2.57)	10–18	10–18	t(138) = −1.12	.266
MoCA (0–30)	26.84 (1.05)	29.94 (0.24)	26–29	29–30	t(138) = −25.00	< 0.001
BDI-II (0–63)	3.89 (2.81)	2.69 (3.16)	0–9	0–9	t(138) = 2.37	.019
ERQ Cognitive Reappraisal	4.57 (1.29)	4.89 (1.16)	2.0–7.0	2.0–7.0	t(138) = −1.57	.120
ERQ Expressive Suppression	3.79 (1.55)	2.89 (1.43)	1.0–6.0	1.0–6.0	t(138) = 3.59	< 0.001
Total recognition (0–24)	12.37 (4.79)	19.19 (2.29)	6–21	14–22	t(138) = −11.01	< 0.001
Women / Men, n	40 / 36	44 / 20	52.6% women	68.8% women	$\chi^2(1) = 3.76$	.052

Note. Welch independent-samples *t*-tests for continuous variables; Pearson chi-squared without continuity correction for sex. MoCA = Montreal Cognitive Assessment; BDI-II = Beck Depression Inventory–Second Edition; ERQ = Emotion Regulation Questionnaire.

right to withdraw at any time without consequence. In the older adult group, decisional capacity was assessed clinically by the referring hospital physician prior to study referral; the experimenter additionally verified comprehension of the consent information at the start of the session and reaffirmed verbally the right to withdraw before any data were collected.

All study data were de-identified at the time of data entry: each participant was assigned a numeric identifier at recruitment, and the linking key between identifier and personal information was stored in a separate, password-protected file accessible only to the corresponding author and the principal investigator. Questionnaire and task data were entered into the analytic database under the numeric identifier and contain no direct or indirect identifiers. Storage and processing of all data complied with the European General Data Protection Regulation (Regulation (EU) 2016/679) and the Spanish Organic Law on the Protection of Personal Data and the Guarantee of Digital Rights (Ley Orgánica 3/2018).

Setting and equipment

Older adults were assessed individually in a quiet examination room at the recruiting university hospital. Younger adults were assessed individually in one of two quiet, similarly equipped offices at the participating university. Across both settings, ambient lighting was held constant during testing, no interruptions were permitted, and only the participant and experimenter were present. Visual stimuli were presented on a 16-inch LCD screen at an approximate viewing distance of 50–70 cm, corresponding to a typical reading or working distance. Screen brightness was kept at the manufacturer's default setting and was not modified between sessions; formal photometric calibration of luminance, contrast, or colour reproduction was not performed, and we declare this as a methodological limitation in the Discussion. Viewing distance was not constrained with a chinrest or fixed restraint, which we acknowledge as an additional methodological limitation; however, instructions to maintain a comfortable seated posture were standardised across sites, and equipment specifications were identical across the two evaluation contexts.

Sensory acuity was not formally measured. Participants self-reported any diagnosed visual or auditory deficit at recruitment, and prescribed corrective lenses or hearing aids were worn during testing where applicable. We acknowledge that undetected mild sensory impairments, particularly common in adults aged 80 years or older, may have contributed to the recognition deficits observed in the older group; this limitation is addressed in the *Limitations* subsection of the Discussion.

Materials

Emotional facial expression identification (EFE) task

Facial emotion recognition was assessed with a forced-choice identification paradigm comprising 24 colour, computer-generated facial expressions representing six basic emotions (happiness, sadness, surprise, fear, anger, disgust), with four exemplars per emotion. All stimuli were presented at high emotional intensity, generated by full activation of the canonical action units (AUs) listed in Table 2; lower-intensity exemplars from the same stimulus set were not included in this study to reduce task duration and minimise fatigue effects in older participants.

The stimulus set used in the present study was developed by Johannes Heiner Ellgring, using 3D facial modelling software (Poser 6; Curious Labs, Santa Cruz, CA, subsequently distributed by Smith Micro), a commercially distributed application for which a regular user licence had been obtained at the time of stimulus creation. The methodological specifications of the stimuli — that is, the FACS action units and the high-intensity parameterisation used to construct each emotional expression — are reported in full in Table 2 of the present manuscript, ensuring methodological reproducibility independently of the imagery itself. The stimuli were parametrically built from the muscle movements specified in the Facial Action Coding System (FACS; Ekman & Friesen, 1978; Ekman et al., 2002), ensuring that each expression reflected a standardised configuration of action units rather than the idiosyncratic features of a photographed actor. The facial configurations followed canonical AU patterns for each emotion: happiness (AU 6 + 12 + 26), sadness (AU 1 + 4 + 15), surprise (AU 1 + 2 + 5 + 26), fear (AU 1 + 4 + 5 + 20 + 26), anger (AU 4 + 5 + 24), and disgust (AU 4 + 9 + 10 + 15) (see Table 2). Stimulus development and AU implementation were conducted by an experienced FACS coder, consistent with the methodological approach used in prior work employing the same stimulus family (García-Rodríguez et al., 2009, 2012a, 2012b ;Ruiz-García & García-Rodríguez, 2026). The stimuli were created prior to the era of generative artificial intelligence imagery and rely entirely on muscle-based parametric specification rather than on learned image generation; no generative AI tools were used in the creation, modification, or selection of the facial stimuli.

From a methodological standpoint, systematic reviews of facial emotion recognition tasks have highlighted limitations of using photographed actors' faces, particularly regarding uncontrolled variability in

Table 2
Facial action coding system (FACS) action unit specifications for the six emotional expressions.

Emotion	AU components	Description
Happiness	AU 6 + 12 + 26	Cheek raiser + lip corner puller + jaw drop
Sadness	AU 1 + 4 + 15	Inner brow raiser + brow lowerer + lip corner depressor
Surprise	AU 1 + 2 + 5 + 26	Inner brow raiser + outer brow raiser + upper lid raiser + jaw drop
Fear	AU 1 + 4 + 5 + 20 + 26	Inner brow raiser + brow lowerer + upper lid raiser + lip stretcher + jaw drop
Anger	AU 4 + 5 + 24	Brow lowerer + upper lid raiser + lip pressor
Disgust	AU 4 + 9 + 10 + 15	Brow lowerer + nose wrinkler + upper lip raiser + lip corner depressor

Note. AU = action unit. All stimuli were presented at high emotional intensity, generated by full activation of the canonical action units. Stimuli were created using Poser 6 (Curious Labs, Santa Cruz, CA) by an experienced FACS coder, prior to the era of generative artificial intelligence imagery.

emotional intensity, expressiveness, and idiosyncratic facial features (Ferreira et al., 2021). Such variability may introduce noise that is especially problematic in ageing research, where subtle group differences can be obscured or inflated by stimulus-related factors. A key advantage of using standardised, computer-generated expressions is experimental control: intensity, viewpoint, and facial movement patterns can be held constant across exemplars, improving internal validity and comparability across participants. Converging evidence indicates that avatar-based emotional expressions can engage core affective circuitry in a manner broadly comparable to human facial stimuli; for example, fMRI studies have shown reliable amygdala activation to both human and avatar emotional expressions (Moser et al., 2007).

Trial structure and response collection

Each trial began with a centrally presented fixation cross (1200 ms), followed by a blank black screen (600 ms), then an emotional face stimulus (1200 ms), and a final fixation cross (1200 ms). After stimulus offset, the participant was prompted with the question “Which emotion is shown in this face?”; the six emotion labels remained visible on screen during the response phase, in order to reduce demands on verbal memory for emotion category names (see Fig. 1). Response time was unlimited to minimise speed–accuracy trade-offs and to keep the dependent variable focused on identification accuracy rather than motor speed. The presentation order was randomised across participants to mitigate sequence learning and familiarity effects, and no performance feedback was provided during or after the task.

Responses were given verbally and recorded manually by the experimenter on a standardised response sheet with one cell per trial. Manual recording was a deliberate methodological choice to reduce potential confounding by visuomotor slowing, fine motor difficulties, or unfamiliarity with computer interfaces—non-trivial concerns when testing very old adults. Two procedural rules were applied to minimise recording bias: (a) participants were allowed to respond freely and the experimenter did not paraphrase or reformulate their answer, and (b) in cases of verbal self-correction, the participant’s final response was retained. Responses were subsequently transcribed by the same experimenter into the analytic database. Original response sheets were retained and remain available for verification on request.

The same researcher administered all assessments to both age groups and was therefore not blind to age-group membership, which is intrinsically observable in this design. Importantly, the ERQ and BDI-II protocols were administered before the EFE task, but their scores were not computed until the entire experimental session was completed and all data had been entered into the analytic database; consequently, the experimenter was unaware of any participant’s emotion-regulation profile during administration of the EFE task. This procedural feature mitigates—although does not eliminate—the possibility of experimenter bias with respect to the central hypotheses concerning the regulation–recognition relationship.

The primary outcome was total identification accuracy (range 0–24). Secondary outcomes were emotion-specific accuracy scores (range 0–4 per emotion), used as the within-subject dependent variable in the mixed-effects models.

Global cognitive screening

Global cognitive functioning was screened with the Spanish official version of the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), as authorised by the MoCA Cognition Group and obtained through the official distribution channel. The MoCA is a brief 30-point screening tool covering attention, executive functions, memory, language, visuospatial abilities, and orientation, with high sensitivity for detecting mild cognitive impairment at commonly used cut-offs (Nasreddine et al., 2005). The instrument was administered by a certified MoCA user (the corresponding author) following the standard protocol. The MoCA was used both to characterise global cognitive status and to operationalise the inclusion criterion (MoCA $\geq$ 26).

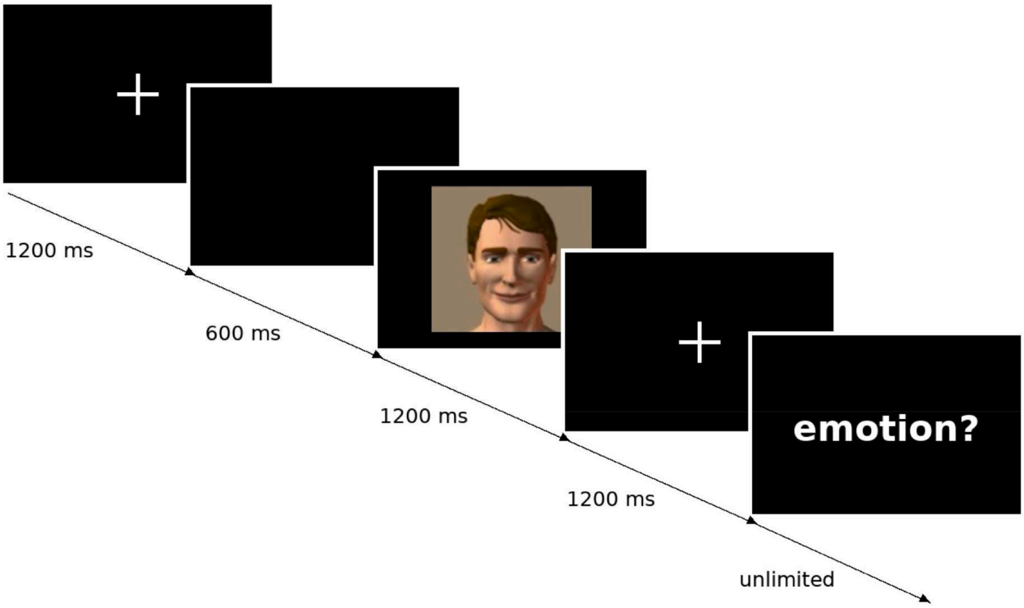

Fig. 1. Example of a trial run for the EFE identification task. Each trial began with a centrally presented fixation cross (1200 ms), followed by a blank black screen (600 ms), the emotional face stimulus (1200 ms), and a final fixation cross (1200 ms); after stimulus offset, participants responded to the prompt “emotion?” with no time limit. The face shown is illustrative only. The stimulus set is described in *Methods, Materials, EFE task* and the FACS specifications for all six emotions are reported in Table 2; copyright over the stimulus images resides with the original developer (see *Availability of data and materials* in the Title page). The stimuli are 3D computer-generated models built parametrically from FACS action units; no generative artificial intelligence tools were used in their creation, modification, or selection.

Note. Stimuli were generated with Poser 6 (Curious Labs, Santa Cruz, CA) and parametrically built from FACS action units by an experienced FACS coder. All stimuli were presented at high emotional intensity. The stimuli were created prior to the era of generative artificial intelligence imagery and rely entirely on muscle-based parametric specification.

Emotion regulation

Habitual emotion regulation strategies were assessed using the Spanish adaptation of the Emotion Regulation Questionnaire (ERQ; Cabello et al., 2013; original version: Gross & John, 2003), a 10-item self-report measure indexing two strategy families: cognitive reappraisal (six items) and expressive suppression (four items). Items were rated on a 7-point Likert-type scale (1 = *strongly disagree*, 7 = *strongly agree*) and averaged within subscales to yield separate reappraisal and suppression scores; higher scores reflect more frequent habitual use of the respective strategy. The Spanish adaptation by Cabello et al. (2013) has shown adequate internal consistency (Cronbach's $\alpha = 0.79$ for cognitive reappraisal and $\alpha = 0.75$ for expressive suppression in the original validation) and a stable two-factor structure across age groups. Reliability indices could not be re-computed in the present sample because data were retained at the subscale-score level rather than at item level; the psychometric properties reported in the original Spanish validation are therefore relied upon to support the adequacy of the instrument in this study population.

Depressive symptoms

Depressive symptom severity was assessed using the Spanish adaptation of the Beck Depression Inventory–II (BDI-II; Sanz et al., 2003; original version: Beck et al., 1996), a 21-item self-report inventory with each item rated on a 0–3 scale, producing a total score ranging from 0 to 63. The Spanish adaptation by Sanz et al. (2003) has shown high internal consistency (Cronbach's $\alpha = 0.89$) and adequate factorial validity in Spanish general-population samples. As for the ERQ, item-level data were not retained in the analytic database, and reliability indices could not therefore be re-computed in the present sample. The BDI-II was used to characterise depressive symptom load and, consistent with the study's exclusion criteria, to identify and exclude individuals with moderate-to-severe depression (BDI-II > 15).

Procedure

Participants were assessed individually in a single session lasting approximately 60 min. The assessment sequence was identical for all participants and was structured as follows: (a) brief sociodemographic interview and verification of inclusion and exclusion criteria; (b) MoCA cognitive screening; (c) BDI-II depressive symptom assessment; (d) ERQ emotion regulation questionnaire; (e) EFE facial emotion identification task. The fixed administration order ensured that the regulation and depressive-symptom self-reports were completed before the emotion-perception task, and—as noted in the EFE task description—the experimenter did not score the questionnaires until after the entire session was completed.

Statistical analysis

All analyses used linear mixed-effects models (LMMs) on emotion-specific accuracy scores (range 0–4), with by-participant random intercepts. Mixed-effects models were preferred over repeated-measures ANOVA because they (a) provide a more flexible treatment of within-subject covariance without imposing the sphericity assumption, (b) yield direct effect-size estimates with confidence intervals, and (c) allow simultaneous estimation of fixed-effect interactions and adjustment for covariates within a single coherent model. Continuous predictors (cognitive reappraisal, expressive suppression, BDI-II, education) were grand-mean-centred prior to analysis to facilitate interpretation of main effects in the presence of interactions.

The principal model (M3a) included Group (younger, older), Emotion (six levels), centred ERQ Cognitive Reappraisal, and centred ERQ Expressive Suppression as fixed effects, with all two- and three-way interactions of theoretical interest, and adjustment for sex, education and BDI-II as additional covariates. Significant interactions were decomposed by fitting separate within-group LMMs and computing simple slopes of each ERQ subscale at each emotion level, with 95% confidence intervals. Omnibus effects were tested by Wald F. Sensitivity analyses (a) excluded participants with MoCA = 26 strict to test the robustness of effects within an even more restricted cognitive range (M4); and (b) refitted an exploratory Group × Sex × Emotion model to evaluate whether sex modified the principal age-by-emotion pattern (M5). Given the observed non-centrality parameters, post-hoc statistical power for the principal three-way Group × Emotion × Regulation interactions exceeded 0.98 at $\alpha = 0.05$ for both ERQ subscales. As a complementary sensitivity-style benchmark, the smallest effect detectable at 80% power with the available sample size, $\alpha = 0.05$ and the present model degrees of freedom corresponded to Cohen's $f \approx 0.07$, well below conventional medium-effect thresholds. We acknowledge that post-hoc power computed from observed F statistics is largely a transformation of the obtained p value and not a substitute for an a priori calculation; we report it here in response to the editor's specific request and treat the sensitivity benchmark above as the more informative quantity. Regarding multiplicity, the two omnibus three-way interactions tested in M3a (Group × Emotion × Cognitive Reappraisal; Group × Emotion × Expressive Suppression) were pre-specified as the principal confirmatory tests of the regulation–recognition hypothesis and were therefore evaluated without adjustment for multiplicity. The within-group simple-slopes decompositions reported in Table 5 (24 emotion-specific coefficients in total) are descriptive in nature, intended to characterise the qualitative pattern of the omnibus interactions; their associated p values are reported uncorrected and are interpreted in terms of consistency of sign and magnitude across emotions, not as independent confirmatory tests. Analyses were conducted in Python 3.12 using NumPy and SciPy, with custom REML implementations for the LMM fits; the principal model results were verified against the GLM output of the original analyses in IBM SPSS Statistics.

Results

Sample characteristics

Descriptive statistics for the two age groups are reported in Table 1. As expected from the recruitment procedure, older and younger adults differed in age ($M = 83.74$ vs. $M = 22.00$ years), MoCA score ($M = 26.84$ vs. $M = 29.94$)—both groups, by design, scoring at or above the conventional screening cut-off—and BDI-II score ($M = 3.89$ vs. $M = 2.69$), although both groups remained well within healthy ranges on the latter two indices. Years of formal education did not differ between groups ($M = 13.58$ vs. $M = 14.06$; $p = .265$). Older adults reported significantly higher use of expressive suppression than younger adults ($M = 3.79$ vs. $M = 2.89$; $p < .001$), whereas the two groups did not differ in cognitive reappraisal ($M = 4.57$ vs. $M = 4.89$; $p = .120$). Sex distribution differed marginally between groups (52.6%vs. 68.8% women; $\chi^2(1) = 3.76$, $p = .052$), motivating its inclusion as a covariate in the principal model.

Group × emotion interaction in identification accuracy

The principal mixed-effects model revealed a robust Group × Emotion interaction, $F(5, 801) = 19.81$, $p < .001$ (Table 3; Fig. 2). To characterise the interaction, group differences were tested for each emotion. Older adults performed comparably to younger adults for happiness ($M = 3.26$ vs. 3.25; difference < 0.02 points, $p = .94$) but showed substantial deficits across the remaining five emotions: sadness ($\Delta = -1.71, p < .001$), anger ($\Delta = -1.77, p < .001$), disgust ($\Delta = -0.66$, $p = .002$), surprise ($\Delta = -1.56$, $p < .001$), and fear ($\Delta = -1.13$, $p < .001$). The Emotion main effect was significant, $F(5, 801) = 55.85$, $p < .001$, indicating that even after collapsing across age groups some emotions were systematically more difficult than others (notably disgust and fear); however, this main effect should be interpreted in light of the Group × Emotion interaction.

The Group main effect was non-significant in the LMM, $F(1, 801) =$

Table 3
Identification accuracy by group and emotion.

Emotion	Older (n = 76) M (SD)	Older 95% CI	Younger (n = 64) M (SD)	Younger 95% CI
Happiness	3.26 (0.97)	[3.04, 3.49]	3.25 (0.98)	[3.01, 3.49]
Sadness	2.11 (1.17)	[1.84, 2.37]	3.81 (0.39)	[3.71, 3.91]
Anger	2.11 (1.38)	[1.79, 2.42]	3.88 (0.49)	[3.75, 4.00]
Disgust	1.21 (1.25)	[0.93, 1.50]	1.88 (1.18)	[1.58, 2.17]
Surprise	2.32 (1.50)	[1.97, 2.66]	3.88 (0.33)	[3.79, 3.96]
Fear	1.37 (0.94)	[1.15, 1.58]	2.50 (0.94)	[2.26, 2.74]

Note. Cell means out of 4 trials per emotion. 95% CIs computed using Student's t-distribution. See Fig. 2 for graphical display.

0.27, $p = .603$. This apparent inconsistency with the substantial overall age-related deficit reflects the parameterisation of the model: with treatment coding using older adults and happiness as references, the Group main effect estimates the older–younger difference at the reference emotion (happiness), where performance is virtually identical between groups (see Table 2). The substantive age-related deficit emerges in the Group × Emotion interaction and in the cell-mean comparisons reported above.

Three-way interactions: group × emotion × regulation

The two key omnibus tests targeted by the central hypothesis—the three-way Group × Emotion × Cognitive Reappraisal and Group × Emotion × Expressive Suppression interactions—were both significant (Table 3): $F(5, 801) = 7.84$, $p < .001$ for cognitive reappraisal, and $F(5, 801) = 3.93$, $p = .002$ for expressive suppression. Two- and three-way interactions involving regulation were also significant, indicating that the contribution of habitual regulation to recognition accuracy is qualified by both age and emotion category. To unpack these high-order interactions, separate within-group LMMs were fitted to obtain the simple slope of each ERQ subscale at each emotion, adjusting for the other subscale and the basic covariates. Results are reported in Table 4 and visualised in Fig. 3.

Cognitive reappraisal

Within older adults, the average simple slope of cognitive reappraisal across emotions was positive and reliable, $\beta = +0.33$, 95% CI [+0.18, +0.48], $t(449) = 4.44$, $p < .001$, indicating that higher trait reappraisal predicted better recognition overall. The slope was positive and significant for happiness (+0.34, $p = .002$), sadness (+0.64, $p < .001$), anger (+0.25, $p = .023$), and fear (+0.40, $p < .001$), with non-significant trends in the same direction for disgust (+0.18, $p = .111$) and surprise (+0.16, $p = .138$). The largest reappraisal benefit emerged for sadness, the emotion with the strongest age-related decrement.

Within younger adults, the average reappraisal slope was negligible and non-significant, $\beta = +0.05$, 95% CI [−0.01, +0.11], $t(377) = 1.58$, $p = .116$, but emotion-specific slopes were heterogeneous: a positive and large slope for disgust (+0.47, $p < .001$) was offset by negative slopes for happiness (−0.20, $p = .009$) and fear (−0.19, $p = .013$), and null slopes for sadness, anger, and surprise. The qualitative dissociation in average reappraisal between groups was confirmed by the omnibus Group × Cognitive Reappraisal interaction, $F(1, 801) = 12.89$, $p < .001$.

Expressive suppression

The pattern reversed for expressive suppression. In older adults, the average simple slope was essentially zero, $\beta = +0.01$, 95% CI [−0.09, +0.11], $t(449) = 0.16$, $p = .871$, although emotion-specific slopes departed from zero in opposite directions: positive for surprise (+0.24, $p = .006$) and fear (+0.20, $p = .018$), with non-significant negative trends for anger (−0.14, $p = .105$) and disgust (−0.14, $p = .097$). In younger adults, by contrast, the average slope was positive and reliable, $\beta = +0.09$, 95% CI [+0.04, +0.14], $t(377) = 3.31$, $p = .001$, with significant positive slopes for happiness (+0.21, $p < .001$) and fear (+0.21, $p = .001$) and non-significant slopes elsewhere. The omnibus Group × Expressive Suppression interaction, $F(1, 801) = 6.59$, $p = .010$, confirmed the difference in average suppression effects between age

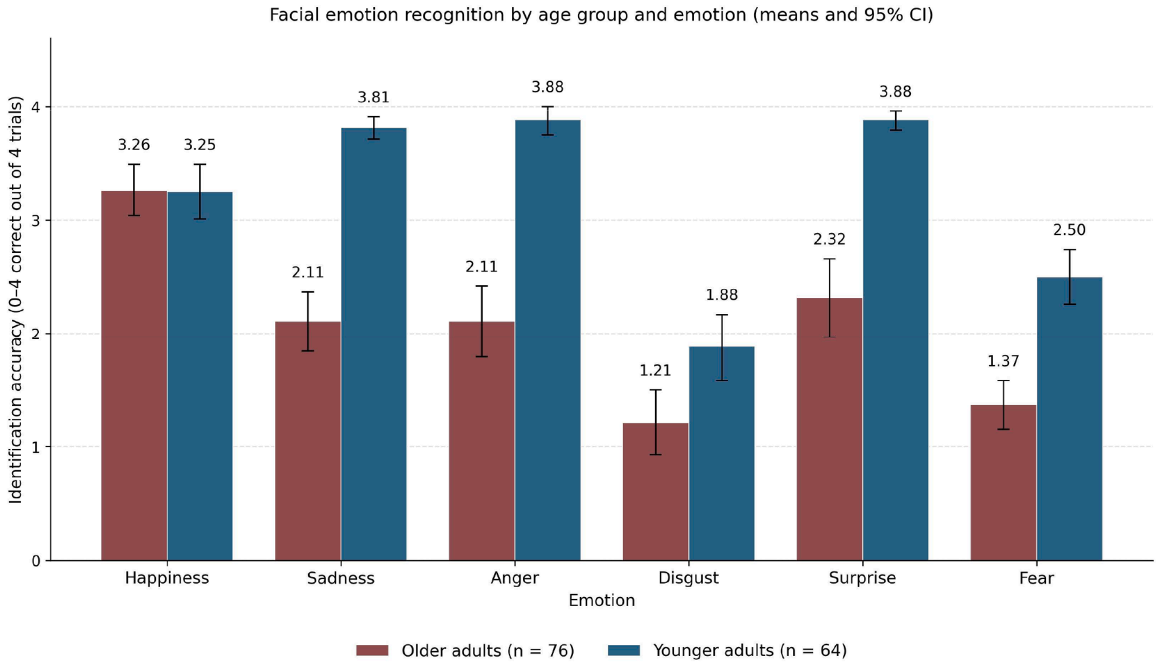

Fig. 2. Facial emotion recognition accuracy by age group and emotion.
Note. Bars show mean identification accuracy (out of 4 trials per emotion). Error bars represent 95% confidence intervals computed using Student's t-distribution. Older adults (n = 76) and younger adults (n = 64). The Group × Emotion interaction was significant in the principal LMM, F(5, 801) = 19.81, p < .001.

Table 4
Omnibus tests from the principal linear mixed-effects model (M3a).

Effect	F	df_1	df_2	p
Group main effect	0.27	1	801	.603
Emotion main effect	55.85	5	801	< 0.001
Group × Emotion	19.81	5	801	< 0.001
ERQ Cognitive Reappraisal (main)	10.73	1	801	.001
Group × Cognitive Reappraisal	12.89	1	801	< 0.001
Emotion × Cognitive Reappraisal	5.11	5	801	< 0.001
Group × Emotion × Cognitive Reappraisal	7.84	5	801	< 0.001
ERQ Expressive Suppression (main)	1.38	1	801	.241
Group × Expressive Suppression	6.59	1	801	.010
Emotion × Expressive Suppression	6.86	5	801	< 0.001
Group × Emotion × Expressive Suppression	3.93	5	801	.002
Sex (covariate)	7.98	1	801	.005
Education (covariate)	9.46	1	801	.002
BDI-II (covariate)	35.86	1	801	< 0.001

Note. Wald F omnibus tests from a random-intercept linear mixed-effects model fitted by REML. Predictors: Group (Younger vs. Older), Emotion (six levels), grand-mean-centred ERQ Cognitive Reappraisal and Expressive Suppression, and their two- and three-way interactions, with grand-mean-centred Sex (female = 1), Education and BDI-II as covariates. Random intercept by participant. The Group main effect is conditional on the reference combination of predictors (Older, Happiness, mean ERQ, male, mean education, mean BDI-II); see Results for the substantive interpretation of cell means.

groups.

Together, these results describe a double dissociation in the functional coupling between regulation and recognition: in older adults, cognitive reappraisal predicted overall recognition (with emotion-specific peaks for sadness and fear), while expressive suppression did not; in younger adults, expressive suppression predicted overall recognition (with emotion-specific peaks for happiness and fear), while cognitive reappraisal did not.

Effects of covariates

Sex, years of education, and depressive symptomatology each contributed independently to the model. Female participants showed marginally higher recognition than male participants overall, $\beta = +0.28$, 95% CI [+0.09, +0.47], $F(1, 801) = 7.98$, $p = .005$. Years of formal education predicted accuracy positively, $\beta = +0.05$ per year, 95% CI [+0.02, +0.09], $F(1, 801) = 9.46$, $p = .002$. The BDI-II covariate showed a positive within-group association with recognition ($\beta = +0.10$ per BDI point, 95% CI [+0.07, +0.13], $F(1, 801) = 35.86$, $p < .001$), opposite in direction to the between-group pattern. Because BDI scores in the present sample were uniformly subclinical (range 0–9 in both groups, well below the inclusion threshold of 15), this within-group association reflects variation in mild dysphoric symptomatology, not clinical depression. While unexpected, this small effect is consistent with prior reports that subclinical dysphoria can be associated with heightened vigilance to emotional cues (Harkness et al., 2010); given its limited magnitude and exploratory nature, we do not consider it a primary finding of the study and report it for transparency.

Sensitivity analyses

Two sensitivity analyses were conducted (Table 5). First, the principal model was refitted excluding the 41 older adults who scored exactly at the cognitive inclusion threshold (MoCA = 26), restricting the sample to $n = 99$ (35 older, 64 younger). Note that this represents an additional restriction within an already cognitively preserved sample (all participants MoCA $\geq$ 26 by design), and reduces the older sample further. The principal three-way Group × Emotion × Regulation interactions remained significant for both reappraisal and suppression in this further-restricted subsample ($F(5, 561) = 5.75$, $p < .001$ and $F(5, 561) = 3.27$, $p = .006$, respectively), indicating that the central pattern is robust even within a very narrow cognitive range. The two-way Group × Reappraisal effect attenuated in the restricted subsample ($F(1, 561) = 0.02$, $p = .880$), which is consistent with the reduced cognitive variance and reduced statistical power available in this stricter subsample. The Group × Emotion interaction also remained robust, $F(5, 561) = 18.70$, $p < .001$.

Second, an exploratory Sex × Group × Emotion analysis (omitting regulation predictors) was conducted to examine whether age effects on recognition varied by participant sex. The three-way interaction was non-significant, $F(5, 814) = 0.65$, $p = .660$, supporting the decision to include sex as an additive covariate rather than as an interactive factor in the principal model. As anticipated, statistical power for this three-way interaction was limited by the unbalanced sex distribution across groups (Table 1).

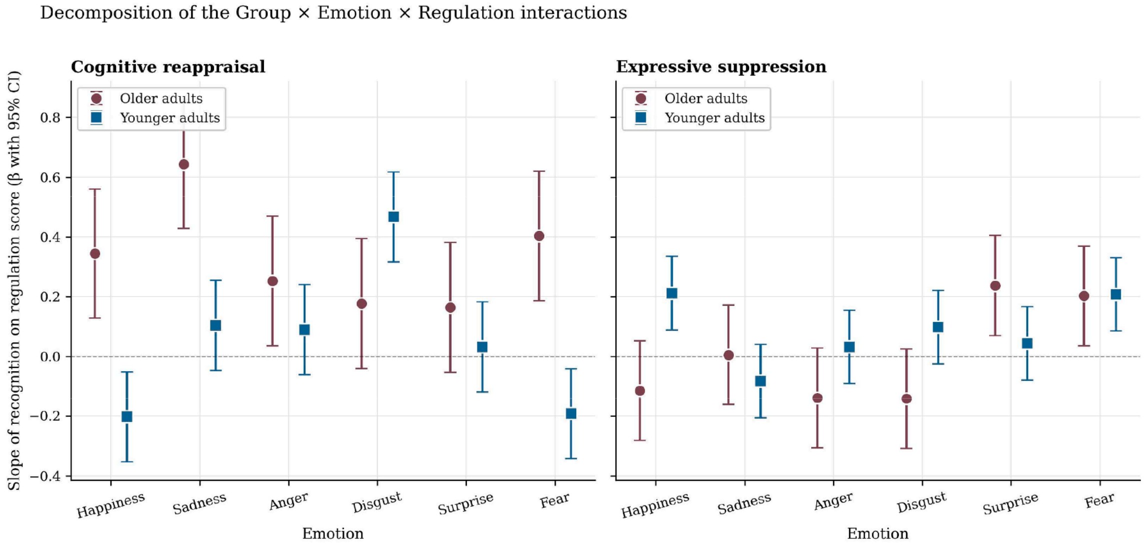

Fig. 3. Decomposition of the group × emotion × regulation interactions: simple slopes by group and emotion.
Note. Slopes obtained from within-group linear mixed-effects models adjusting for the other ERQ subscale, sex, education, and BDI-II. Error bars represent 95% confidence intervals. Left panel: cognitive reappraisal. Right panel: expressive suppression. Both three-way interactions were significant: group × emotion × cognitive reappraisal, F(5, 801) = 7.84, p < .001; Group × Emotion × Expressive Suppression, F(5, 801) = 3.93, p = .002.

Table 5
Within-group simple slopes for the regulation–recognition relationship by emotion (decomposition of the three-way group × emotion × ERQ interactions).

Cognitive reappraisal

Emotion	Older β	Older 95% CI	Older p	Younger β	Younger 95% CI	Younger p
Happiness	+0.34	[+0.13, +0.56]	.002	−0.20	[−0.35, −0.05]	.009
Sadness	+0.64	[+0.43, +0.86]	< 0.001	+0.10	[−0.05, +0.25]	.178
Anger	+0.25	[+0.04, +0.47]	.023	+0.09	[−0.06, +0.24]	.242
Disgust	+0.18	[−0.04, +0.39]	.111	+0.47	[+0.32, +0.62]	< 0.001
Surprise	+0.16	[−0.05, +0.38]	.138	+0.03	[−0.12, +0.18]	.678
Fear	+0.40	[+0.19, +0.62]	< 0.001	−0.19	[−0.34, −0.04]	.013
Average	+0.33	[+0.18, +0.48]	< 0.001	+0.05	[−0.01, +0.11]	.116

Expressive suppression

Emotion	Older β	Older 95% CI	Older p	Younger β	Younger 95% CI	Younger p
Happiness	−0.11	[−0.28, +0.05]	.180	+0.21	[+0.09, +0.33]	< 0.001
Sadness	+0.01	[−0.16, +0.17]	.948	−0.08	[−0.21, +0.04]	.188
Anger	−0.14	[−0.31, +0.03]	.105	+0.03	[−0.09, +0.16]	.606
Disgust	−0.14	[−0.31, +0.03]	.097	+0.10	[−0.02, +0.22]	.118
Surprise	+0.24	[+0.07, +0.40]	.006	+0.04	[−0.08, +0.17]	.485
Fear	+0.20	[+0.04, +0.37]	.018	+0.21	[+0.08, +0.33]	.001
Average	+0.01	[−0.09, +0.11]	.871	+0.09	[+0.04, +0.14]	.001

Note. Coefficients (β) reflect the change in identification accuracy (0–4 scale) per one-unit increase in the corresponding ERQ subscale score, estimated from within-group LMMs adjusting for the other ERQ subscale, sex, education, and BDI-II. Confidence intervals are 95%, calculated as β ± 1.96 × SE. Average slopes correspond to the unweighted mean of the six emotion-specific slopes within each group, tested as a contrast on the LMM coefficients. See Fig. 3 for graphical display.

Discussion

The present study examined how habitual emotion regulation strategies relate to facial emotion recognition in younger and older adults using a design that deliberately restricted the older sample to cognitively preserved individuals. We replicated, with a more flexible analytic approach, the well-established pattern of preserved happiness recognition alongside selective decrements for the remaining five basic emotions in older adults (Calder et al., 2003; Ruffman et al., 2008). We further showed that the relationship between trait emotion regulation and recognition accuracy is qualitatively different in older and younger adults, in a manner that constitutes a double dissociation at the level of average regulation effects, and that maps onto distinct emotion-specific patterns. Because all older participants were screened to MoCA ≥ 26 by design, these effects cannot plausibly be attributed to global cognitive decline; they are therefore informative about specifically emotional or socio-cognitive ageing. Three sets of findings deserve detailed comment.

Age-related differences in recognition and regulation

The Group × Emotion interaction (Fig. 2; Table 2) is consistent with two decades of meta-analytic and primary research showing that ageing affects negative-emotion recognition disproportionately, while sparing recognition of happiness. This is well-explained by the convergence of two factors: the lower perceptual demands of happiness, whose canonical configuration relies on a single highly salient action unit (AU 12), and a positivity effect in attention and memory (Mather & Carstensen, 2005), although the relative weight of each factor remains debated (Isaacowitz & Stanley, 2011). Our older sample showed particularly large decrements in sadness, anger, and surprise, consistent with prior reports (Mill et al., 2009; Sullivan et al., 2007). The pattern was preserved despite the use of high-intensity stimuli, which has previously been shown to attenuate age-related deficits relative to lower-intensity exemplars (Orgeta & Phillips, 2008); this suggests that the deficits we observed represent a conservative estimate of those that would emerge in more ecologically demanding contexts where emotional cues are subtler. Crucially, the design ensured that all older participants were cognitively preserved, so the deficits cannot be explained by mild cognitive impairment or related cognitive declines.

Group differences in habitual regulation followed a pattern that is partially congruent and partially divergent with the broader literature. Consistent with prior findings (Brummer et al., 2014; Charles & Carstensen, 2010; Schirda et al., 2016), older adults reported comparable levels of cognitive reappraisal to younger adults, suggesting that this strategy remains accessible across adulthood. However, expressive suppression was significantly higher in older adults than in younger adults. This pattern diverges from the seminal observation by John and Gross (2004) of an age-related decline in suppression, but is consistent with subsequent reports of cohort-specific patterns of emotional inhibition in non-North American samples (Brummer et al., 2014; Matsumoto et al., 2008). The directionality of this difference warrants further investigation in cross-cultural and cross-cohort designs.

A double dissociation in the regulation–recognition coupling

The central finding of this study is that the average within-group association between trait regulation and recognition reverses across age groups (Table 4; Fig. 3; see also Figure S1 in Supplementary Material for a participant-level scatter of these associations): in older adults, cognitive reappraisal predicted overall recognition while suppression did not, whereas in younger adults, suppression predicted overall recognition while reappraisal did not. This is a quantitative double dissociation supported by tight confidence intervals on the average slopes and by both two-way (Group × Reappraisal: $F = 12.89$, $p < .001$; Group × Suppression: $F = 6.59$, $p = .010$) and three-way (Group × Emotion × Reappraisal: $F = 7.84$, $p < .001$; Group × Emotion × Suppression: $F = 3.93$, $p = .002$) interactions in the principal model.

The pattern in older adults is consistent with the SAVI model (Charles, 2010) and with the more general proposal that ageing entails increased reliance on cognitive, deliberative regulation to compensate for declines in perceptual and attentional efficiency (Mather, 2012; Reed & Carstensen, 2012). To the extent that habitual reappraisal indexes a more general capacity to construct alternative emotional appraisals, its association with recognition in older adults may reflect not a direct perceptual benefit but a downstream advantage in retrieval, labelling, or schema-based reconstruction of facial cues that are less perceptually crisp than they would be at younger ages. The largest reappraisal benefit in older adults emerged for sadness and fear, two emotions for which the age-related decrement was most pronounced, consistent with this compensatory account Table 6.

The pattern in younger adults invites a different interpretation. Higher habitual suppression was associated with better recognition of happiness and fear, but not of sadness, anger, surprise, or disgust. Two non-mutually-exclusive accounts are plausible. First, frequent expressive suppression may sharpen attention to others' emotional signals: individuals who routinely manage their own expressions may have developed compensatory perceptual sensitivity to contour and timing cues in others' faces, particularly for the highest-arousal expressions (happiness in social contexts, fear in threat-relevant contexts). Second, the positive correlation may be partially carried by individual

Table 6
Sensitivity analyses.

(a) Principal LMM excluding participants with MoCA = 26 strict (n = 99)

Effect	F	df_1	df_2	p
Group main effect	2.28	1	561	.132
Emotion main effect	25.34	5	561	< 0.001
Group × Emotion	18.70	5	561	< 0.001
ERQ Cognitive Reappraisal (main)	1.80	1	561	.181
Group × Cognitive Reappraisal	0.02	1	561	.880
Emotion × Cognitive Reappraisal	4.48	5	561	< 0.001
Group × Emotion × Cognitive Reappraisal	5.75	5	561	< 0.001
ERQ Expressive Suppression (main)	0.09	1	561	.760
Group × Expressive Suppression	2.81	1	561	.094
Emotion × Expressive Suppression	3.81	5	561	.002
Group × Emotion × Expressive Suppression	3.27	5	561	.006
Sex (covariate)	9.60	1	561	.002
Education (covariate)	0.72	1	561	.397
BDI-II (covariate)	9.62	1	561	.002

(b) Exploratory Sex × Group × Emotion model

Effect	F	df_1	df_2	p
Group main effect	1.54	1	814	.215
Sex main effect	4.45	1	814	.035
Emotion main effect	30.97	5	814	< 0.001
Group × Emotion	7.91	5	814	< 0.001
Sex × Emotion	1.38	5	814	.228
Group × Sex	2.46	1	814	.117
Group × Sex × Emotion	0.65	5	814	.660

Note. (a) Excluding the 41 older participants who scored exactly at the cognitive inclusion threshold (MoCA = 26) yielded n = 99 (35 older, 64 younger). Both three-way Group × Emotion × ERQ interactions remain significant. (b) Exploratory model omitting regulation predictors and including Sex as a between-subjects factor. The three-way Group × Sex × Emotion interaction was non-significant, supporting the decision to include Sex as an additive covariate rather than as an interactive factor in the principal model.

differences in social vigilance or interpersonal monitoring, which covary with both habitual suppression and emotion recognition in younger adults. The data here do not adjudicate between these accounts, and the absence of an analogous benefit in older adults is itself informative: in older age, suppression appears decoupled from recognition, perhaps because the cognitive resources that mediate this coupling in younger adults are differentially taxed.

It bears emphasis that the double dissociation is at the level of average effects across emotions: emotion-specific slopes within each group are heterogeneous, and several individual cells of the design depart from the average pattern (e.g., positive effects of suppression on surprise and fear in older adults, despite a null average; negative effects of reappraisal on happiness and fear in younger adults, despite a near-zero average). These specific patterns warrant cautious interpretation given the secondary nature of the contrasts and the absence of pre-specified hypotheses for individual emotions; we report them descriptively to support hypothesis-generation in future work.

Theoretical integration: a regulatory reorganisation in cognitively preserved ageing

Taken together, the present findings suggest that the functional coupling between emotion regulation and emotion recognition undergoes qualitative reorganisation between younger and older adulthood, even in cognitively preserved samples. In younger adulthood, the regulation–recognition interface is primarily shaped by suppression: habitual suppressors show enhanced recognition for the highest-arousal expressions, while reappraisal's effects are restricted to selective modulation of specific emotion categories. In older adulthood, the interface is primarily shaped by reappraisal: habitual reappraisers demonstrate enhanced recognition both globally and selectively, while suppression's influence becomes emotion-specific rather than global.

This reorganisation integrates several existing theoretical frameworks. From SST (Carstensen, 2006), it inherits the prediction that older adults prioritise emotional goals and may favour reappraisal as a regulatory strategy. From the cognitive resource account (Opitz et al., 2014; Urry & Gross, 2010), it borrows the principle that individual differences in regulation become more consequential for other cognitive capacities as resources become constrained. From the SAVI model (Charles, 2010), it incorporates the insight that age-related vulnerabilities can transform the functional significance of regulatory processes. And from Gross's process model (2015), it extends the bidirectional relationship between regulation and perception, demonstrating that habitual regulation does not merely manage emotional reactions but shapes the very perception of emotional information in others. Critically, because our older sample was selected to be cognitively preserved, this reorganisation cannot be reduced to general cognitive decline: it represents a specifically socio-emotional shift in the functional architecture of regulation–recognition coupling.

Limitations and future directions

Several limitations qualify the interpretation of these findings. First, our age-comparative design used extreme groups of younger and older adults, which maximises power for detecting age-related effects but does not permit inferences about middle adulthood or about the trajectory of these effects with continuous ageing. Future work should extend the present analyses to lifespan samples to characterise the trajectory of regulation–recognition coupling across middle adulthood.

Second, the older sample was selected by design to be cognitively preserved (MoCA ≥ 26), substantially above the conventional cut-off for mild cognitive impairment screening. This inclusion criterion was central to the rationale of disentangling emotional from cognitive contributions to age-related recognition deficits, and constitutes a strength rather than a weakness of the study with respect to the central hypothesis. However, it does limit the generalisability of our findings to community-dwelling older adults with broader cognitive heterogeneity, and to those at risk for or with mild cognitive impairment. The age-related recognition deficits we observed are best interpreted as a lower bound: in cognitively healthy older adults, recognition is already substantially reduced relative to younger adults, and the deficit is likely larger in samples with mixed cognitive functioning. The sensitivity analysis (M4) showed that the principal interactions are robust to even stricter cognitive restriction, supporting the conclusion that the regulation–recognition coupling we describe is not driven by participants at the threshold of the inclusion criterion.

Third, the cross-sectional design precludes causal inferences. We cannot determine whether high reappraisal use causally improves recognition in older adults or whether some third factor (e.g., crystallised verbal ability, social engagement, or emotional reserve) drives both. Longitudinal and intervention studies, including reappraisal training in older adults, would clarify the causal status of these associations.

Fourth, the experimental task employed only high-intensity facial expressions, and recognition was indexed by accuracy in a forced-choice paradigm without response-time recording. The use of high-intensity stimuli probably underestimates age-related deficits relative to ecological conditions in which emotional cues are subtler; future work should examine whether the regulation–recognition coupling observed here generalises to lower-intensity stimuli, dynamic stimuli, or naturalistic facial displays. The same researcher administered all sessions and was therefore not blind to participants' age group, an unavoidable feature of in-person assessments. We mitigated this by deferring scoring of the regulation questionnaires until after the entire session was complete, ensuring that the experimenter was unaware of participants' regulation profile during task administration; this procedural feature reduces, but does not eliminate, potential experimenter bias regarding the central regulation hypotheses.

Fifth, although sensory acuity was screened verbally and corrective lenses or hearing aids were confirmed during testing, formal sensory testing was not conducted. Subclinical sensory deficits, particularly in the oldest participants (range 70–97), may have contributed to the observed deficits beyond the cognitive and regulatory factors we modelled. The visual presentation apparatus was held constant across testing sites (16-inch LCD, 50–70 cm viewing distance, manufacturer's default brightness, constant ambient lighting) but no formal photometric calibration of the display was performed; while constancy of equipment minimises between-participant variability, residual differences in display luminance or contrast that we cannot characterise quantitatively cannot be ruled out. Future research should incorporate brief sensory screening (e.g., near-vision acuity, contrast sensitivity, pure-tone audiometry where relevant) and routine display calibration to partial out these contributions.

Sixth, ERQ and BDI-II reliability could not be re-computed in the present sample because data were retained at the subscale-score level rather than at the item level. Reliability indices reported in the original Spanish validations (Cabello et al., 2013; Sanz et al., 2003) are therefore relied upon to support the adequacy of these instruments in this study; this is a limitation of the present dataset that we acknowledge transparently, and future replications should retain item-level data to permit sample-specific psychometric analyses.

Finally, the study did not include a measure of behavioural emotion regulation in vivo, nor did it include physiological correlates of either recognition or regulation. The ERQ is a self-report measure of habitual regulation and may differ from regulation as enacted in real-time emotional contexts (Aldao et al., 2010). Combining self-report with implicit, behavioural, and physiological indices in future work would refine our understanding of how regulation and perception interact in ageing.

Conclusion

In a sample of 140 cognitively preserved younger and older adults, we observed a robust and replicable age-related decrement in facial emotion recognition that spared happiness and was largest for sadness, anger, and surprise. Crucially, the relationship between habitual emotion regulation and recognition accuracy differed qualitatively between age groups in a manner consistent with a double dissociation: in cognitively preserved older adults, cognitive reappraisal predicted recognition; in younger adults, expressive suppression predicted recognition. Because the older sample was screened to MoCA ≥ 26 by design, these findings support the proposition that age-related differences in facial emotion recognition include a specifically emotional component that cannot be reduced to global cognitive decline. The results extend models of socioemotional ageing by treating emotion regulation and emotion recognition as interacting components of social perception, and they highlight habitual regulation strategies as a potentially modifiable factor in the maintenance of social-cognitive function across adulthood.

Ethics approval and consent to participate

The study protocol was approved by the Drug Research Ethics Committee (Comité de Ética de la Investigación con Medicamentos, CEIm) of Hospital Universitario 12 de Octubre, Madrid, Spain (internal reference 20/604; approved 31 January 2023). The study was conducted in accordance with the Declaration of Helsinki (1964 and subsequent amendments) and adhered to the recommendations of the International Committee of Medical Journal Editors (ICMJE). All participants provided written informed consent prior to enrolment. Decisional capacity in older adults was assessed by the referring hospital physician at recruitment, and consent procedures included plain-language explanation of the study aims, voluntary participation, and the right to withdraw at any time without consequence.

Consent for publication

Not applicable; the manuscript does not contain identifiable individual data.

Availability of data and materials

Three distinct constraints apply to the materials underlying this work. First, individual participant data are not publicly available because the original ethics approval (CEIm 20/604) does not authorise public deposition of individual participant data, including data collected within a hospital setting; de-identified group-level data may be made available from the corresponding author upon reasonable request and following approval of the original ethics committee. Second, the facial stimulus set used in the emotion identification task was developed by Johannes Heiner Ellgring and colleagues at the Institut für Psychologie, Julius-Maximilians-Universität Würzburg, and copyright over the stimulus images resides with the Würzburg group. The stimuli are therefore not redistributable by the present authors, and researchers wishing to use the same stimulus set should contact the Würzburg group directly. The methodological specifications of the stimuli — namely the FACS action unit configurations and intensity parameters used to construct each emotional expression — are reported in full in Table 2 of the manuscript and therefore remain publicly accessible for purposes of methodological reproducibility, independently of the imagery itself. Third, the analysis pipeline forms part of an ongoing doctoral thesis by the corresponding author. Public deposition of the analytic code prior to thesis defence carries the recognised risk that an unpublished methodological protocol may be reused by third parties without due citation of the original thesis work, which is currently under preparation. The corresponding author has therefore retained the full code for the duration of the thesis preparation, and commits to depositing the analysis code at the Open Science Framework after the thesis has been defended, with a persistent identifier that will be communicated to the journal for inclusion in a note added in proof or in a subsequent corrigendum if required. The full code is available to editorial reviewers under confidentiality during the review process for the specific purpose of analytic verification, on request through the editorial office.

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Use of generative artificial intelligence

The authors declare that no generative artificial intelligence (GenAI) tools were used at any stage of this work, including the creation, modification or selection of the facial stimuli, figures, tables, or text of this manuscript. The facial stimuli employed in the emotion identification task are 3D computer-generated models constructed manually from Facial Action Coding System (FACS) action units by an experienced FACS coder (H.E.) using Poser 6 (Curious Labs, Santa Cruz, CA), prior to the era of generative AI imagery, and rely entirely on muscle-based parametric specification rather than learned image generation.

CRediT authorship contribution statement

Álvaro Ruiz-García: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Beatriz García-Rodríguez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Antonio Martínez-Salio:** Writing – review & editing, Supervision. **Heiner Ellgring:** Writing – review & editing, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.aggp.2026.100291.

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