Social Neuroscience

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/psns20

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To cite this article: Despina Antypa, Konstantinos Kafetsios, Panagiotis Simos, Marina Kyvelea, Emmanouela Kosteletou, Thomas Maris, Efrosini Papadaki & Ursula Hess (2024) Distinct neural correlates of accuracy and bias in the perception of facial emotion expressions, Social Neuroscience, 19:3, 215-228, DOI: 10.1080/17470919.2024.2403187

To link to this article: https://doi.org/10.1080/17470919.2024.2403187

SOCIAL NEUROSCIENCE
2024, VOL. 19, NO. 3, 215–228
https://doi.org/10.1080/17470919.2024.2403187

Routledge
Taylor & Francis Group

RESEARCH PAPER

Distinct neural correlates of accuracy and bias in the perception of facial emotion expressions

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ABSTRACT

We investigated neural correlates of Emotion Recognition Accuracy (ERA) using the Assessment of Contextualized Emotions (ACE). ACE infuses context by presenting emotion expressions in a naturalistic group setting and distinguishes between accurately perceiving intended emotions (signal), and bias due to perceiving additional, secondary emotions (noise). This social perception process is argued to induce perspective taking in addition to pattern matching in ERA. Thirty participants were presented with an fMRI-compatible adaptation of the ACE consisting of blocks of neutral and emotional faces in single and group-embedded settings. Participants rated the central character's expressions categorically or using scalar scales in consequent fMRI scans. Distinct brain activations were associated with the perception of emotional vs. neutral faces in the four conditions. Moreover, accuracy and bias scores from the original ACE task performed on another day were associated with brain activation during the scalar (vs. categorical) condition for emotional (vs. neutral) faces embedded in group. These findings suggest distinct cognitive mechanisms linked to each type of emotional rating and highlight the importance of considering cognitive bias in the assessment of social emotion perception.

ARTICLE HISTORY
Received 11 August 2023
Revised 9 August 2024
Published online 19 September 2024

KEYWORDS
Emotion perception; social; fMRI; accuracy; bias

Introduction

The emotional expressions of others are a rich source of social information that conveys cues to peoples' affective and mental states. Emotional expressions have evolved to communicate information that allows perceivers to infer other people's intentions and to take appropriate action (Darwin, 1872; Matsumoto et al., 2008). Therefore, the accurate assessment of emotional expressions is crucial for the regulation of relationships and for social functioning more generally (Adolphs, 2002; Fischer & Manstead, 2008). Even though there is a lively discussion regarding the link between specific expressions and internal states on the sender side (see e.g., Crivelli & Fridlund, 2019; Hess, 2017), the use of emotion expressions in the arts, films, and literature demonstrates that observers use these expressions as sources of information about others' inner states.

Recent years have seen an increased interest in the way social context impacts emotion perception (Barrett et al., 2011; Niedenthal & Brauer, 2012). However, this emphasis on context has yet to pass on to Emotion Recognition Accuracy (ERA) research. Up until very recently the burgeoning ERA research, within different fields and subfields (Côté et al., 2011; Elfenbein et al., 2007; Kaltwasser et al., 2017; Philippot et al., 1999; Schmid Mast & Darioly, 2014), has been dependent on tasks that focused on assessing participants' cognitive abilities for expression pattern matching while ignoring perceivers' social perception (see, Hess & Kafetsios, 2021). Specifically, when assessing the ability to correctly decode emotional facial expressions, participants are usually asked to label single, prototypical facial expressions drawn from standardized sets of facial expressions that are presented without context (Ekman & Friesen, 1976; Fischer & Manstead, 2008; Lundqvist et al., 1998; Matsumoto et al., 2000; Mayer et al., 2003; Nowicki & Duke, 1994; Rosenthal et al., 1979; Scherer & Scherer, 2011; Schlegel et al., 2019). These tests typically require participants to select from a (short) list of emotion labels

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/17470919.2024.2403187

the one that best describes the depicted emotional expression. That is, decoding accuracy is defined as the ability to associate one (correct) label with a single emotion expression shown without social context. In fact, it can be argued that the typical approach, which uses only a small number of such forced-choice labels, does not engage emotion recognition processes at all, as many expressions demand only emotion discrimination. For example, if only one positive label is presented, all the participant has to do to correctly "decode" a positive emotion is to make a positive–negative discrimination (see, Bänziger et al., 2009). Together, the use of expressions without any social context and the focus on a single emotion implies that this type of stimulus does not engage participants' social competences and ignores the important impact of context for the emotion recognition process (Barrett et al., 2011; Hess & Hareli, 2015).

In line with the above considerations and a functional perspective on social perception (Gibson, 1979; Kruglanski, 1989), we have proposed a novel model and method for assessing Emotion Recognition Accuracy with the Assessment of Contextualised Emotion (ACE, Hess & Kafetsios, 2021; Kafetsios & Hess, 2023). The ACE model extends current models of Emotion Recognition Accuracy assessment in two ways. First, the ACE model proposes that there are two distinct, measurable facets of emotion decoding: (1) the perception of the expresser's intended emotion signal (e.g., sadness for a sad expresser), which we refer to as *accuracy* and (2) the perception of other, secondary, expressions that may or may not be actually shown but are perceived (e.g., anger for a sad expresser) which we refer to as *bias*. This conceptualization is based on the finding that observers tend to perceive multiple emotions even when judging emotional expressions considered to be "pure" (Russell & Fehr, 1987; Yrizarry et al., 1998). These mixed perceptions may be based on different sources such as facial morphology and facial wrinkles (Hess et al., 2012) as well as on the perceivers' own personality. For example, individuals with more insecure attachment tend to over-attribute negative affect to peoples' facial displays (Magai et al., 2000).

To capture both accuracy and bias, the ACE allows decoders to report on a range of presented and non-presented emotions using scalar ratings. Accuracy is indexed by the perceived intensity of the sender's intended expression (accuracy index); bias corresponds to the aggregate intensity of non-intended, perceived emotions (bias index). In this respect, the ACE model responds to calls to examine truth (accuracy) and bias processes in social perception in combination under the premise that both contribute meaningfully to social judgments (Quadflieg & Penton-Voak, 2017; West & Kenny, 2011; Zaki & Ochsner, 2011).

Second, the ACE model proposes that there are two paths to decoding emotion expressions. First, pattern matching by which an observer associates specific features of the expression with specific emotions (Buck, 1984). For example, upturned corners of the mouth or lowered eyebrows are recognized as smiles or frowns, respectively, and a perceiver thus chooses the labels "happy" or "angry" based on this pattern.[1] This process does not rely on the perceiver's wider social knowledge but only on knowledge about specific facial configurations, similar to the approach used by facial expression recognition software. This assumption then justifies that participants are presented with contextless faces, often even with hairlines removed, to better show-cast these informative elements.

However, there is a second process, which is based on the perceiver's social knowledge: perspective taking. Perspective taking uses emotion knowledge. For example, when someone has received good news we may assume the person to be happy rather than disappointed. Another source of information is the social group membership of the expresser. People hold stereotypes about members of different groups and these stereotypes can inform emotion perception (Kirouac & Hess, 1999). We propose that in most situations, observers use this form of perspective taking and their accumulated emotion knowledge to actively make sense of the expression in its context. Such a process involves social knowledge engagement. That is, to be able to use perspective taking to deduce emotional states based on facial expressive information in context, participants engage in social cognition and use theory of mind (Frith & Frith, 2005).

The ACE, therefore, adds social context in Emotion Recognition Accuracy by presenting pictorial stimuli with naturalistic facial expressions of a group of three individuals (the two surrounding individuals express congruent or incongruent emotions to those of the central individual).[2] Early neuroimaging research on emotional expressions, using traditional approaches to Emotion Recognition Accuracy, has focused on the investigation of pattern matching (Buck, 1984). That is, these approaches examined the neural correlates of categorical judgments of single, context-less facial expressions (e.g., Critchley et al., 2000, Narumoto et al., 2000).

[1]Notably, pattern matching can be carried out either in a configural or a holistic fashion (see, e.g., Tanaka & Farah, 1993).
[2]In the present study, only single individuals and groups with congruent emotional expressions were used.

Yet, neuroscientific evidence indicates that the perception of emotional expressions involves increased activation in an extended brain network. This network includes regions linked to visual perception of faces, attention to salient and/or affective stimuli, and social cognition such as mentalizing, Theory of Mind, mind-reading, and empathy. In particular, results from meta-analyses (Dricu & Frühholz, 2016; Haxby et al., 2002; Liu et al., 2021) converge in demonstrating that the visual perception of emotional faces is linked to greater activations in fusiform gyrus (incl. fusiform face area, FFA) and other visual areas (incl. inferior and middle occipital gyrus, lingual gyrus). Amygdala and other limbic areas (incl. orbitofrontal cortex, cingulate cortex, thalamus), brain regions associated with attention to salient and/or affective stimuli, have been also found engaged in facial emotion perception tasks (Armony & Vuilleumier, 2013; Dricu & Frühholz, 2016). Moreover, facial emotion processing has been shown to recruit brain regions related to social cognition, such as posterior superior temporal sulcus, inferior frontal cortex, and dorsomedial prefrontal cortex (Adolfi et al., 2017; Dricu & Frühholz, 2016; Fossati, 2012; Pitcher & Ungerleider, 2021).

Importantly, the activation of specific distinct brain areas depends on the specific instructions and context parameters used during facial emotion perception tasks (Dricu & Frühholz, 2016; Hinojosa et al., 2015; Wieser & Brosch, 2012). Instructions for emotion evaluation vs. passive perception of emotion stimuli have been associated with broader brain activations, including regions related to social cognition (mind-reading: Dricu & Frühholz, 2016). Similarly, context parameters, such as group embedded stimuli and emotion labeling have been linked to distinct mechanisms during emotion processing (Wieser & Brosch, 2012). Furthermore, the N170 component, an electrophysiological face perception index, can be modulated by context congruency (Hinojosa et al., 2015). Studies using social scenes and interactions as naturalistic stimuli have, moreover, shown engagement of a broad brain network similar to the one found in facial emotion processing research (Arioli et al., 2021; Deuse et al., 2016).

All of the above indicate that different task instructions and especially a contextual setting, in accordance with the ACE model (instructions for scalar rating and group embedded presentation), as well as different conditions (instructions for categorical rating and/or single-face presentation), engage distinct brain regions related to sensory processing, attention to salient or affective stimuli, and social cognition during facial emotion perception. This has important implications for the predictive value of such an assessment. In everyday life emotions are invariably shown in some form of social context, and be it an imagined one (Fridlund, 1991). Thus, assessments that exclude social context and recur to approaches that do not engage the relevant brain regions are less likely to predict real-life outcomes.

The present study aimed to address key issues in the study of emotion perception processing, taking into consideration the crucial role of contextual parameters and task instructions in the neural correlates of emotion processing. The first objective of the present study was to evaluate the claim that emotion processing is associated with distinct brain activations for single versus group-embedded facial expressions, as well as when participants are asked to rate emotion using categorical versus scalar scales. To address this objective, we constructed an fMRI-compatible adapted version of the ACE consisting of short blocks of neutral and emotional faces in single and group-embedded settings. Participants were asked to rate the emotion of the central character either categorically (which would predominantly engage processes typically linked to accuracy ratings in the context of the ACE model) or using a five-point scale to approximate a dimensional (scalar) rating. According to the ACE model, this type of rating can be used to assess processes related to both accuracy and bias.

The second objective of the present study was to assess the behavioral relevance of regional changes in activation across experimental conditions in the fMRI-compatible ACE task. To address this objective, we correlated the degree of change in hemodynamic activity in in-group-embedded vs. single faces as moderated by the type of rating performed by participants (scalar or categorical) with accuracy and bias scores derived from the original ACE task (Kafetsios & Hess, 2022; study 7) performed online on a different day. Whereas the fMRI-compatible task was designed to simulate the cognitive processing modes postulated by the ACE model, meeting the strict temporal restrictions of fMRI task design, it was not suitable for the calculation of valid accuracy and bias performance indices. Thus, data from the standard ACE tasks were used to examine correlations between distinct processing indices (of accuracy and of bias) with changes in regional brain activity across different conditions of social emotion processing. If brain activity in areas related to perspective-taking is observed for the scalar rating and group stimuli, in comparison to the categorical assessment and single stimuli, this would provide significant support to the argument that the ACE engages regions other than perceptual and semantic which are typically expected to be associated with pattern matching explanations in contextless facial emotion perception tasks.

Materials and methods

Participants

Thirty-three healthy adults without a history of neurological or psychiatric disorders and sensory or motor deficits were recruited for the study (15 women, 18 men, mean age = 27.82, SD = 5.45). Of those, three participants did not provide usable fMRI data due to technical issues; therefore, fMRI analyses were performed on 30 participants (13 women, 17 men, mean age = 27.7, SD = 5.6 years). Of those, three did not complete the follow-up online questionnaires, so analyses including the online questionnaires (here, ACE-face short; on the second objective) included 27 participants (12 women, 15 men, mean age = 27.52, SD = 5.54). Sample size was defined based on previous fMRI research on emotion perception using similar design and/or procedure (Pitcher et al., 2019; Satpute et al., 2013, 2016). Additional inclusion criteria were to be above 18 years old, ability to speak and read the local language fluently, and right handedness (all inclusion criteria were checked by self-reports). This convenience sample was recruited through ads posted in the Voutes campus of the University of Crete. All participants had normal or corrected to normal vision and provided written consent in accordance with the Declaration of Helsinki. The study was not pre-registered; it was approved by the Research Ethics Committee of the University of Crete.

Stimuli

The photos presented during the fMRI task were taken from the Assessment of Contextualized Emotions-faces (ACE-faces; Hess et al., 2016). In the present study, neutral and emotional faces (happy, sad, angry) were shown either as single or group-embedded stimuli, with the central person's emotion in congruence with the others' (for more details regarding the ACE, please see: Hess et al., 2016; Kafetsios & Hess, 2023). The stimulus set consisted of 80 images [5 male and 5 female groups × 4 emotions (happy, sad, angry, and neutral) × 2 conditions (single-face and group-embedded)].

Design and procedure

To familiarize themselves with the stimulus rating response procedure as well as the face stimuli, participants underwent a training session outside the MRI using the same stimulus set as in the fMRI compatible version of the ACE. The fMRI recording session was divided into four runs, corresponding to the experimental conditions of interest (single face/categorical rating, single face/scalar rating, group-embedded /categorical rating, group-embedded/scalar rating; Figure 1). The order of runs was counterbalanced on the single vs. group-embedded factor. Each run comprised six blocks of 10 stimuli (five depicting an emotional single or central face [group-embedded runs] and five depicting a neutral single or central face). Within each run a total of 30 neutral (10 different images repeated three times) and 30 emotional faces (10 angry, 10 happy, and 10 sad) were presented in counterbalanced order. Prior to each block, a black screen with a white fixation cross at the center was presented for 3.5 sec. The presentation of each image lasted for 2 sec followed by a rating scale for 5 sec.

Participants were instructed to rate the central person's emotion either on a categorical or on a scalar scale. In the categorical rating runs they were asked to select the emotion presented from a list of five emotions (e.g., happy, angry, sad, disgust, neutral). In the scalar rating runs, they were asked to rate the intensity of a single pseudo-randomly pre-selected emotion on a five-point scale (ranging from 1 [not at all] to 5 [very much]). Responses were provided through a pneumatic response pad with the right hand. Participants pressed one button with their index finger to select the appropriate emotion or emotional intensity, accordingly, and their thumb to confirm their response.

Within a week following the fMRI scan, participants completed a set of online questionnaires that included the ACE-brief task (Kafetsios & Hess, 2022; study 7). Participants were presented with a series of 16 images showing four emotions (sad, happy, angry, disgust) expressed by one person, who was shown either alone or surrounded by two other individuals who showed either the same or a neutral expression. Participants' task was to rate, on a five-point scale, the degree to which the central person expressed each of seven emotions (calm, fear, anger, surprise, disgust, sad, happy). Two indices are calculated: Accuracy (the rated intensity for the target emotion scale, e.g., the anger intensity on the anger scale for an angry expression) and bias (the mean of the ratings on all non-target scales). Please note that the ACE-brief task includes only emotional stimuli and roughly corresponds to scalar conditions of the fMRI task (the fMRI task was adapted to fMRI restrictions and setting and enriched to allow direct comparisons with regular emotional perception tasks).

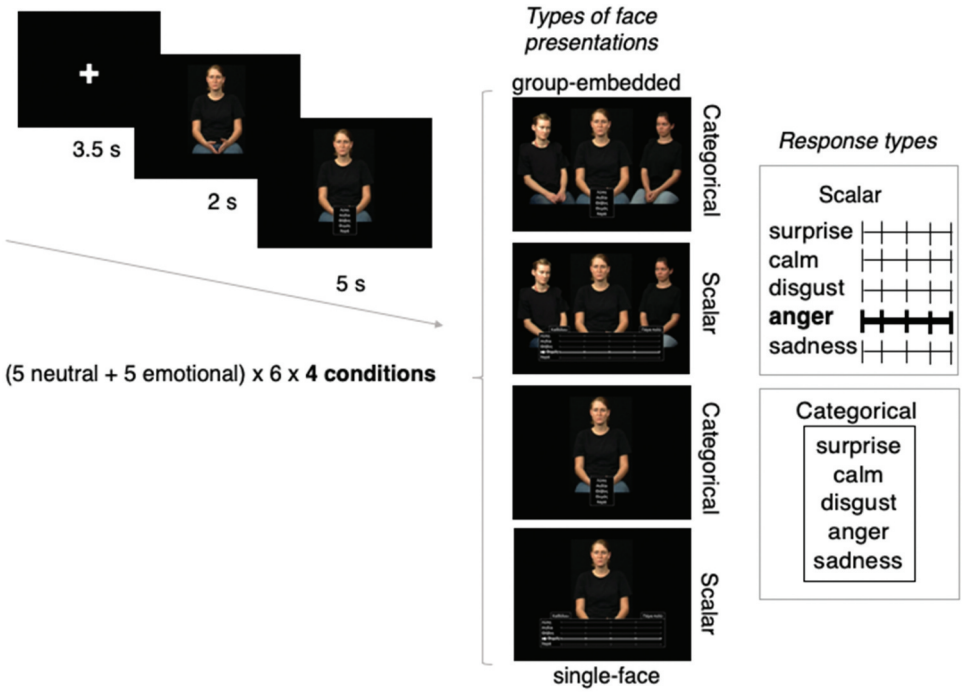

Figure 1. Design of and stimuli used in the FMRI task. Each run started with a fixation cross, followed by series of images of faces in single-face or group-embedded setting. After 2 sec the image of the face was accompanied by a response scale (either categorical or scalar) which remained on the screen for 5 sec. Participants were trained to press one key on a pneumatic response pad with their right index finger to select the appropriate response and with their right thumb to confirm their response.

Imaging data acquisition and analysis

fMRI data were acquired using an upgraded 1.5 T Siemens Vision/Sonata MR scanner (Erlangen, Germany) with powerful gradients (Gradient strength: 45 mT/m, Gradient slew rate: 200 mT/m/ms) and a standard four channel head array coil. For the BOLD-fMRI, a T2*-weighted, fat saturated 2D-FID-EPI sequence was used with the following parameters: repetition time (TR) 3500 ms, echo time (TE) 50 ms, field of view (FOV) 192 × 192× 108 mm (x; y; z), acquisition voxel size 3 × 3 x 3 mm. Whole brain scans consisted of 36 transverse slices with 3 mm slice thickness and no interslice gap. The timeseries recorded in each block comprised 125 volumes (time points). Additionally, high resolution anatomical images were acquired sagittally, using a 3D magnetization-prepared rapid acquisition gradient echo sequence (3D-MPRAGE) with the following parameters: TR 9.8 ms, TE 4.6 ms, flip angle 8 degrees, inversion time (TI) 922 ms, FOV 180 × 230 (x; z), with acquisition voxel size of 0.98 × 0.98 (x; z) and slice thickness of 3 mm.

Image preprocessing was performed in SPM12. Initially, EPI scans were spatially realigned to the middle image of the time-series using second-degree B-spline interpolation algorithms and motion-corrected through rigid body transformations (three translations and three rotations about each axis). Next, anatomical and functional images were co-registered, spatially normalized to a common brain space (MNI template) and finally, spatially smoothed using a Gaussian kernel of 8 mm FWHM and high pass filtered with a time constant of 128 seconds.

For the main analysis, the preprocessed signal was analyzed using a fixed effect General Linear Model (GLM) in SPM12. Data from each participant were combined across runs and conditions of eight event types [regressors of interest: neutral single with categorical rating (nSC), emotional single with categorical rating (eSC), neutral single with scalar rating (nSD), emotional single with scalar rating (eSD), neutral group with categorical rating (nGC), emotional group with categorical rating (eGC), neutral group with scalar rating (nGD), and emotional group with scalar rating (eGD)]. The temporal derivatives for each type of event and the six motion parameters for each run were included in the model as controls (see Supplementary Material for design matrix).

The first objective of the study was addressed by computing profiles of facial emotion-related activation characteristics for each of the four conditions of the experiment through paired t-tests. Each test evaluated differences during the processing of emotional vs. neutral faces in the following experimental conditions:

(i) single-face setting with categorical rating, (ii) single-face setting with scalar rating, (iii) group-embedded setting with categorical rating, and (iv) group-embedded setting with scalar rating.

The second objective of the study was addressed by preparing single-subject maps from contrasts assessing additional activations linked to the presentation of emotional vs. neutral stimuli in a group setting and with scalar rating (i.e., emotional vs. neutral stimuli in group-embedded vs. single setting with scalar vs. categorical rating, triple interaction). Correlations of the above-mentioned contrast maps with the accuracy or bias index from the original ACE task performed online on a separate day (ACE-Faces short) were tested by entering accuracy and bias scores as covariates in second-level analyses.

All second-level activations were assessed for statistical significance by applying a threshold of $p < 0.001$ and a minimum cluster size of 10 voxels (activations that remained significant after FDR-correction are marked accordingly).

Results

Brain activations during facial emotion processing in single-person and group-embedded settings with categorical and scalar rating

Imaging results for the four main contrasts demonstrate distinct facial emotion-related neural correlates for scalar and categorical ratings presented either in single-person or group-embedded setting and are presented in Figure 2 and Supplementary Table 1.

Compared to the processing of single faces, processing of facial emotion in the group-embedded setting was associated with more widespread activation. When participants were asked to perform the less cognitively demanding categorical rating, processing faces in social context engaged the left insula, a brain region known to be associated with emotion processing (the activation of another emotion processing node, right hippocampus, did not survive FDR correction). Additional activation clusters were found in the right superior frontal and superior temporal gyri, whereas exploratory analyses

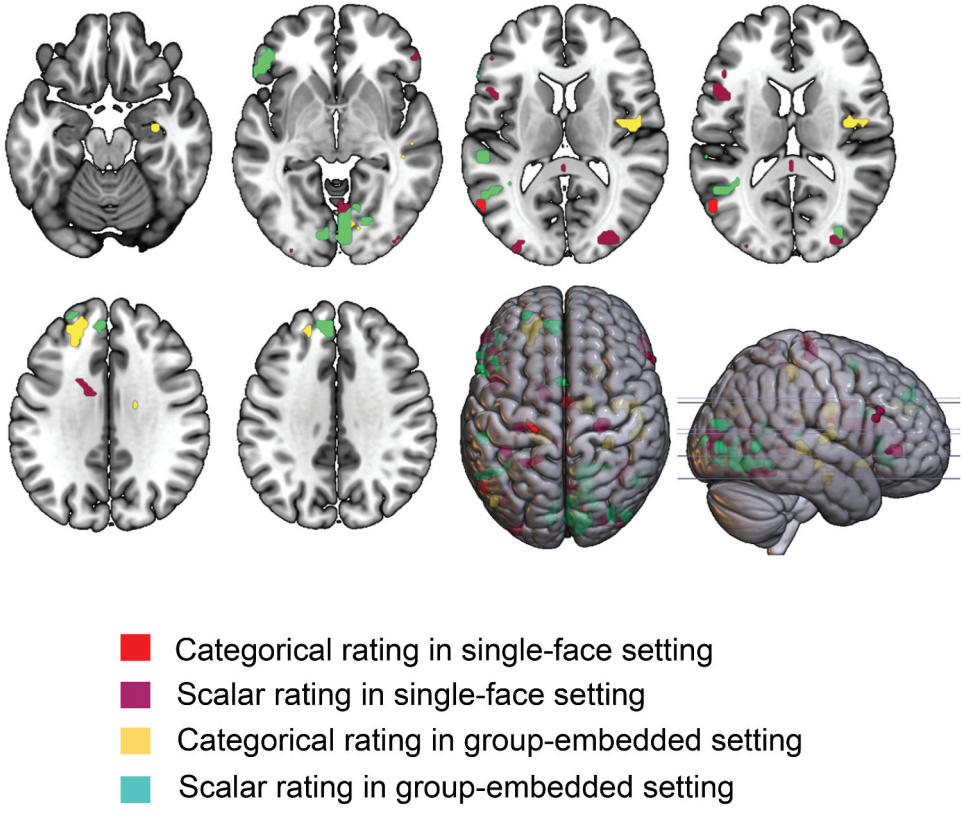

Figure 2. Brain activations associated with facial emotion processing in scalar and categorical scales, single and group-embedded settings. Results presented for $p < .001$ and cluster size > 10 voxels.

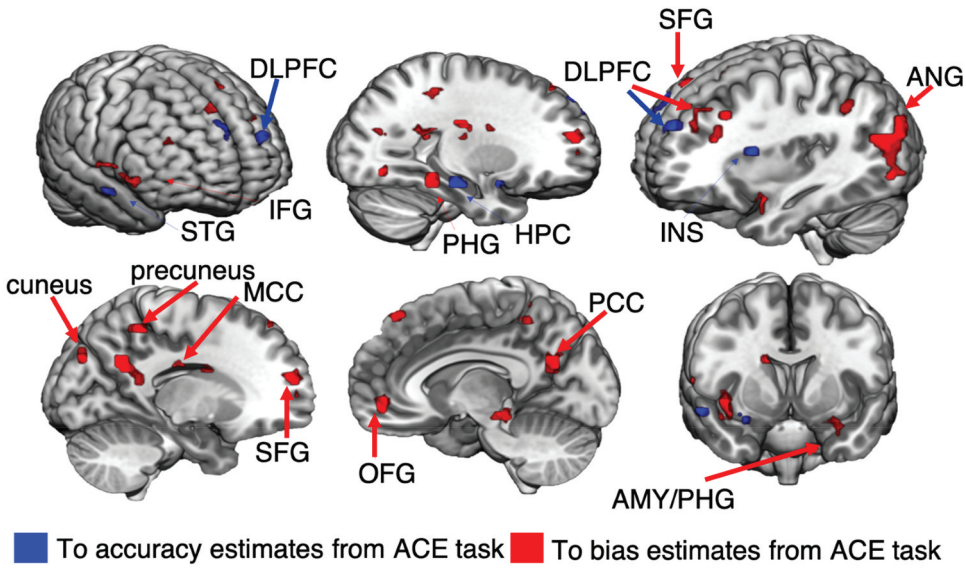

Figure 3. Brain activations associated with rating emotional vs. neutral faces in group-embedded vs. single-person setting for scalar vs. categorical ratings correlated with individual accuracy and bias estimates ($p < .001$ uncorrected, minimum cluster size > 10 voxels). Arrows indicate activation clusters that survived FDR correction ($p \leq .05$). STG: Superior temporal gyrus, OFC: orbitofrontal cortex, PCC: posterior cingulate cortex, PHG: parahippocampal gyrus, HPC: hippocampus, IFG: inferior frontal gyrus, ANG: angular gyrus, DLPFC: dorsolateral prefrontal Cortex.

without FDR correction revealed activation clusters in the lingual gyrus, somatosensory cortex, and putamen, and left angular gyrus. By contrast, activity during categorical ratings of single faces was restricted to somatosensory and middle temporal cortex in the left hemisphere, and no activation for this condition survived FDR correction (see Supplementary Table S1, activations significant after FDR correction noted with asterisks and presented in bold font).

The additional cognitive demands involved in scalar ratings were associated with activity in the inferior frontal gyrus and dorsal extrastriate cortex (regardless of the presence of social context). Facial emotion processing in the group-embedded setting was distinctly associated with activation clusters in dorsomedial and dorsolateral prefrontal regions, which, however, did not survive FDR correction. Additional activation clusters in ventral extrastriate visual cortex were common to both categorical rating conditions. After FDR correction, both scalar rating conditions were linked with activations in inferior frontal and lingual gyri, whereas in the group-embedded condition they were linked only with additional middle temporal gyrus activation (conversely, in the single-face condition only with additional cuneus activation; see Supplementary Table S1).

Correlations between brain activations and accuracy/bias indices during processing of facial emotion

Average scores on the accuracy index during the online ACE-brief task were 3.60 ($SD = .49$) with bias scores averaging 1.62 ($SD = .32$). Correlational results show that accuracy and bias estimates were related to the engagement of distinct brain regions in facial emotion perception as revealed by the triple interaction (emotional vs. neutral stimuli in group-embedded vs. single setting with scalar vs. categorical rating). As shown in Table 1 and Figure 3, and these correlations did not survive FDR correction, accuracy scores were negatively correlated with activations in the left superior frontal gyrus, right hippocampus/parahippocampal gyrus, right dorsolateral prefrontal cortex, left posterior cingulate cortex and medial frontal gyrus, right superior temporal gyrus, and right and left insula (uncorrected results).

There were extensive negative correlations between individual bias scores and regional activations. After FDR correction, an extensive brain network emerged, including portions of the cingulate cortex (right posterior cingulate cortex, left anterior cingulate cortex, right cingulate gyrus), insula, right precuneus, right and left angular gyrus, left midbrain, and right parahippocampal gyrus (see Table 1, noted with asterisks and presented in bold font). In

Table 1. Correlations between brain activations during fMRI facial emotion processing and accuracy and bias scores from the online ACE task.

Brain area	Side	BA	MNI			k	*T*
			x	y	z		
Accuracy scores to:							
Scalar vs. categorical rating for emotional vs. neutral stimuli for group-embedded vs. single setting							
SFG	L	9/10	−18	59	32	22	−4.521
HPC/PHG	R	48	30	−19	−16	21	−5.150
DLPFC	R	9/8	9	59	38	15	−4.353
PCC/precuneus	L	31	−24	−52	32	15	−6.163
MFG	L	8/9	−45	14	38	15	−3.989
STG	R	38/21	57	5	−10	13	−5.421
INS	L	13	−27	11	14	12	−5.386
INS	R	13/34	30	5	−16	10	−4.319
Bias scores to:							
Scalar vs. categorical rating for emotional vs. neutral stimuli for group-embedded vs. single setting							
ANG	**L**	**39**	**−48**	**−70**	**17**	**172**	**−7.733**
PCC*	**R**	**23/31**	**−12**	**−61**	**20**	**138**	**−5.622**
INS*	**R**	**13**	**42**	**8**	**−7**	**66**	**−4.617**
ACC*	**L**	**32/10**	**−9**	**47**	**−4**	**43**	**−5.376**
Precuneus/CG*	**R**	**5/7**	**0**	**−46**	**50**	**37**	**−4.145**
ANG*	**R**	**39**	**39**	**−58**	**23**	**34**	**−4.453**
MB*	**L**		**−9**	**−31**	**−16**	**31**	**−5.391**
Fusiform/PHG*	**R**	**37/20**	**30**	**−37**	**−16**	**31**	**−5.804**
CG*	**R**	**23**	**18**	**−19**	**29**	**30**	**−4.512**
SFG	R	10	18	53	17	24	−5.017
STG	R	48	57	−13	11	24	−4.659
SFG/DLPFC	L	9	−24	38	41	22	−4.205
CUN	R	18/19	6	−79	32	21	−4.135
SFG	L	6	−12	17	62	21	−4.975
SFG	R	8	6	41	53	20	−4.344
IFGtriang	R	45/47	57	29	2	18	−4.694
PHG/AMY	L	28/34	−30	5	−19	16	−4.724
CUN	R	18/31	15	−73	20	15	−5.458
IFGoperc	R	6	63	14	11	13	−4.909
IPL	L	40	−42	−43	38	13	−4.946
MFG	L	48	−24	32	23	12	−4.749
Brainstem	R/L		6	−31	−19	12	−4.160
HPC	L	37/36	−27	−34	−7	12	−4.608
Precuneus	L	5	−6	−46	62	11	−4.287
MFG/DLPFC	L	9	−24	26	35	11	−5.111
Fusiform	R	19	30	−67	−7	11	−5.027
SFG	R	10	18	56	5	11	−4.017
CN	R		18	−1	23	10	−4.067
LING	L	18	−3	−70	−1	10	−4.675
MFG	R	46	36	38	29	10	−4.972

BA: Brodmann area; MNI: Montreal Neurological Institute; MOG: middle occipital gyrus; MB: midbrain; SMA: supplementary motor area; STG: superior temporal gyrus; SPL: superior parietal lobule; CB: cerebellum; SFG: superior frontal gyrus; HPC: hippocampus; PHG: parahippocampal gyrus; DLPFC: dorsolateral prefrontal cortex; PCC: posterior cingulate cortex; MFG: middle frontal gyrus; INS: insula; MOG: middle occipital gyrus; AG: angular gyrus; LING: lingual gyrus; CAL: calcarine sulcus; ITG: inferior temporal gyrus; IPL: inferior parietal lobule; MTG: middle temporal gyrus; MCC: middle cingulate cortex; ACG: anterior cingulate gyrus; CG: cingulate gyrus; CUN: cuneus; IFGtriang: triangular part of the inferior temporal gyrus; AMY: amygdala; IFGoperc: opercular part of the inferior frontal gyrus; CN: caudate nucleus. Results presented for $p \leq .001$ and cluster size > 10 voxels. Activations significant after FDR correction are marked with asterisks and presented in bold font.

uncorrected analyses, correlations highlighted several additional regions (left middle temporal gyrus, left precuneus, right and left superior frontal gyrus, right superior temporal gyrus, left dorsolateral prefrontal cortex, right cuneus, right triangular and opercular part of the inferior frontal gyrus, left amygdala, left inferior parietal, left and right middle frontal gyrus, left hippocampus, right caudate, and left lingual gyrus).

Finally, and notably, correlations with accuracy and bias scores in certain (common) brain regions (dorsolateral prefrontal cortex, insula, posterior cingulate, superior frontal and temporal gyri) involved distinct voxel clusters (based on their anatomical coordinates).

Discussion

Despite an increased interest in the way social context impacts emotion perception, there is very little research on how context impacts Emotion Recognition Accuracy (ERA). We investigated whether emotion processing is associated with distinct brain activations for single versus group-embedded facial expressions, as well as when participants are asked to rate emotion using categorical versus scalar scales in an fMRI-compatible adapted version of the ACE emotion decoding accuracy task (Hess & Kafetsios, 2021; Kafetsios & Hess, 2023). The study results demonstrate that facial emotion recognition in single versus group-embedded settings was linked to distinct brain activations as was the use of categorical versus scalar scales. Notably, individual scores for accuracy and bias in facial emotion perception from the original ACE task (performed on another day) were associated with distinct brain deactivations during the fMRI-compatible emotion decoding task across single-face and group-embedded settings. These findings indicate that discrete brain mechanisms underlie the perception of emotional facial expressions probed with different emotion evaluation instructions and scales and highlight the importance of including cognitive bias measures in the assessment of social emotion perception.

Brain activations during facial emotion processing in single-person and group-embedded settings with categorical and scalar rating

Regarding the central research question, the presentation and evaluation of emotional expressions which include a social context (i.e., group-embedded presentation) was linked to activation in brain regions related to social information processing, thus supporting the notion that this form of stimulus engages social cognition. Specifically, perception of emotional expressions in the group-embedded setting was associated with extended brain activations, in accordance with evidence from social cognition research (Arioli et al., 2021; Deuse et al., 2016; Hinojosa et al., 2015). In particular, uncorrected activations during emotion perception on the conventional categorical scale and without social context were restricted to somatosensory and middle temporal cortex activation indicating language and semantic memory processing and visual perception. Although this is in agreement with the findings of previous studies with similar designs (Adolphs et al., 2000; Critchley et al., 2000; Sel et al., 2014; for review see:; Dricu & Frühholz, 2020), unlike in this previous research, in our study none of these activations survived FDR correction. This divergence is likely due to differences between the ACE set stimulus and standard stimulus sets (Ekman & Friesen, 1976; Lundqvist et al., 1998) utilized in previous research: the ACE is composed of naturalistic, spontaneous emotion expressions of both face and body of the participant. Importantly, such expressions are of lower intensity than the often starkly exaggerated prototypical expressions used in many standard sets.

Conversely, activations during emotion perception in social context with the same (categorical) emotion rating, comprised several brain regions related to emotion processing and social cognition, including insula, superior frontal and superior temporal gyri (activations that survived FDR correction), as well as hippocampus and angular gyrus (activations that did not survive FDR correction) (Adolfi et al., 2017; Mason & Just, 2011; Montagrin et al., 2018; Pitcher & Ungerleider, 2021; Uddin et al., 2017). Emotion perception in social context combined with scalar emotion rating (as in the original ACE Task) was linked to activation in pars orbitalis of the inferior frontal gyrus, a brain region associated with the perception of semantics and emotion (Belyk et al., 2017), as well as in middle temporal gyrus, part of the core semantic network (Binder et al., 2009), and in lingual gyrus, engaged in visual processing and linked to face and emotion perception (Meaux & Vuilleumier, 2016). Notably, all these activations survived FDR correction. There was also some evidence for additional activations, which did not survive FDR correction, in dorsomedial and dorsolateral prefrontal brain areas, indicating that this condition engaged additional processes, including social cognition, such as perspective taking, thinking about others or mind-reading (Amodio & Frith, 2006; Dricu & Frühholz, 2016; Iacoboni et al., 2004).

Both in single and group-embedded settings, the evaluation of the presented emotional expressions with scalar rating prompted the engagement of the inferior frontal gyrus and ventral extrastriate cortex, brain regions related to emotion perception (these activations survived FDR correction; Liu et al., 2021; Müller et al., 2018; Sabatinelli et al., 2011). Importantly, the findings from the scalar rating conditions agree with Dricu and Frühholz's (2016) meta-analysis which directly compared the neural correlates of emotion processing with explicit evaluation of the emotion vs. incidental emotion perception showing distinct engagement of inferior frontal cortex regions, visual association, and dorsomedial prefrontal cortex areas. Moreover, these results agree with similar findings from studies comparing categorical and scalar ratings in self-reports of affective experiences (Satpute et al., 2013, 2016). Overall, using scalar ratings

in the perception of emotional expressions was linked to a broader engagement of emotion processing brain regions, including extended visual processing, as well as social cognition components.

Correlations of brain activations with accuracy and bias scores in facial emotion perception

The second objective of the study was addressed through correlational analyses between the degree of change in hemodynamic activity across the four experimental conditions and individual accuracy and bias scores in facial emotion perception. The latter were computed from participants' responses during the original online version of the ACE task performed out-of-the-scanner since timing restrictions imposed in the design of the fMRI-compatible version of the task did not permit valid estimation of accuracy and bias indices according to the ACE model. In particular, accuracy and bias indices were negatively correlated with the degree of change in hemodynamic activity across the four experimental conditions. Correlational analyses did not focus on the degree of change in hemodynamic activity during processing emotional vs. neutral faces in each experimental condition separately. Instead, we concentrated on changes in activation when performing scalar judgments of facial emotion as compared to categorical judgments as a function of social context (i.e., as revealed by the triple-interaction contrast). These activations were expected to reflect neuronal processes involved in the appreciation of social context as well as bias in the perception of facial expressions which, according to the ACE model, is amplified when participants asked to consider alternative emotions.

Accuracy scores, which correspond to the perception of the emotion intended by the expresser, correlated with activations in brain regions involved in emotion processing and social cognition, including superior frontal gyrus, hippocampus, dorsolateral prefrontal cortex, posterior cingulate cortex, medial frontal and superior temporal gyrus, and insula (Dricu & Frühholz, 2016; Haxby et al., 2002; Liu et al., 2021). In particular, the accuracy index in this study correlated negatively with the engagement of brain regions associated with higher level processing of the expressed emotion as a social cue, i.e., understanding others' intention or perspective (Amodio & Frith, 2006; Dricu & Frühholz, 2016). As higher accuracy was associated with lower activation of these brain regions (or lower accuracy with higher activation), this process might be more sensitive to ambiguous stimuli, requiring more effort for mental scanning, selection, and decision making. Please note, however, that none of these findings survived FDR correction for multiple comparisons and therefore should be considered with caution.

Conversely, bias scores, which assess perception of non-intended emotions, correlated with activations in several additional regions linked to emotion processing and social cognition, such as the angular gyrus, posterior and anterior cingulate cortex, insula, precuneus, and parahippocampal gyrus (surviving FDR correction), as well as superior frontal and temporal gyrus, dorsolateral prefrontal cortex, amygdala, and inferior frontal gyrus (not surviving FDR correction) (Dricu & Frühholz, 2016; Haxby et al., 2002; Liu et al., 2021). Notably, higher bias scores were associated with relative disengagement of brain regions linked to emotion processing as internal signal (Adolfi et al., 2017; Oosterwijk et al., 2015; Spunt & Adolphs, 2019). We surmise that higher bias scores reflected greater effort to minimize self-bias and be more objective and stimulus-bound during emotion perception; along these lines, the greater the activation in self-relevant brain regions during the task, the less internal biases in emotion perception were reported.

In summary, accuracy- and bias-related indices correlated with activity in partly distinct brain regions, suggesting that the use of social context and scalar emotion rating in emotion perception tasks involves distinct, possibly complementary, neural mechanisms. These findings agree with the notion that scalar ratings of emotional expressions embedded in a social context can assess additional features of emotion perception processing (Hess & Kafetsios, 2021; Hess et al., 2016; Kafetsios & Hess, 2013, 2022). Recall that, unlike conventional, hit rate-based techniques for the accurate decoding of emotional expressions, ACE accuracy and bias indices address distinct facets of variability (Kafetsios & Hess, 2022; Kafetsios et al.; 2023), in line with the Truth & Bias model of emotion perception (West & Kenny, 2011). Therefore, the approach is notably different from existing methods that rely on hit rates (e.g., Wingenbach et al., 2016) or a signal detection analysis of those (e.g., Grimshaw et al., 2004).

Limitations and future directions

Despite its strengths the present study has certain limitations. First, the adaptation of the ACE task into an fMRI-compatible version and the inclusion of categorical rating conditions for comparison to the scalar ones, required simplification of the task and adherence to time limitations. In the scalar conditions, participants

were shown five emotions to rate their intensity on main character, and they were prompted with a seemingly random choice of one emotion to rate (either for accuracy or for bias), under strict time constraints. Although circumstances obviously differ compared to the standard ACE task, where participants have ample time to provide scalar ratings on all seven emotions, the adapted version was designed to elicit neuronal activation associated with the intent to consider alternative emotions and social context when making a scalar judgment. Accordingly, systematic changes in activity as a function of the type of judgment across social context conditions may optimally be represented by triple-interaction contrasts. The latter could reflect the degree of change in emotion-related hemodynamic activity (i.e., emotional vs. neutral faces) when making a scalar judgment compared to a more straightforward categorical judgment, as moderated by the presence of social context. It may also reflect, the degree of change in emotion-related activity associated with the presence of social context as moderated by the type of judgment participants are asked to make. In short, the present study provides a first insight into a mechanism previously not studied. Future research should be able to improve the design and task specifications, in order to either replicate or repute our findings.

Another limitation of the present study is the use of static, summative simulation of social context instead of dynamic, time-evolving emotional expressions in naturalistic social contexts, more similar to a real-world experience (such as in: Pitcher et al., 2014, 2023). Future research could address this issue including complementary advanced methods and computational modeling to combine approaches and advance the field.

Conclusion

It was speculated that the ACE's infusion of context in the form of emotion expressions in a naturalistic group setting induces perspective taking, in addition to pattern matching (Hess & Kafetsios, 2021). The findings of the present study support this notion as they suggest that distinct brain networks are linked to each type of emotion assessment and indicate that emotion-related brain activations during contextualized facial emotion perception tasks distinctly relate to accuracy and bias estimates of facial emotion perception. Notably, the classic approach to emotion recognition assessment – the use of a single, contextless face and limited forced choice labels – only engages perceptual and semantic regions. Brain regions associated with more complex processing and social cognition are only activated when scalar scales and/or group facial expressions are used. In fact, when stimuli are presented as in the ACE (scalar scales and group facial expressions) the most extensive processing of the stimuli is found. Moreover, accuracy and bias indices correlated with activations in distinct brain areas associated with the additional features of the ACE task. These findings have important implications for the use of Emotion Recognition Accuracy scores to predict real-world consequences.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Hellenic General Secretariat for Research and Development by a Grant [grant number KA10413] awarded to K. K. and the University of Crete, and partly supported by Research Grant [grant number 22-15238S] to K. K. by the Czech Science Foundation.

Data availability statement

Scripts and processed data supporting this study's findings are available at Open Science Framework (https://osf.io/vjgws/).

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