



The positivity effect reflects preserved perceptual sensitivity: a signal detection theory analysis of facial emotion recognition in ageing

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ABSTRACT

Older adults typically show reduced recognition of negative facial emotions alongside relative preservation of happiness—the positivity effect. Whether this pattern reflects differences in perceptual sensitivity, response strategy, or both has not been tested with Signal Detection Theory (SDT). SDT decomposes performance into perceptual sensitivity (d') and response criterion (c), allowing us to determine whether age-related changes operate at the perceptual or decisional level. Seventy-six older adults and sixty-four young adults completed a six-alternative forced-choice identification task with 24 computer-generated facial expressions spanning six basic emotions. Older adults showed markedly lower global sensitivity, confirmed by bootstrap. A significant Group $\times$ Emotion interaction qualified this main effect: the sensitivity deficit was substantially smaller for happiness than for all other emotions. Group differences in criterion were confined to sadness, anger and surprise and were largely accounted for by the coupling between c and d' inherent to the task; for happiness, older adults showed a small, non-significant trend towards a more liberal criterion. Confusion analysis revealed that errors concentrated on emotion pairs sharing overlapping Action Units. These findings locate the positivity effect primarily at the level of early perceptual encoding, with at most a modest decisional contribution.

1. Introduction

Recognising the emotional expression on another person's face is a fundamental perceptual task requiring the observer to extract, classify, and interpret configural and featural information from a complex visual stimulus (Adolphs, 2002; Calder & Young, 2005). The Facial Action Coding System (FACS; Ekman & Friesen, 1978) specifies each basic emotion in terms of a specific configuration of Action Units (AUs)—individual facial muscle movements. Several emotions share key AUs: fear and surprise both involve AUs 1 and 5 (inner brow raise and upper lid raise), anger and fear share AU 4 (brow lowerer), and sadness and disgust both recruit AU 15 (lip corner depressor). From a psychophysical standpoint, facial emotion recognition can therefore be conceptualised as a signal detection problem: the observer must discriminate among stimuli that are not perfectly separable in perceptual space (Gillespie et al., 2015; Tsoi et al., 2008).

A large body of evidence indicates that normal ageing is associated with reduced accuracy in recognising negative facial emotions, with

relative preservation of happiness (Ruffman et al., 2008). Meta-analyses document consistent age-related deficits for anger, sadness, and fear, whereas the recognition of happy expressions remains largely intact across the lifespan (Hayes et al., 2020; Ruffman et al., 2008). This pattern has been described as the *positivity effect*—the tendency of older adults to preferentially process positive over negative information (Mather & Carstensen, 2005; Reed et al., 2014).

Theoretical accounts of the positivity effect differ in their proposed mechanisms. The Socioemotional Selectivity Theory (SST; Carstensen et al., 1999) holds that older adults, aware of a foreshortened time horizon, prioritise emotionally meaningful and positive goals, leading to a motivational reorientation away from negative stimuli. Under SST, the positivity effect is a top-down, goal-directed phenomenon that should manifest primarily in attentional allocation and decisional tendencies. Neuropsychological accounts, by contrast, attribute age-related changes in emotion recognition to structural and functional changes in the brain's social network (Phillips et al., 2002; Ruffman et al., 2008). Under this account, the positivity effect reflects *differential* perceptual

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degradation rather than motivational bias.

A critical gap concerns the level of processing at which the age-related asymmetry operates. If the positivity effect is primarily motivational, it should be reflected in a shift in response criterion (*c*)—older adults being more conservative when labelling negative emotions—rather than in perceptual sensitivity (*d'*). If it is primarily perceptual, the deficit should appear in *d'* itself, with happiness showing a smaller sensitivity reduction. Conventional accuracy-based measures cannot resolve this distinction because they conflate perceptual ability and decision strategy.

Signal Detection Theory (SDT; Green & Swets, 1966; Macmillan & Creelman, 2005) provides a principled framework for this decomposition. Perceptual sensitivity (*d'*) quantifies the capacity to discriminate the target emotion from other emotions, independently of response tendency. Response criterion (*c*) quantifies the decisional threshold. Several studies have demonstrated the value of applying SDT to facial emotion recognition in clinical populations: Tsoi et al. (2008) found that patients with schizophrenia showed reduced sensitivity for happy faces but a more liberal criterion for fearful and sad faces; Faith et al. (2022) found that psychopathy was associated with a criterion shift for fear but with reduced sensitivity only for anger; Gillespie et al. (2015) found broadly reduced sensitivity in sexual offenders; and Tiberi et al. (2024) extended this approach to dynamic expressions in forensic inpatients.

Despite this growing body of work, to our knowledge no study has applied SDT to the recognition of facial emotional expressions in normal ageing. The present study addresses this gap in 76 older adults and 64 young adults. We predict a generalised reduction in *d'* in older adults, and crucially a *Group* × *Emotion* interaction in *d'*, with happiness showing a substantially smaller sensitivity reduction than negative emotions—locating the positivity effect at the perceptual rather than the decisional level.

2. Method

2.1. Participants

One hundred and forty individuals participated: 76 older adults (36 men, 47.4%; *M* age = 83.74, *SD* = 7.68, range = 70–97) and 64 young adults (20 men, 31.3%; *M* age = 22.00, *SD* = 3.30, range = 19–28). Demographic characteristics are reported in Table 1. The groups did not differ in education ($t(138) = -1.12, p = .265$) or sex ($\chi^2(1) = 3.12, p = .077$). As expected, Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) scores were higher in young adults (*M* = 29.94, *SD* = 0.24) than in older adults (*M* = 26.84, *SD* = 1.05; $t(138) = -23.13, p < .001$); all participants scored ≥ 26 . Beck Depression Inventory-II (BDI; Beck et al., 1996) scores were nominally higher in older adults (*M* = 3.89, *SD* = 2.81) than in young adults (*M* = 2.69, *SD* = 3.16; $t(138) = 2.39, p = .018$), though both groups scored well below the clinical threshold (maximum = 9 in both groups; clinical cutoff ≥ 15).

Table 1
Demographic and cognitive characteristics of older and young adults.

Variable	Older adults (<i>n</i> = 76)	Young adults (<i>n</i> = 64)	Group comparison
Age, <i>M</i> (<i>SD</i>)	83.74 (7.68)	22.00 (3.30)	–
Range	70–97	19–28	
Sex (men/women)	36/40	20/44	$\chi^2(1) = 3.12, p = .077$
Education, years <i>M</i> (<i>SD</i>)	13.58 (2.53)	14.06 (2.57)	$t(138) = -1.12, p = .265$
MoCA, <i>M</i> (<i>SD</i>)	26.84 (1.05)	29.94 (0.24)	$t(138) = -23.13, p < .001$
BDI, <i>M</i> (<i>SD</i>)	3.89 (2.81)	2.69 (3.16)	$t(138) = 2.39, p = .018$

Note. MoCA = Montreal Cognitive Assessment. BDI = Beck Depression Inventory. All participants scored ≥ 26 on the MoCA and ≤ 9 on the BDI (clinical cutoff ≥ 15).

Exclusion criteria included BDI ≥ 15 , MoCA < 26 , current or past psychiatric or neurological disorder, and psychotropic medication. All participants underwent a medical pre-screening conducted by a physician, and normal or corrected-to-normal visual acuity was an inclusion criterion; participants with any uncorrected visual or auditory impairment were not enrolled. All participants provided written informed consent in accordance with the Declaration of Helsinki. The study was approved by the ethics committee of the Distance University of Madrid.

With 76 and 64 participants per group, the study had $> 95\%$ power to detect Cohen's $d = 0.62$ at $\alpha = 0.05$ (the smallest effect size observed, for happiness), and $> 99\%$ power for all other emotions.

2.2. Stimuli and task

Twenty-four computer-generated facial expressions representing six basic emotions (happiness, sadness, surprise, fear, anger, disgust) were presented in a six-alternative forced-choice (6-AFC) paradigm, with four exemplars per emotion (two male, two female avatars; Fig. 1 shows one exemplar of each emotion, and Fig. 2 the trial sequence). Stimuli were created using 3D facial modelling software (Poser 6; Curious Labs) and parametrically built from FACS-specified muscle movements (Ekman et al., 2002; Ekman & Friesen, 1978) at maximum intensity (Level 5). This stimulus set, generated and FACS-coded by an experienced certified coder, has been validated and employed in previous studies of facial emotion recognition in ageing and in clinical populations (García-Rodríguez et al., 2009; García-Rodríguez, Casares-Guillén, et al., 2012; García-Rodríguez, Vincent, et al., 2012; Ruiz-García et al., 2026; Ruiz-García & García-Rodríguez, 2026). AU configurations are summarised in Table 2. Each trial began with a fixation cross (1200 ms) and a blank screen (600 ms); the face was then presented for 1200 ms, followed by a second fixation cross (1200 ms), after which the six emotion labels appeared and remained on screen until a response was given (Fig. 2). Stimuli were presented in a pseudorandomised fixed order on a grey background. Participants selected the emotion from six labelled buttons. The task was administered using PsychoPy2 (Peirce et al., 2019). No feedback was provided.

2.3. Signal detection theory analysis

The 6-AFC paradigm was decomposed into six binary subproblems (Macmillan & Creelman, 2005; Stanislaw & Todorov, 1999). For each emotion *i* and each participant, a Hit was defined as responding *i* when emotion *i* was presented (4 signal trials), and a False Alarm as responding *i* when a different emotion was presented (20 noise trials). Raw proportions were adjusted using the log-linear correction (Hautus, 1995). Sensitivity *d'* and criterion *c* were calculated from the standard equal-variance Gaussian model. Global *d'* and *c* were computed by averaging across the six emotion-specific values. Uncertainty was quantified via nonparametric bootstrap (5000 resamples).

2.4. Statistical analyses

Group differences in global *d'* and *c* were tested with independent-samples *t*-tests. The primary analysis used a 2 (Group) × 6 (Emotion) mixed ANOVA with repeated measures on Emotion, conducted separately for *d'* and *c*. Mauchly's test indicated violation of sphericity for *d'* (Greenhouse–Geisser $\epsilon = 0.49$); the corresponding within-subject effects were corrected accordingly. Emotion-specific comparisons were adjusted with the Benjamini–Hochberg FDR procedure. To test whether group differences in *c* reflected an independent decisional change or mathematical coupling with *d'*, we computed (a) the Pearson correlation between *d'* and *c* within each group, and (b) the partial correlation between *c* and group membership after partialling out *d'*, at the global level and separately for each emotion. Error patterns were examined via confusion matrices and chi-square tests.

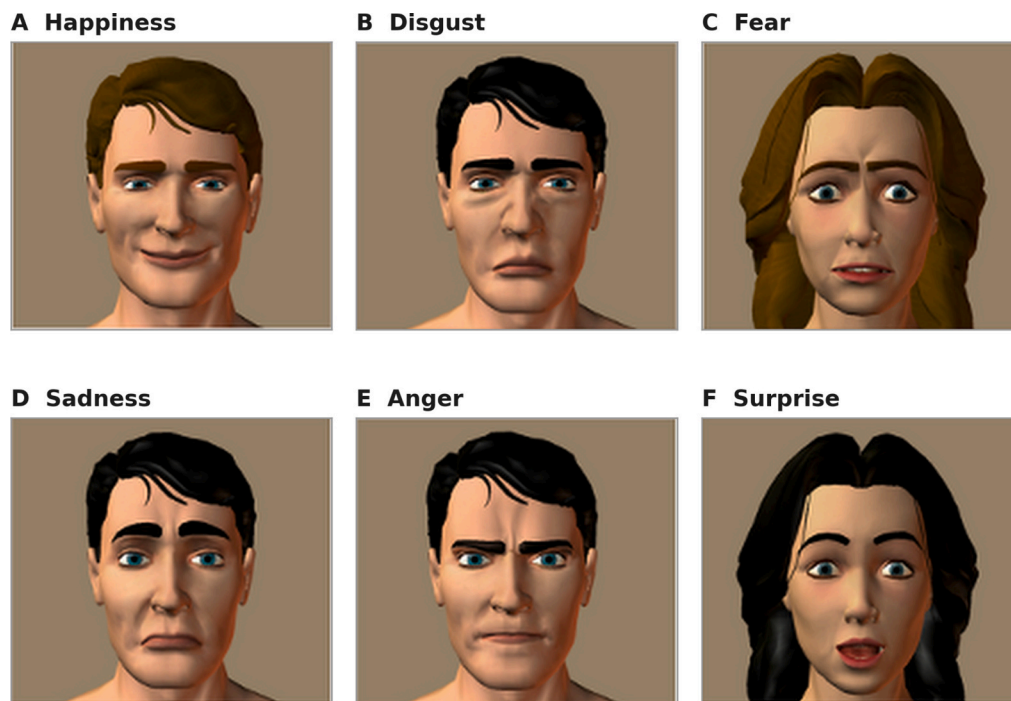


Fig. 1. Example stimuli. One exemplar of each of the six emotional expressions used in the task, shown in the order adopted in Tables 3–4 and Figs. 4–5: (A) happiness, (B) disgust, (C) fear, (D) sadness, (E) anger, (F) surprise. Each expression was rendered at maximum intensity from its FACS-specified Action Units (Table 2). The full set comprised four exemplars per emotion (two male and two female avatars).

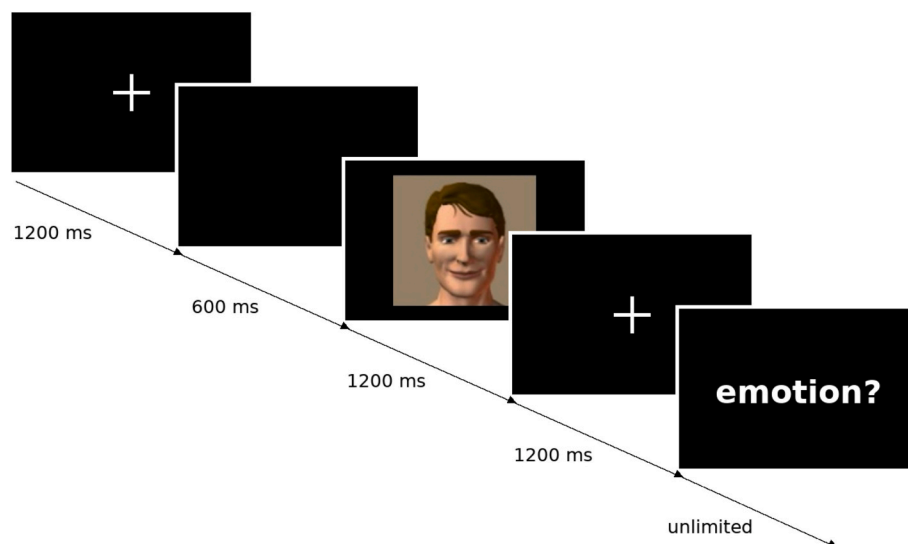


Fig. 2. Trial sequence. Fixation cross (1200 ms), blank screen (600 ms), facial stimulus (1200 ms), fixation cross (1200 ms), and response screen, which remained until the participant selected one of the six emotion labels. No feedback was provided.

3. Results

3.1. Demographic and clinical characteristics

Demographic data are summarised in Table 1. Groups were matched on education ($p = .265$) and sex ($p = .077$). MoCA scores differed ($p < .001$), with all participants meeting the inclusion threshold (≥ 26). BDI scores were nominally higher in older adults but remained well below the clinical range in both groups (maximum = 9 in both groups).

3.2. Global sensitivity and criterion

Older adults showed substantially lower global perceptual sensitivity ($d' = 1.33$, $SD = 0.33$) than young adults ($d' = 2.47$, $SD = 0.28$; $t(138) = -21.61$, $p < .001$; Cohen's $d = 3.72$, 95% CI [3.26, 4.33]). Bootstrap confirmed the group difference excluded zero (95% CI: [1.04, 1.24]; Fig. 3). Global criterion was more conservative in older adults ($c = 0.622$ vs. 0.436; $t(138) = 18.40$, $p < .001$). However, d' and c were nearly perfectly correlated within both groups ($r_{\text{older}} = -0.881$; $r_{\text{young}} = -0.866$), and the partial correlation of c with group membership after partialling out d' was negligible ($r_{\text{partial}} = 0.014$, $p = .872$). At the global level, the group difference in c is therefore accounted for by

Table 2

Facial Action Coding System (FACS) action unit specifications for the six emotional expressions.

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

Note. AU = Action Unit (Ekman & Friesen, 1978). 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.

coupling with d' rather than by an independent decisional effect.

3.3. Sensitivity by emotion: a significant group $\times$ emotion interaction

The mixed ANOVA on d' revealed significant main effects of Group ($F(1, 138) = 466.88, p < .001, \eta^2 = 0.77$) and Emotion (GG-corrected $F(2.4, 338) = 51.01, p < .001, \eta^2 = 0.27$), and a significant Group $\times$ Emotion interaction (GG-corrected $F(2.4, 338) = 11.38, p < .001, \eta^2 = 0.08$). Fig. 4A and Table 3 display emotion-specific results. The crucial

pattern was the markedly smaller deficit for happiness (Cohen's $d = 0.62$, 95% CI [0.29, 0.99]) relative to every other emotion: disgust ($d = 1.55$), fear ($d = 1.79$), sadness ($d = 2.23$), anger ($d = 2.47$), and surprise ($d = 2.62$). All BH-adjusted comparisons were significant (all $p_{BH} < 0.001$).

3.4. Criterion by emotion

The mixed ANOVA on c revealed significant main effects of Group ($F(1, 138) = 338.59, p < .001, \eta^2 = 0.71$) and Emotion ($F(5, 690) = 44.84, p < .001, \eta^2 = 0.25$; sphericity was not violated for $c, \epsilon = 1.04$), and a significant Group $\times$ Emotion interaction ($F(5, 690) = 10.47, p < .001, \eta^2 = 0.07$). Emotion-specific criterion values and group comparisons are reported in Table 4 and Fig. 4B. Older adults adopted a more conservative criterion than young adults for sadness (Cohen's $d = 1.12$), anger ($d = 1.26$) and surprise ($d = 1.74$; all $p_{BH} < 0.001$). No group difference emerged for disgust ($p_{BH} = 0.193$) or fear ($p_{BH} = 0.897$). For happiness, the difference was in the opposite direction—older adults were nominally more liberal ($c = 0.45$ vs. 0.56)—and did not reach significance after correction ($p_{BH} = 0.077, d = -0.33$). The pattern of c differences therefore mirrors the pattern of d' differences only for the three emotions with the largest sensitivity deficits.

Emotion-specific partial correlations between c and group membership after partialling out d' (Table 4) indicated that the criterion shifts for sadness and anger were fully accounted for by coupling with d' (partial $r = 0.07$ and 0.06 , both ns), whereas a residual conservative shift remained for surprise (partial $r = 0.23, p = .006$). For happiness, disgust and fear, partialling out d' revealed that older adults were relatively more liberal than their sensitivity would predict (partial $r = -0.35, -0.21$ and -0.30 , respectively; all $p < .05$), an effect most pronounced for happiness. These opposing residual shifts cancel at the global level, which explains the negligible global partial correlation reported above.

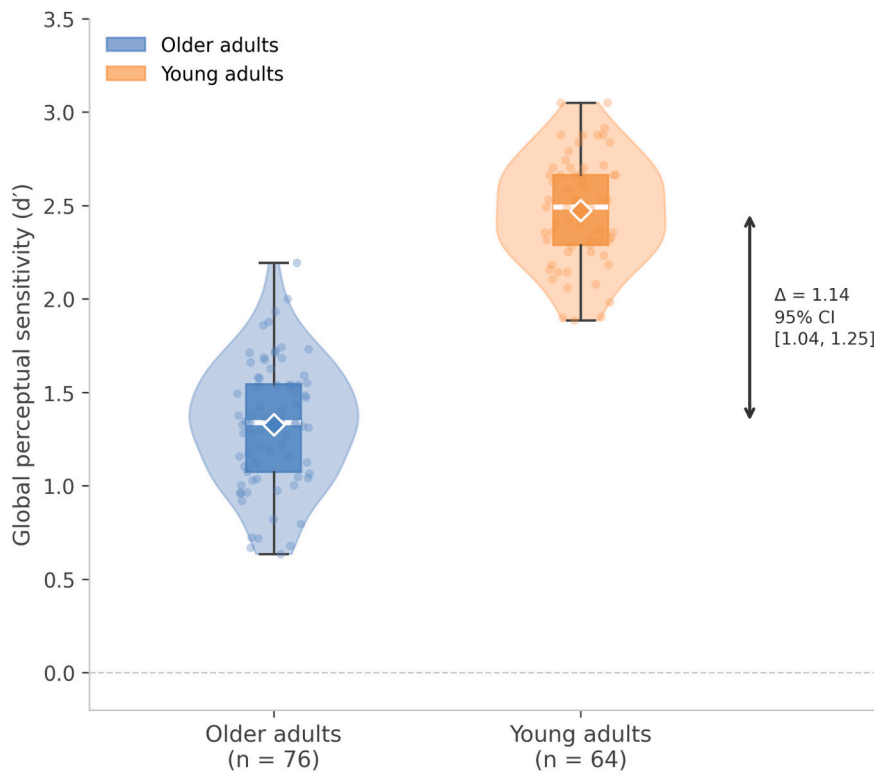
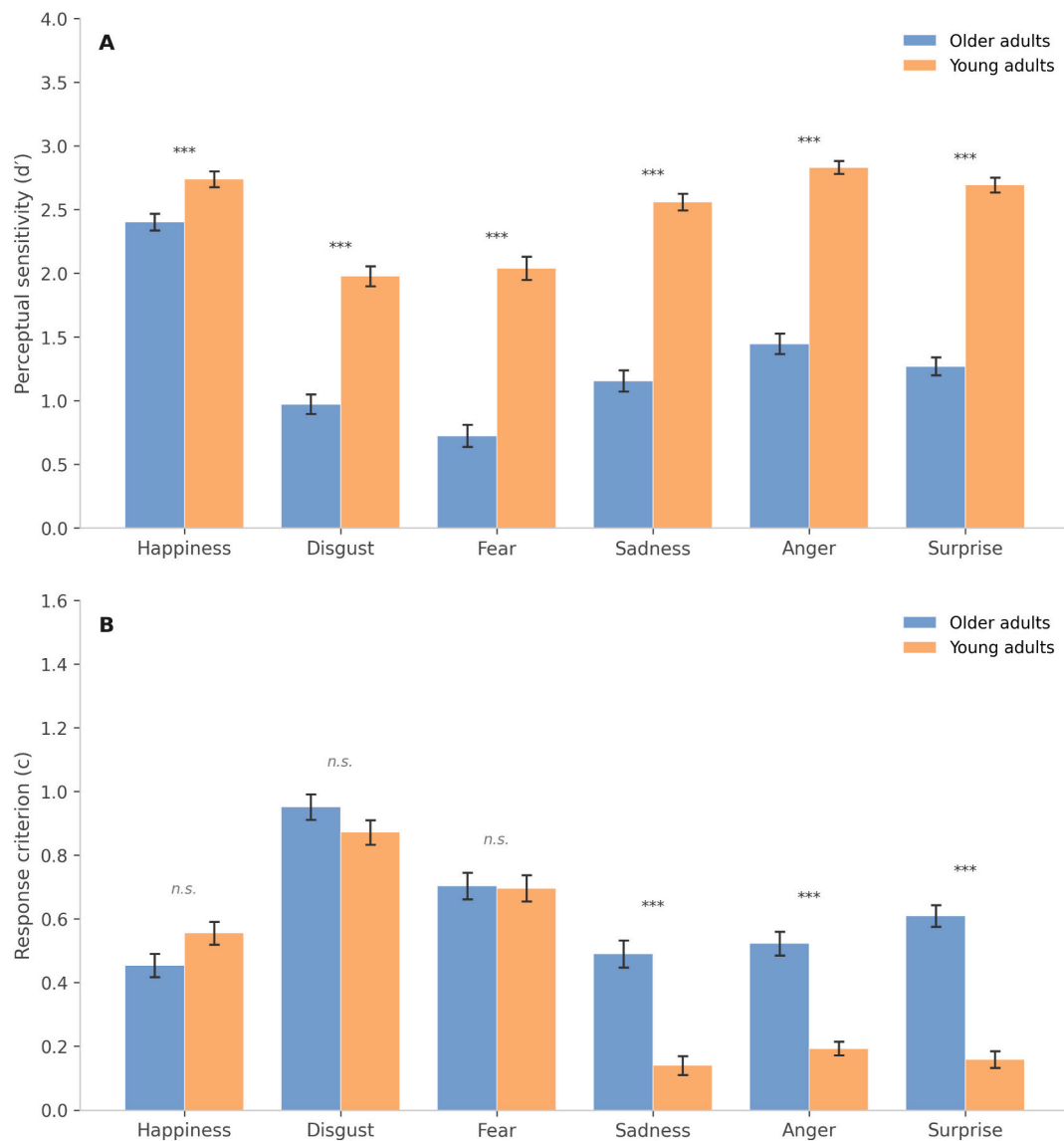


Fig. 3. Global perceptual sensitivity (d') by group. Violin plots display the full distribution; boxes span the interquartile range with median (white line) and mean (diamond); whiskers extend to the most extreme values within $1.5 \times$ IQR. Individual data points are jittered. The annotation shows the bootstrap 95% confidence interval for the group difference (5000 resamples).



Error bars = ± 1 SE. *** $p_{BH} < .001$; n.s. = not significant after Benjamini-Hochberg correction.

Fig. 4. Perceptual sensitivity (d' ; Panel A) and response criterion (c ; Panel B) by emotion and group. Bars show group means; error bars represent ± 1 standard error of the mean. Asterisks denote significant group differences after Benjamini-Hochberg correction (*** $p_{BH} < 0.001$); n.s. = not significant. In Panel A all six comparisons are significant; in Panel B only sadness, anger and surprise differ between groups, whereas happiness, disgust and fear do not (see Table 4).

Because emotion-specific c estimates rest on only four signal trials each, these partial correlations should be regarded as exploratory.

3.5. Confusion analysis

In older adults, the most frequent errors were disgust misidentified as sadness (102 trials), the bidirectional fear-surprise confusion (95 and 77 trials respectively), and disgust misidentified as anger (63 trials; Fig. 5). In young adults, the dominant errors were also disgust-sadness (58 trials) and fear-surprise (43 trials). Chi-square tests confirmed that confusion patterns differed from chance in both groups (older: $\chi^2(25) = 2257.19$, $p < .001$; young: $\chi^2(25) = 4880.74$, $p < .001$). The qualitative similarity of dominant confusion pairs across groups—driven by shared AUs—is consistent with inherent stimulus ambiguity amplified by reduced sensitivity in older adults.

3.6. Associations with individual differences (older adults)

Global d' showed no significant correlation with MoCA score ($r = -0.079$, $p = .500$), BDI score ($r = 0.140$, $p = .229$), or years of education ($r = -0.095$, $p = .414$). These null results should be interpreted cautiously given the restricted MoCA range and modest power for individual-difference analyses.

4. Discussion

The present study applied Signal Detection Theory to facial emotion recognition in ageing. Older adults showed a robust generalised reduction in perceptual sensitivity, accompanied by a significant Group $\times$ Emotion interaction in which happiness showed a markedly smaller sensitivity deficit than all other emotions. Group differences in criterion were confined to sadness, anger and surprise and were largely accounted for by their coupling with d' ; for happiness, older adults showed a small,

Table 3
Perceptual sensitivity (d') by emotion and group.

Emotion	Older d' M (SD)	Young d' M (SD)	t(138)	pBH	Cohen's d [95% CI]	ηp^2
Happiness	2.40 (0.58)	2.74 (0.50)	−3.63	< 0.001	0.62 [0.29, 0.99]	0.09
Disgust	0.97 (0.68)	1.98 (0.63)	−9.04	< 0.001	1.55 [1.20, 1.98]	0.37
Fear	0.72 (0.76)	2.04 (0.73)	−10.44	< 0.001	1.79 [1.43, 2.25]	0.44
Sadness	1.15 (0.73)	2.56 (0.52)	−12.86	< 0.001	2.23 [1.80, 2.77]	0.55
Anger	1.45 (0.69)	2.83 (0.40)	−14.16	< 0.001	2.47 [2.06, 3.03]	0.59
Surprise	1.27 (0.61)	2.69 (0.47)	−15.14	< 0.001	2.62 [2.20, 3.18]	0.62
Global	1.33 (0.33)	2.47 (0.28)	−21.61	< 0.001	3.72 [3.26, 4.33]	0.77

Note. d' = perceptual sensitivity (Hautus log-linear correction). pBH = Benjamini–Hochberg adjusted p -value. Cohen's d = (Young M – Older M) / pooled SD. Bootstrap 95% CI based on 5000 resamples. ηp^2 from pairwise t -tests. Global row averages across the six emotions.

Table 4
Response criterion (c) by emotion and group.

Emotion	Older c M (SD)	Young c M (SD)	t (138)	pBH	Cohen's d [95% CI]	Partial r (p)
Happiness	0.45 (0.32)	0.56 (0.29)	−1.96	0.077	−0.33 [−0.67, −0.01]	−0.35 (< 0.001)
Disgust	0.95 (0.35)	0.87 (0.31)	1.41	0.193	0.24 [−0.09, 0.59]	−0.21 (0.015)
Fear	0.70 (0.37)	0.70 (0.33)	0.13	0.897	0.02 [−0.32, 0.36]	−0.30 (< 0.001)
Sadness	0.49 (0.37)	0.14 (0.23)	6.50	< 0.001	1.12 [0.81, 1.50]	0.07 (0.436)
Anger	0.52 (0.32)	0.19 (0.18)	7.28	< 0.001	1.26 [0.94, 1.67]	0.06 (0.517)
Surprise	0.61 (0.30)	0.16 (0.21)	10.13	< 0.001	1.74 [1.41, 2.19]	0.23 (0.006)
Global	0.62 (0.07)	0.44 (0.04)	18.40	< 0.001	3.18 [2.84, 3.69]	0.01 (0.872)

Note. c = response criterion (Hautus log-linear correction); higher values indicate a more conservative criterion for reporting the emotion. Cohen's d = (Older M – Young M) / pooled SD, so that positive values indicate a more conservative criterion in older adults. Bootstrap 95% CI based on 5000 resamples. pBH = Benjamini–Hochberg adjusted p -value. Partial r = correlation between c and group membership (older = 1) after partialling out d' ; negative values indicate that older adults were more liberal than predicted by their d' , positive values that they were more conservative. Global row averages across the six emotions; the global partial correlation is reported in the text.

non-significant trend in the liberal direction. Together, these results indicate that the positivity effect in facial emotion recognition is rooted primarily in relative preservation of perceptual sensitivity for happiness, rather than in a top-down shift in response bias.

4.1. The positivity effect as a perceptual phenomenon

The Group $\times$ Emotion interaction in d' has direct theoretical implications. SST (Carstensen et al., 1999) posits a motivational shift that should express itself primarily in response strategy—a more liberal criterion for positive stimuli or a more conservative one for negative ones. The criterion data offer only weak support for this prediction: the conservative shifts for sadness, anger and surprise tracked the sensitivity

deficits rather than exceeding them, and the liberal trend for happiness was small and not significant after correction. Neuropsychological accounts (Ruffman et al., 2008) predict that the sensitivity deficit should be larger for negative emotions than for happiness—precisely the pattern observed, and with large effect sizes. The present results therefore favour a primarily bottom-up, perceptual account, without excluding a modest motivational contribution (see below). Happiness is characterised by a distinctive diagnostic AU configuration (AU 6 + 12) whose core components are not shared with any other basic emotion studied here—its only point of overlap being the jaw drop (AU 26), a low-diagnostic component also present in surprise and fear, and by a lifetime of prioritised processing of this ecologically frequent and socially functional signal.

4.2. Generalised sensitivity decline and neural substrates

Beyond happiness, the sensitivity deficit was remarkably uniform across the five other emotions (Cohen's d range: 1.55–2.62), consistent with generalised perceptual decline associated with age-related changes in frontal and temporal regions (Ruffman et al., 2008). The particularly large deficits for anger and surprise may reflect their high structural ambiguity with fear (shared AU 4, and shared AUs 1 and 5, respectively), rendering these pairs especially vulnerable to perceptual noise amplified by ageing.

4.3. Feature-level sensitivity and stimulus rendering

Why should sensitivity to happiness be spared while sensitivity to the remaining emotions declines uniformly? A feature-level account dovetails with the present findings. Work on diagnostic facial features shows that happiness is transmitted predominantly by the mouth region (AU 12), whereas fear, anger and sadness are transmitted predominantly by the eye and brow region (AUs 1, 2, 4 and 5; Smith et al., 2005; see also Calvo & Nummenmaa, 2008). Eye-tracking studies of ageing consistently show that older adults fixate the eyes less and the mouth more than young adults, and that this scanning pattern predicts their poorer recognition of eye-diagnostic expressions (Circelli et al., 2013; Sullivan et al., 2007; Wong et al., 2005). Furthermore, age-related losses in contrast sensitivity at mid-to-high spatial frequencies (Owsley, 2011) would disproportionately degrade the fine-grained brow and eyelid cues that discriminate the negative emotions, while leaving the coarse, high-contrast mouth configuration of happiness comparatively intact. An age-related reduction in sensitivity to upper-face features therefore offers a parsimonious mechanism for the emotion-specific pattern of d' observed here.

A related question is whether the rendering of expressions on synthetic faces obscures the subtle lip and brow changes that differentiate the negative emotions, thereby exaggerating the happiness advantage. Avatar faces of this kind engage core face-processing circuitry, including the amygdala, in a manner broadly comparable to photographic faces (Moser et al., 2007), and two further observations argue against this interpretation of the age effect. First, the stimuli were FACS-coded at maximum intensity, so that the diagnostic brow and lid AUs of each expression were fully activated (Table 2; Fig. 1). Second, young adults reached near-ceiling identification for sadness, anger and surprise (95–98% correct; Fig. 5B), indicating that the rendered cues were sufficient to support discrimination; the age effect thus reflects the observer rather than the absence of the cue. Nevertheless, synthetic faces lack the skin-texture changes (e.g., crow's-feet wrinkling accompanying AU 6, nasolabial deepening accompanying AU 9) that in natural faces provide redundant, lower-spatial-frequency evidence for an expression. This reduced redundancy may make synthetic expressions less forgiving of a degraded upper-face signal than photographic ones, and could accentuate reliance on the mouth. Whether the emotion-specific pattern reported here is attenuated with photographic stimuli that preserve texture cues is a question for future work.

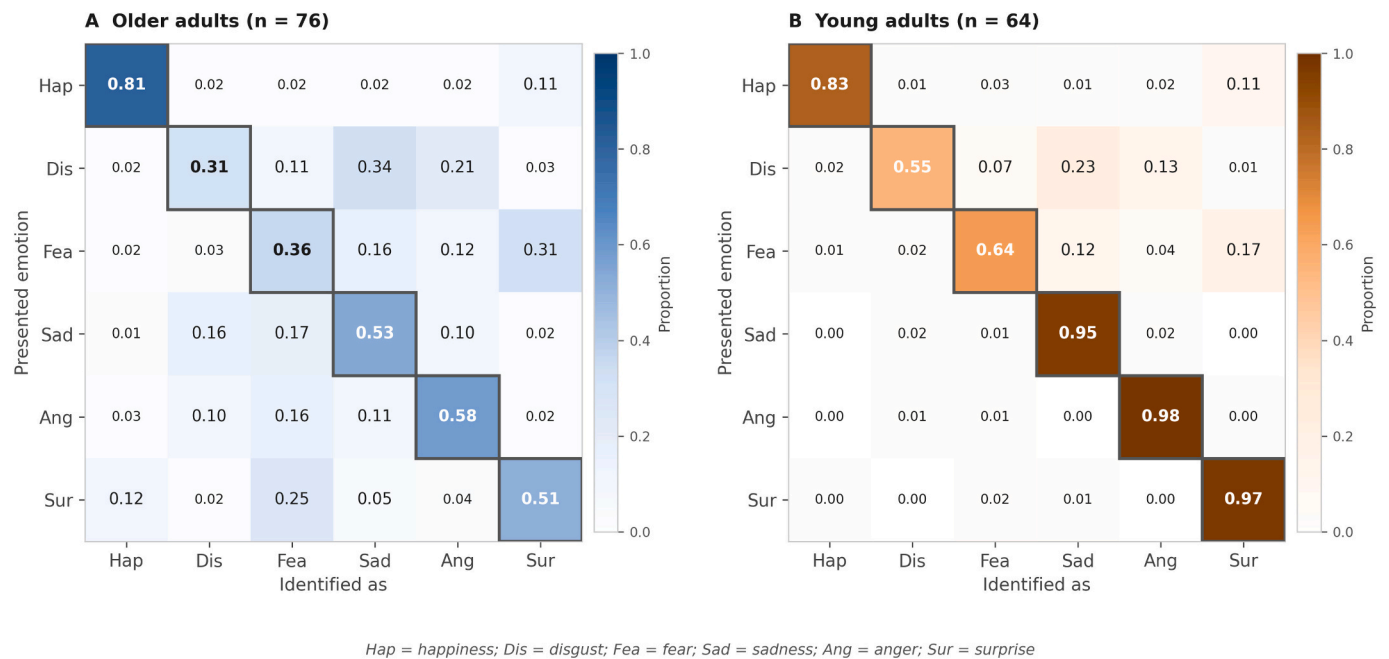


Fig. 5. Confusion matrices for older adults (Panel A) and young adults (Panel B). Each cell shows the proportion of trials on which the presented emotion (row) was identified as each emotion (column). Diagonal cells = correct identifications; off-diagonal cells = errors. Emotions are listed in the same order as in Tables 3–4 and Fig. 4. Hap = happiness; Dis = disgust; Fea = fear; Sad = sadness; Ang = anger; Sur = surprise.

4.4. Response criterion: coupling and emotion-specific shifts

At the global level, the more conservative criterion of older adults ($c = 0.62$ vs. 0.44) was fully accounted for by coupling with d' (partial $r = 0.01$), replicating the pattern reported for stroke survivors by Ruiz-García and García-Rodríguez (2026). In forced-choice tasks with limited item density, d' and c are not orthogonal under the equal-variance Gaussian model, and a raw group difference in c cannot be interpreted as a decisional effect without this check.

The emotion-level analysis, however, shows that the global null masks emotion-specific structure. Criterion shifts were confined to sadness, anger and surprise—the three emotions with the largest sensitivity deficits—and for sadness and anger were entirely explained by coupling. For surprise a residual conservative shift remained, which warrants replication. For happiness, disgust and fear, no raw group difference emerged, but once d' was partialled out older adults proved relatively more liberal than their sensitivity would predict. The happiness result is of particular theoretical interest, because a more liberal criterion for positive expressions is precisely what a motivational account such as SST would predict. A modest decisional contribution to the positivity effect therefore cannot be excluded. Its magnitude, however, is small (raw Cohen's $d = -0.33$, not significant after correction) relative to the sensitivity effects ($d = 1.55$ – 2.62 for the negative emotions), and the emotion-specific criterion estimates rest on four signal trials each. We therefore regard the primary locus of the positivity effect as perceptual, with a possible secondary decisional component that merits direct testing with designs that manipulate payoffs or base rates to dissociate c from d' . Methodologically, these results indicate that the partial correlation of c on d' should be reported at the emotion-specific as well as the global level, since opposing emotion-specific shifts can cancel in the aggregate.

4.5. Confusion patterns

The dominant confusions—disgust→sadness, fear↔surprise, and disgust→anger—have clear structural justifications in FACS. These patterns were qualitatively consistent across age groups, suggesting they

reflect inherent stimulus ambiguity rather than age-specific processing biases. In older adults, reduced sensitivity amplifies error frequency proportionally, with AU-overlapping pairs showing the highest absolute error counts.

4.6. Limitations

The SDT decomposition was applied to a 6-AFC task with only 4 signal trials per emotion, yielding wide individual-level confidence intervals and coarse emotion-specific criterion estimates. Generalised Recognition Theory (Ashby & Townsend, 1986) would provide a more complete account but requires substantially more trials. Stimuli were computer-generated avatars at maximum intensity, limiting ecological validity (see also the discussion of rendering above). Presentation order was fixed across participants. The groups differed in age, sex distribution, and MoCA (expected), precluding strong causal attribution. The absence of neuroimaging precludes structure-specific inferences. Importantly, normal or corrected-to-normal visual acuity was verified during medical pre-screening and constituted an inclusion criterion, so the pronounced sensitivity deficit in older adults cannot be attributed to uncorrected age-related sensory loss; nevertheless, fine-grained psychophysical indices of contrast sensitivity were not obtained, and subtle visual differences within the normal range cannot be entirely excluded.

A further limitation concerns the apparent age of the avatars, which depict young adults (Fig. 1). An own-age bias—superior processing of faces from one's own age group—is well established for face identity memory (Rhodes & Anastasi, 2012) and has also been reported for the decoding of emotional expressions (Fölster et al., 2014; Riediger et al., 2011). We therefore cannot rule out that the use of young-looking avatars contributed to the deficit of older adults, nor can the present design test whether such a contribution was larger for the more difficult expressions. Three considerations nonetheless argue against own-age bias as the primary driver of our results. First, evidence for an own-age advantage in expression identification is inconsistent: Ebner and Johnson (2009) found no such advantage in older adults, and older faces tend to be harder to decode for raters of all ages (Fölster et al., 2014). Second, the pattern we observe—uniform deficits across five

emotions with relative sparing of happiness—reproduces the meta-analytic pattern obtained with photographic stimuli of mixed poser ages (Hayes et al., 2020; Ruffman et al., 2008). Third, own-age effects are thought to operate through differential attention to, and perceptual expertise with, age-specific facial morphology (Ebner et al., 2011; Rhodes & Anastasi, 2012), mechanisms that should affect all expressions of a given face rather than selectively those that depend on upper-face cues. A direct test would require a stimulus set that crosses poser age with expression, which we recommend for future work.

5. Conclusions

Ageing is associated with a robust and generalised reduction in perceptual sensitivity for facial emotional expressions. Crucially, the deficit is significantly smaller for happiness than for all other basic emotions, locating the positivity effect primarily at the level of early perceptual encoding. Criterion shifts were confined to sadness, anger and surprise and were largely accounted for by coupling with d' ; a small trend towards a more liberal criterion for happiness suggests that a secondary decisional contribution cannot be excluded. These findings provide evidence against a purely top-down, motivational account of the positivity effect, and demonstrate the value of SDT—applied at both the global and the emotion-specific level—in characterising socioemotional changes in ageing.

Additional measures

Participants also completed the Emotion Regulation Questionnaire (Gross & John, 2003), which is not analysed in the present report as it is not relevant to the SDT framework applied here.

CRedit authorship contribution statement

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

Ethics declaration

Written informed consent to take part in the study and to publish the article has been obtained from all participants or their legal representatives. The privacy rights of participants have been observed.

This study was performed in compliance with relevant laws, regulatory frameworks and guidelines where the research took place.

This study was approved by the Research Ethics Committee (Comité de Ética de la Investigación con Medicamentos) of Hospital Universitario 12 de Octubre, Madrid, Spain.

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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.

Data availability

The anonymised dataset will be deposited in a public repository upon acceptance.

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