The role of outgroup homogeneity and the neurodynamics of the frontal cortex during beauty comparisons

George Zacharopoulos[1,2*], Katharina Ohmann[1,3], Niklas Ihssen[1,4], Gayannee Kedia[3,5],
Thomas Mussweiler[3,6], David E.J. Linden[1,7]

Affiliations:
[1]Cardiff University Brain Research Imaging Centre (CUBRIC), School of Psychology, Cardiff University, UK
[2]School of Psychology, Faculty of Medicine, Health and Life Sciences, Swansea University, UK
[3]Social Cognition Center Cologne, University of Cologne, Germany
[4]Department of Psychology, Durham University, UK
[5]Department of Psychology, University of Graz, Graz, Austria
[6]London Business School, Regent's Park, London, NW1 4SA, UK
[7]Department of Psychiatry and Neuropsychology, School of Mental Health and Neuroscience, Maastricht University Medical Center, Universiteitssingel 40, 6229 ER Maastricht, the Netherlands

*Correspondence:

George Zacharopoulos
School of Psychology, Faculty of Medicine, Health and Life Sciences, Swansea University, UK, SA28PP

E-mail: g.zacharopoulos@swansea.ac.uk

Abstract

The distance effect states that the closer two compared magnitudes (e.g. two numbers, physical attractiveness in two faces), the more difficult the comparison, and the greater the activity of the frontoparietal control network. However, it is unclear whether this network is also recruited to the same extent when we perform ingroup and outgroup beauty comparisons and whether the activation of these networks is tracked by interindividual variation in the perceptions we hold about an outgroup. We recorded brain activity with fMRI, where participants compared the beauty of two women ostensibly either from their ingroup or from an outgroup. Low-distance conditions produced longer response times than the high-distance conditions, and this was found in both the ingroup and outgroup conditions. However, our neuroimaging analyses revealed that the left IFG/anterior insula showed the classic distance effect only during ingroup processing but not during outgroup processing. Notably, individuals exhibiting greater perceptions of outgroup homogeneity showed greater left IFG/anterior insula activity during low-distance ingroup and high-distance outgroup processing relative to high-distance ingroup and low-distance outgroup processing. This set of findings reveals the dynamic role of the prefrontal cortex and its interplay with perceptions of outgroup homogeneity in shaping ingroup and outgroup decision-making.

Keywords: IFG/anterior insula, beauty comparisons, outgroup homogeneity

Introduction

The perception of physical beauty can have far-ranging implications (Kedia et al., 2014). For example, attractive individuals are perceived to possess several positive characteristics (e.g., more intelligent, honest, kind, sociable, dominant, talented, and mentally healthy), and were shown to be treated more favourably (e.g., paid higher salaries, milder criminal sentences) compared to less attractive individuals (Dion et al., 1972; Efran, 1974; Feingold, 1992; Hamermesh & Biddle, 1993; Kaplan, 1978; Langlois et al., 2000; Moss & Page, 1972; Piliavin et al., 1975; Sigall & Ostrove, 1975; Thorndike, 1920). Given the importance of attractiveness, prior work examined the psychological and neurobiological mechanisms by which humans judge the appearance of others. Correlational and experimental methods that mainly assessed attractiveness judgements in response to human physical attributes demonstrated the involvement of several factors in the formation of beauty judgments, such as symmetry, averageness, youthfulness, waist-to-hip ratio, and external or internalized standards (Brown et al., 1992; Hamermesh & Biddle, 1993; Langlois & Roggman, 1990; Perrett et al., 1999; Pettijohn II & Tesser, 1999; Rhodes & Zebrowitz, 2002; Sigall & Ostrove, 1975; Singh, 1993).

Neuroimaging studies highlighted the importance of three brain networks during beauty judgments. The first network involves reward-related areas such as the nucleus accumbens and the orbitofrontal cortex, whereby attractive faces elicit greater activity within these regions (Bray & O'Doherty, 2007; Bzdok et al., 2011; Cloutier et al., 2008; Kawabata & Zeki, 2008; Kim et al., 2007). The second network is the frontoparietal control network, which among other functions subserves mental comparison processes, which are at the heart of beauty judgments (Kedia et al., 2014). A classic effect in the literature that applies in the context of the frontoparietal control network is the distance effect, which states that the closer two compared magnitudes (e.g. two numbers), the more difficult the comparison, and the greater the activity of this frontoparietal control network (Cohen Kadosh et al., 2005; Nieder & Dehaene, 2009). In the context of physical beauty, the distance effect was observed when comparing the beauty of two unknown people (Kedia et al., 2014). In particular, low-distance beauty comparisons elicited longer reaction times, lower accuracy and greater recruitment of the frontoparietal control network compared to high-distance beauty comparisons (Kedia et al., 2014). The same behavioural effect was observed with other types of beauty comparisons, for example when comparing ourselves to an unknown person (i.e., self-other beauty comparison) or when comparing the beauty of a familiar person to that of an unknown person (familiar-other beauty comparison; (Kedia et al., 2019). At the brain level, these types of judgments involved a third network of supplementary motor area/dorsomedial prefrontal cortex frontal and anterior insula, where the effect of distance was stronger for the self-other than the familiar-other comparisons (Kedia et al., 2019). This predilection for self-other comparisons is compatible with the recognized role of these areas in self-referential processing. These studies showed that the engagement of the fronto-striatal "reward", the frontoparietal control "comparison" and the mediofrontal–insular "self" network varied according to the nature of the beauty judgment.

Membership in a social group is a crucial factor influencing beauty judgments. For example, subordinates rate the leaders of their in-groups as significantly more physically attractive than comparably familiar out-group leaders (Kniffin et al., 2014). Nevertheless, the extent to which the activation of the above-outlined neural networks is modulated by the ingroup-outgroup status of the target person has not been investigated thus far. One important factor potentially influencing beauty judgments of outgroup versus ingroup members is outgroup homogeneity, which is the tendency to view members of social outgroups as interchangeable (Hughes et al., 2019). Indeed this tendency has long been considered a core component of intergroup bias and a precursor to stereotyping and discrimination (Hughes et al., 2019). For example, perceiving outgroup members in categorical terms and consequently being unable to distinguish between them constitutes a crucial element of stereotyping, which can have life-changing real-world effects such as faulty eyewitness testimony (Allport et al., 1954; Fiske & Neuberg, 1990; Hughes et al., 2019). However, our knowledge on the extent to which the activation of these networks is shaped by differences in the perception of the outgroup is still limited.

Our present study has two aims: (i) to elucidate the brain networks engaged in ingroup and outgroup beauty comparisons in a classic distance effect paradigm, and (ii) to identify whether the activation of these networks is shaped by perceptions of outgroup homogeneity. To this end, we conducted an fMRI study (**Fig 1**) where we asked participants to compare the beauty of pairs of unknown women ostensibly from the participants' ingroup (ingroup comparison condition) or from an outgroup (outgroup comparison condition). Moreover, in some blocks the beauty difference between the target women was high (high-distance condition) or low (low-distance condition), producing a 2 (group: ingroup vs outgroup) x 2 (distance: high vs low) design. Lastly, we additionally assessed via questionnaire participants' perceptions about the ingroup and outgroup, including a measure of outgroup homogeneity. We used membership of the largest universities of two urban centres in South Wales, Cardiff and Swansea, as "in- "vs. "outgroup" manipulation. Cardiff and Swansea, which are approximately 45 miles apart, are the two biggest cities in Wales based on population size. These two cities represent distinct social identities spanning several social dimensions, including the rugby and football rivalry within and beyond sports stadiums between the "Jacks" of Swansea and the "Bluebirds" of Cardiff. For example, the South Wales derby is a local derby between Welsh association football clubs Cardiff City and Swansea City. Therefore, we believe that an explicit tag of university membership is sufficient to elicit processes related to ingroup/outgroup affiliation given the absence of perceptual or implicit cues of ingroup/outgroup affiliation such as skin colour, gender and age.

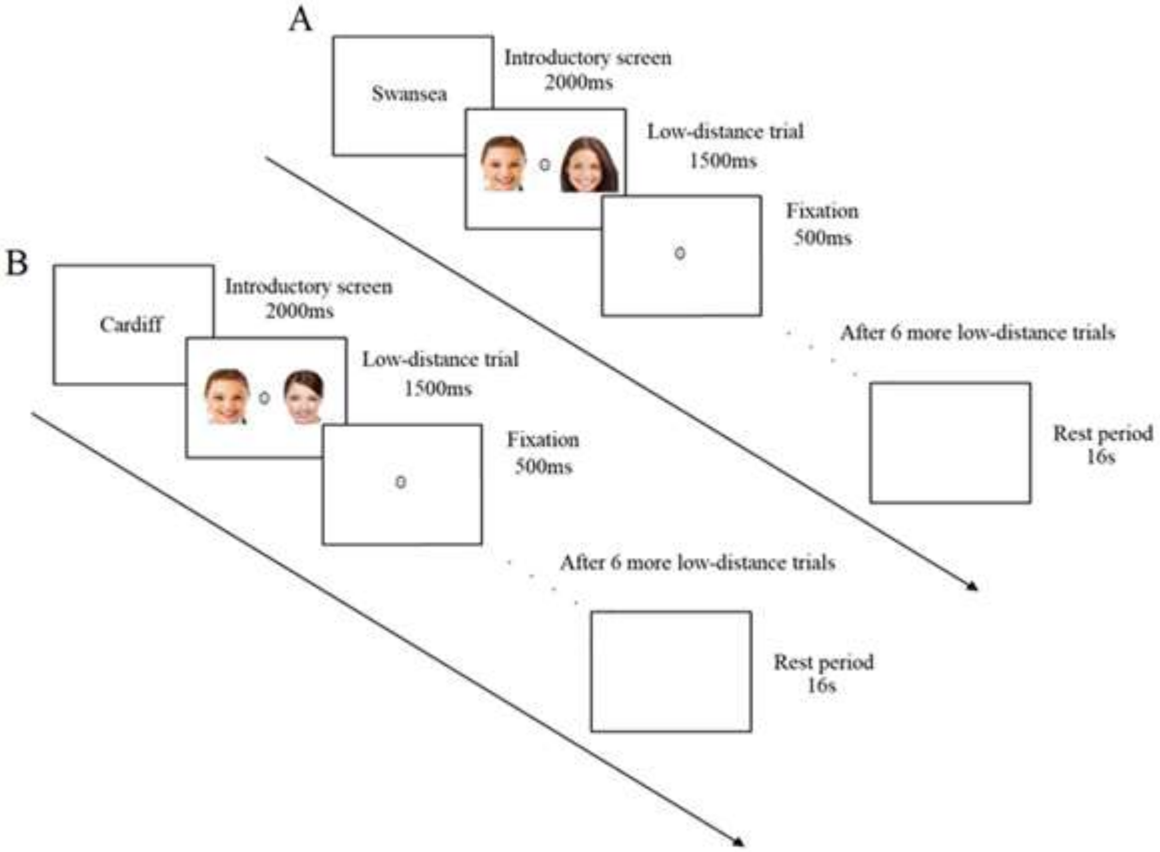


Fig 1. Schematic depiction of the beauty comparison task presented to Cardiff University students. **A**) An example block from the low-distance outgroup comparison (targets from Swansea University) and **B**) an example block from the low-distance ingroup comparison (targets from Cardiff University). Modified with permission from (Ohmann et al., 2016).

Material and Methods

Participants

We recruited 20 healthy participants (average age: 22.60; 10 female) by advertising the study online on Cardiff University notice boards. Participants were only included if they had been residents in Cardiff for at least five years to ensure identification with the city. The study was approved by the Ethics Committee of the School of Psychology at Cardiff University. All participants gave written informed consent according to the Declaration of Helsinki and received £10 as monetary compensation for taking part in the study.

Materials and Methods

The stimulus set used in the present study consisted of 148 coloured images of female faces used in previous fMRI and EEG research (Kedia et al., 2014; Ohmann et al., 2016). These images were pretested for beauty ratings in a separate female sample (Kedia et al., 2014) which enabled the formation of three distinct categories: faces of high beauty, of moderate beauty, and of low beauty. These three groups (i.e, faces of high beauty, of moderate beauty, and of low beauty) were determined before the start of the current study. They were specifically based on pre-test and post-test (ANOVA and t-test) validation analyses the results of which are published in the **Supplementary Material** of our prior work (Kedia et al., 2014). To create high-distance pairs, we matched faces that were judged as being of high and low beauty. Low-distance pairs consisted of moderately attractive faces, combined with faces that were either high or low in beauty. In sum, we created 294 pairs, half of them being of high and half of them being of low distance, whose mean beauty levels did not differ, $t(292)=.061$, $p=.951$, Cohen's $d=.07$. Of note, we defined accuracy or correctness of behavioural responses based on these normative ratings.

To avoid any confounding influence of facial expressions, we created pairs of female faces who either both smiled or both looked neutral. We also equated the distribution of smiling and non-smiling pairs across the low and the high distance condition. Moreover, to rule out that any differences between the conditions arise from differences in low-level visual properties of the stimuli, we calculated mean scores concerning luminance, colour, and local frequency for each pair of images. Our analysis revealed no significant differences between the high and low distance beauty conditions in any of these properties, *t*s(292) < 1.45, *p*s > .148, *d*s < .20. There are several reasons for the suitability of this face database selection. First, the stimulus set consisted of female faces the physical characteristic (tone, shape etc.) of which match the ones of the target (i.e., Welsh) population; therefore, it was believable that the target stimuli represented people from Cardiff and Swansea University students. Second, we used this face database because there were no differences in low-level visual properties (luminance, colour, and local frequency) for each pair of images which could have confounded our analyses. Third, the stimulus set used in the current study (i.e., female faces) was used in previous neuroimaging (fMRI and EEG) research (Kedia et al., 2014; Ohmann et al., 2016).

Cover Story

To establish a group context, we told participants that they would see images of women who studied or worked either at Cardiff University (ingroup) or at Swansea University (outgroup). Ostensibly, these women took part in a photo competition at their respective university which was supposed to lead to the creation of a university calendar. Participants were informed that at the beginning of each block of images, a screen would indicate (see “Introductory screen” in **Fig 1**) whether the subsequently presented women were either from Cardiff or from Swansea University. Participants had to decide on each trial which of the simultaneously presented women they regarded as more attractive.

Questionnaire

To assess individual differences in participants' degree of identification with the group, we created a questionnaire that assessed participants' attitudes towards Cardiff and Swansea University. On a rating scale from 1 (=*not at all*) to 7 (=*very*), one item assessed participants' degree of identification with Cardiff University, three items assessed perceived similarity ((i) "In your opinion: How similar are students from Cardiff University and the University of Swansea?", (ii) "In your opinion: How similar are the students at Cardiff University?") and the outgroup homogeneity measure ("In your opinion: How similar are the students at the University of Swansea?"). The outgroup homogeneity score for each participant, was a single score that was assessed with a single item ("In your opinion: How similar are the students at Swansea University?") on a rating scale from 1 (=*not at all*) to 7 (=*very*). Please note assessing social psychological constructs (e.g., outgroup homogeneity) using a single item has been utilized in several prior studies for a wide range of constructs including political attitudes, life satisfaction, religiosity, self-esteem, and self-efficacy (Gebauer et al., 2017; Hanel et al., 2019; Wolf et al., 2021; Zacharopoulos et al., 2022). Furthermore, this questionnaire contained two items assessing participants' willingness to pay for a calendar displaying female faces from either Cardiff or Swansea University, to measure the degree of identification with the ingroup (How much money would you be willing to pay for a calendar that shows the faces of the female students from Cardiff University?) relative to the outgroup (How much money would you be willing to pay for a calendar that shows the faces of the female students from Swansea University?), in that the more someone is willing to pay for the "ingroup" vs the "outgroup" calendar the more he/she is identified with the ingroup relative to the outgroup. Lastly, the questionnaire featured some demographic variables, such as age, sex, and field of study.

Procedure

Prior to scanning, all participants underwent an MRI safety screening, were familiarized with the scanning environment and performed a ten-trial training session with different stimuli as those used in the fMRI session. The scanning session comprised three functional runs (each 7.6 minutes) and the acquisition of a structural image, leading to a total scanning time of approximately 30 minutes. A single run comprised 14 active blocks (16.5 seconds) and 14 blocks of rest (16 seconds). In each active block, an introductory screen was presented for 2000 milliseconds indicating the following targets' group membership (Cardiff vs Swansea) and was succeeded by seven trials (1500 milliseconds each) of simultaneously presented women that were either all of high or all of low distance. Trials were separated by a fixation cross lasting 500 milliseconds. Stimuli were presented via a 45° angled mirror positioned above the head coil reflecting the projection of a computer screen. Participants indicated on each trial whether they regarded the woman presented on the left or the woman presented on the right as more attractive by pressing a button placed below their left or a button placed below their right hand. Half of the active blocks consisted of trials that presented women who were ostensibly from Cardiff University and the other half that were ostensibly from Swansea University, again half of them being of high and half of them being of low distance (for an example, see **Fig 1**). After the scanning procedure, participants answered the questionnaire described above, were debriefed, thanked, and paid £10.

MRI Data Acquisition

MRI images were acquired with a General Electric 3T scanner equipped with an 8HR Brain parallel head coil for radio frequency transmission/reception. Anatomical high-resolution T1-weighted volume scans ($1mm^3$) were acquired using FSPGR 256*192 3-D sequence (TR=8.8ms; TE=3.5ms; voxel size=1x1x1mm, 182 slices). Functional images were acquired with a gradient-echo EPI sequence [TR=2000ms, TE=35ms, flip angle=80 degrees, slice thickness=3mm, gap=1mm). Each volume consisted of 34 slices obtained in an ascending interleaved order.

fMRI data pre-processing and analyses

Imaging data were analyzed in CONN (Whitfield-Gabrieli & Nieto-Castanon, 2012) (a toolbox in SPM12) using the default MNI-space direct normalization pre-processing pipeline which performs several steps including realignment, slice-timing correction, structural segmentation and normalization, functional normalization and smoothing (FWHM=8mm). In the first-level analyses, separate regressors were included for the four conditions: (i) high-distance ingroup, (ii) low-distance ingroup, (iii) high-distance outgroup, (iv) low-distance outgroup. To remove variations in signal due to movement artefacts, we included the movement parameters (6 overall, 3 translations, and 3 rotations, which are automatically computed during realignment) calculated during the realignment in the models as parameters of no interest. The conditions were initially modelled with a boxcar function from the onset to the offset of each block and the predictors were convolved with a canonical hemodynamic response function to produce the predicted BOLD signal. Moreover, we excluded all runs where there was >2mm movement in either of the three translations (x,y,z), overall we excluded 13% of the runs in this study (i.e., 8 runs from all possible 60). We created three contrasts during the first-level analyses (examining the effects of distance [.5 -.5 .5 -.5], group [.5 .5 -.5 -.5], and the distance*group interaction [.5 -.5 -.5 .5]) and then entered the contrast of parameter estimate images into a second-level group analysis. Please note that since we utilized a whole-brain voxel-wise $P_{FWE}<.05$ threshold the cluster sizes are expected to be smaller relative to using a cluster-wise threshold, this is because the cluster-wise threshold approach uses a more lenient voxel-wise correction (i.e., typically $P_{uncorrected}<.001$) compared to the voxel-wise correction threshold used here ($P_{FWE}<.05$). Statistical analysis was conducted with the SPM toolbox Statistical Non-Parametric Mapping (SnPM, http://warwick.ac.uk/snpm) which uses the GLM to construct *t*-statistic images, which are then assessed for significance using a standard non-parametric procedure based on randomization/permutation testing. Our approach is consistent with current guidelines on the reporting of whole-brain MRI data (Roiser et al., 2016). Throughout the manuscript, the xyz coordinates of each region are in MNI space. The error bars in **Fig 3** represented the 95% confidence intervals in raw beta-weights calculated based on our sample. After completing the second-level analyses, raw beta-weights were extracted from the four regions of interest in response to the relevant contrast of interest using the MarsBar toolbox (Brett et al., 2002) within the SPM package yielding 20 (number of participants) raw beta-weights for every region. We then performed a bivariate correlation (**Fig 4A**) between the individual variation in these raw beta-weights (i.e., 20 values, 1 per participant per region) per region and the corresponding values of the questionnaire items (i.e., 20 values, 1 per participant per questionnaire item). For visualization purposes, we also extracted the raw beta-weights of each of the four conditions separately from the four regions of interest using the MarsBar toolbox (Brett et al., 2002), which we plot in **Fig 3A-D** and **Fig 4B-E**. Of note, apart from the left IFG/insula cluster (**Fig 3C**), three more clusters reached statistical significance during our neuroimaging analyses (see, **Results** section). However, we believe that the cluster in Fig 3A which seems to be within the ventricles may be in response to the smoothing effect, and the patterns in Fig 3B and Fig 3D are difficult to explain in the context of the present study.

Results

Behavioural data

As a first step, we calculated mean reaction times for every participant in each condition and submitted these means to a 2 (group: ingroup vs outgroup) x 2 (distance: high vs low) ANOVA. We observed a strong main effect of distance on the mean reaction time, ($F(1, 19)=87.03$, $P<.001$, $\eta p^2=.821$), whereby, low-distance trials led to longer response times (M=867ms) than high-distance trials (M=784ms; **Fig 2**), and on accuracy ($F(1,19)=157.6$, $P<.001$, $\eta p^2=.892$), whereby, low distance trials led to reduced accuracy (M=78%) than high distance trials (M=92%). We observed no additional main or interaction effects (*p*s>.05) either in our mean reaction time analyses.

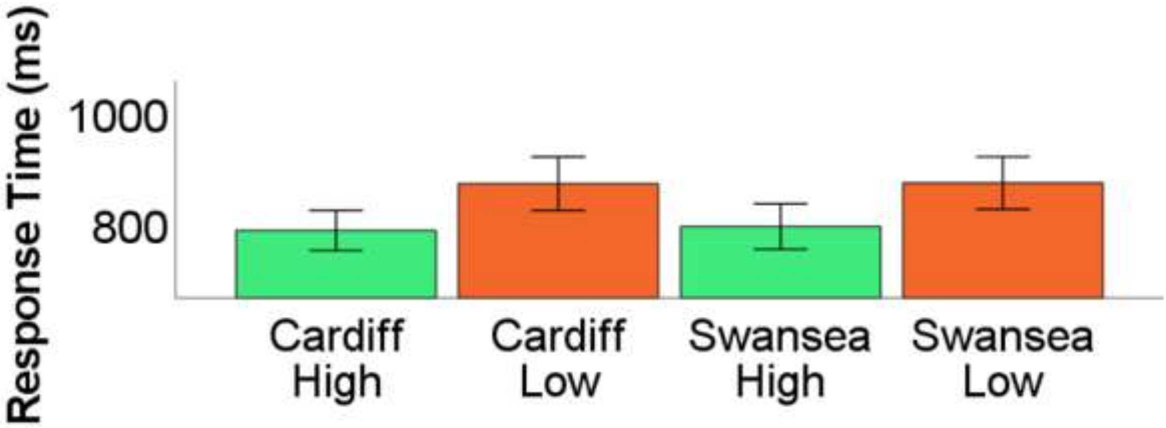
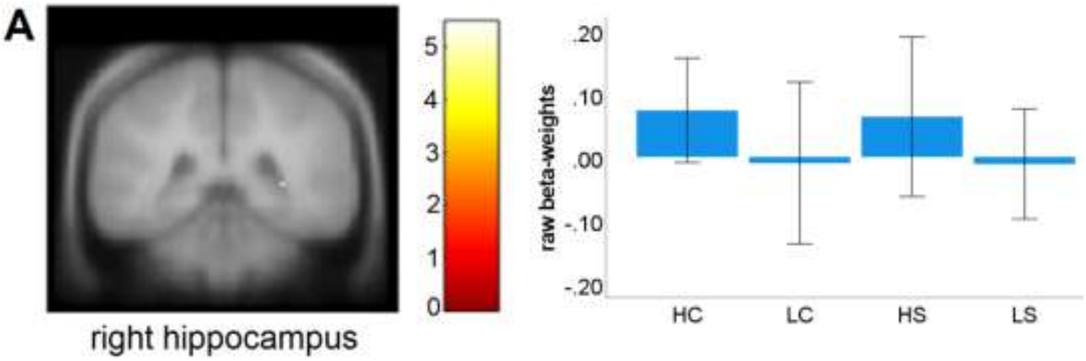


Fig 2. Reaction times regarding high (green) and low (orange) distance trials of pictures displaying women ostensibly from Cardiff (ingroup) and Swansea (outgroup). Error bars represent 95% confidence intervals of means.

Neuroimaging analyses

We examined the effect of distance (high vs low), the effect of group (ingroup vs outgroup) as well as the distance*group interaction at the neural level (for details, see **Materials and Methods** section). The high-distance conditions elicited higher activation in a region neighbouring the right hippocampus (T=5.46, P_{FWE}=.022, x=30, y=-40, z=4, k=6, **Fig 3A**) compared to the low-distance conditions. No significant effect was identified for the contrast ingroup vs outgroup.

We found three clusters with a significant interaction effect. Low-distance ingroup processing and high-distance outgroup processing elicited a negative correlation with the BOLD within the precentral/postcentral gyrus (T=5.78, P_{FWE}=.029, x=-12, y=-32, z=68, k=3, **Fig 3B**) compared to the low-distance ingroup processing and the high-distance outgroup processing. The interaction effect in the left IFG/ anterior insula was driven by higher activation for the ingroup/ low distance condition (T=6.78, P_{FWE}=.006, x=-36, y=20, z=14, k=12, **Fig 3C**) and that in the right IFG/ anterior insula BOLD signal was negatively correlated with the outgroup/ low distance condition (T=6.06, P_{FWE}=.016, x=36, y=8, z=12, k=5, **Fig 3D**).



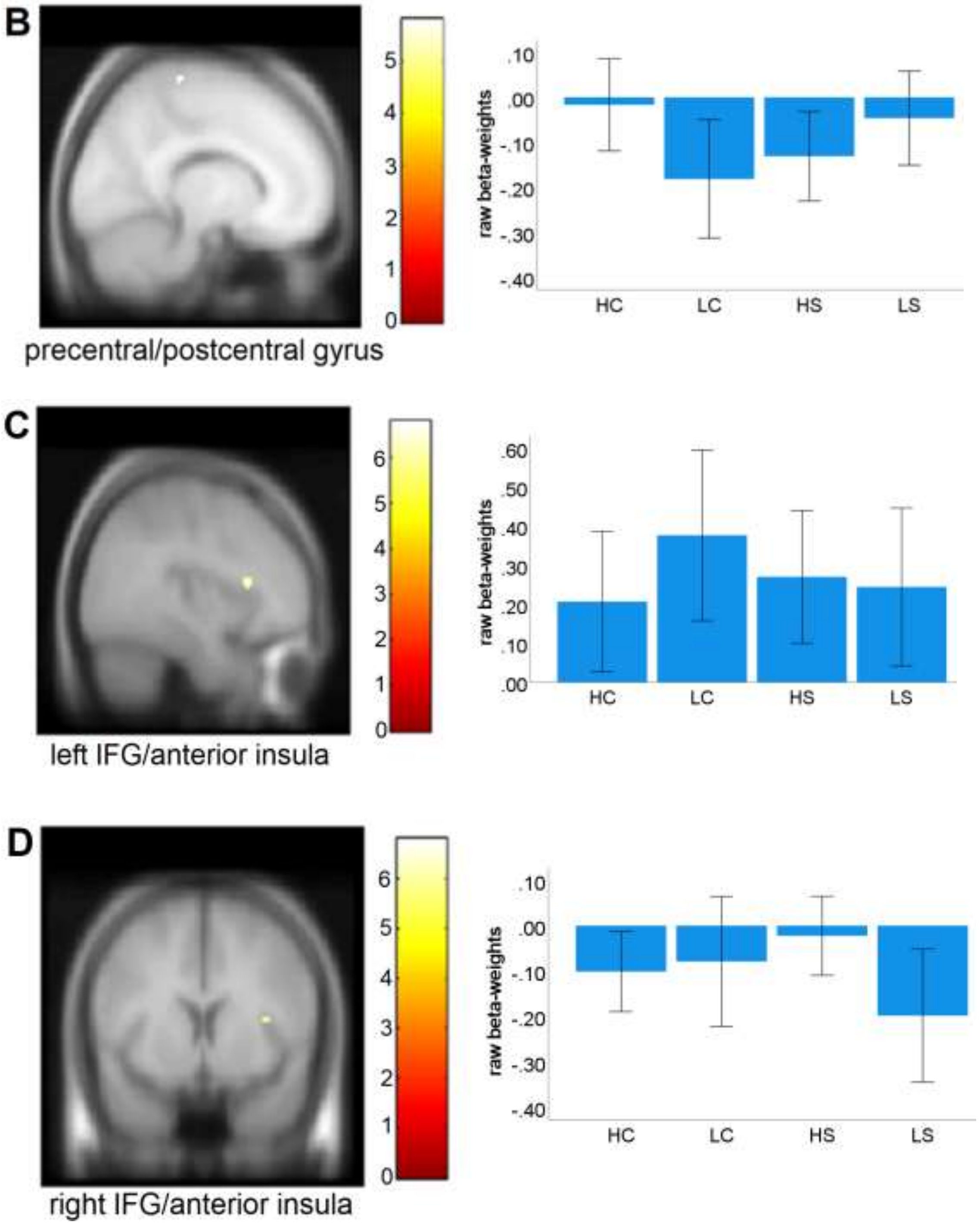


Fig 3. Neuroimaging results in response to the effect of distance (Panel **A**) and the distance*group interaction (Panels **B**, **C**, **D**), and the corresponding raw beta weights (y-axis, error bars represent 95% confidence intervals of means) in each of the four conditions (H=high distance, L=low distance, C=Cardiff, S=Swansea) for each region/panel separately are displayed on the right-hand side.

Neuroimaging-behaviour analyses

After assessing the neuroimaging results, we examined whether interindividual variation in behavioural scores modulated the activity within the four regions identified in the neuroimaging analyses (**Fig 3**). To this end, we extracted the beta-weights of each of the four regions, and after multiple comparison corrections. Specifically, we ran 20 comparisons (4 [brain regions]*5 [questionnaire measures]), and only one comparison survived the FDR correction. Namely, we identified a significant association in the left IFG/ anterior insula, the cluster depicted in **Fig 3C** (**Fig 4A**) and outgroup homogeneity. Specifically, individuals exhibiting perceptions of outgroup homogeneity, assessed with a single item [("In your opinion: How similar are the students at Swansea University?") on a rating scale from 1 (=*not at all*) to 7 (=*very*)], showed greater activity in response to low-distance ingroup processing and high-distance outgroup processing relative to high-distance ingroup processing and low-distance outgroup processing (i.e., raw beta-weights of **Fig 3C**, $\beta=.779$, $t(18)=5.27$, CI=[.555 1.000], $P_{BO}<.001$, $P_{FDR}=0.00104$).

As a next we step, we discerned the extent to which perceptions of outgroup homogeneity shape the four individual brain measures that make up the interaction effect (i.e., high-distance ingroup processing, low-distance ingroup processing, high-distance outgroup processing, low-distance outgroup processing) independently, which was not the case. Namely, outgroup homogeneity scores were not significantly associated with any of the four brain measures independently: high-distance ingroup processing (**Fig 4B**, $\beta=-.062$, $t(18)=-.265$, CI=[-.423 .271], $P_{BO}=.712$), low-distance ingroup processing (**Fig 4C**, $\beta=-.215$, $t(18)=-.934$, CI=[-.525 .086], $P_{BO}=.178$), high-distance outgroup processing (**Fig 4D**, $\beta=-.212$, $t(18)=-.921$, CI=[-.546 .107], $P_{BO}=.195$), low-distance outgroup processing (**Fig 4E**, $\beta=-.141$, $t(18)=-.606$, CI=[-.449 .122], $P_{BO}=.280$).

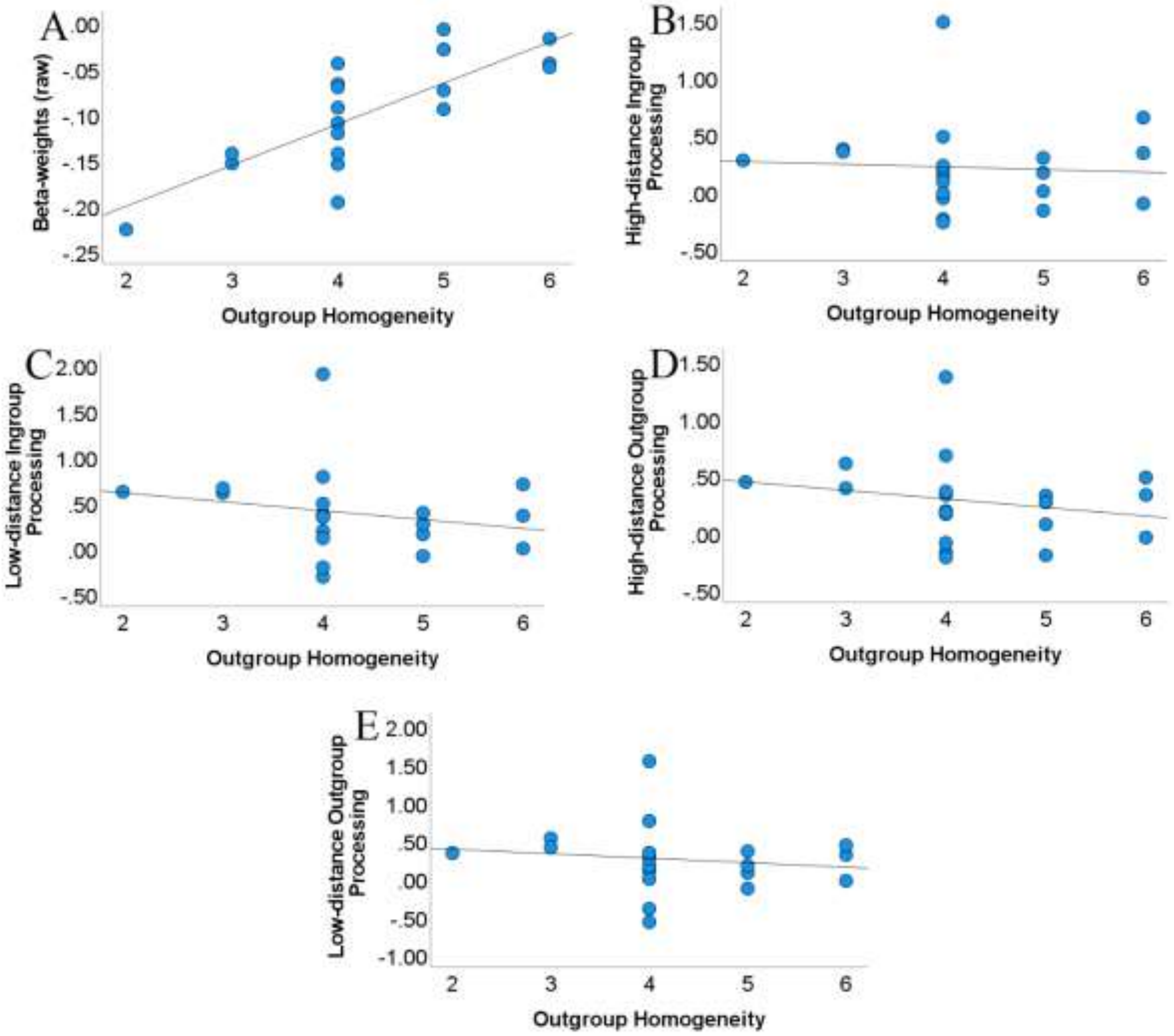


Fig 4. Scatterplots depicting the association between outgroup homogeneity (x-axis) and raw beta-weights obtained from the left IFG/anterior insula in response to A) the interaction contrast, and its four determinants independently: **B**) high-distance ingroup processing, **C**) low-distance ingroup processing, **D**) high-distance outgroup processing, and **E**) low-distance outgroup processing.

Discussion

In the present study, we (i) examined the neural mechanisms of ingroup and outgroup beauty comparisons using an adaptation of a classical magnitude comparison paradigm (Cohen Kadosh et al., 2005; Kedia et al., 2019; Kedia et al., 2014), and (ii) discerned how interindividual variation in outgroup homogeneity relates to these neural mechanisms. Three main findings emerge from this study: (i) low-distance beauty comparisons produced longer reaction times and lower accuracy compared to high-distance beauty comparisons, and this distance effect was found both for the ingroup judgments as well as for outgroup judgments; (ii) the left IFG/anterior insula encoded the group*distance interaction effect, and (iii) interaction-specific activity within this region correlated with outgroup homogeneity assessed via questionnaire.

Our behavioural findings replicated and extended those obtained in the earlier studies from our group with different paradigms (Kedia et al., 2019; Kedia et al., 2014). Specifically, it was previously shown that low-distance beauty comparisons produce slower reaction time and lower accuracy than high-distance beauty comparisons; this distance effect was observed when comparing the beauty of two unknown people, when comparing one's own beauty to an unknown person or when comparing the beauty of a familiar person to that of an unknown person (Kedia et al., 2019; Kedia et al., 2014). Here we extend the distance effect in the context of both ingroup and outgroup beauty comparisons, showing that the distance effect is not modulated by group membership (no significant group*distance interaction). In our study, the coloured images of female faces were identical in the ingroup and the outgroup conditions, and the only difference in these two conditions was the task instructions (i.e., "introductory screen", see **Fig 1**) preceding the presentation of the stimuli and the corresponding beauty judgments. We also observed a trend in that the outgroup conditions elicited longer reaction time compared to the ingroup conditions but this did not reach significance (t(18)=-.924, P=.2, one-tailed).

Our study did not show a general involvement of the frontoparietal control network in response to the low-distance vs high-distance conditions found in some (Kedia et al., 2014) but not all previous studies (Kedia et al., 2019). However, a closer examination of the interaction effects shows that the left IFG/anterior insula encoded the classic distance effect for the ingroup (higher activity in the low-distance compared to the high-distance conditions) but not for the outgroup (no significant differences in activity between the outgroup low-distance and outgroup high-distance conditions). Research suggests that the anterior insula is important in identifying relevant/salient stimuli from the overall stimuli in the environment (Menon & Uddin, 2010) and it was also shown to track the distance effect in the context of attractiveness among social conditions (Kedia et al., 2019). Notably, the left IFG/anterior insula cluster found in this study in response to the group*distance interaction overlaps with the left anterior insula cluster identified previously where the authors found that this cluster tracked the distance effect more strongly for self-other than familiar-other comparisons (Kedia et al., 2019). In the present study, the ingroup conditions are hypothesized to be most relevant/saliant rather than the outgroup conditions, and indeed the left IFG/anterior insula was shown to track the distance effect only in the salient (ingroup) but not the not-salient (outgroup) conditions. However, we appreciated that the sample size was small, particularly for documenting individual differences at the behavioural or at the neuroimaginglevel, thus, these results should be interpreted wth caution. Replication and extension of the current findings need to be investigated in larger sample sizes in future work.

Our study also addresses the link between perceptions of outgroup homogeneity and brain activity. Despite the considerable knowledge of the psychological building blocks of prejudice (processes of social categorization, prejudice formation, and intergroup emotion and perception), our understanding of the neurocomputational bases of outgroup homogeneity is only beginning to emerge (Amodio & Cikara, 2021). An fMRI study revealed outgroup homogeneity effects in early face-selective cortex suggesting that outgroup deindividuation emerges at some of the earliest stages of face perception in the form of reduced neural sensitivity to variability among other-race faces (Hughes et al., 2019). Moreover, the human brain uses different neural systems to sort people into different groups and dynamic neural responses within these systems predicted racial biases in face recognition and altruistic intention (Zhou et al., 2020). Here we extend these findings by showing that perceptions of outgroup homogeneity are not confined to sensory areas, but also found in the frontal cortex. Specifically, individuals exhibiting greater perceptions of outgroup homogeneity showed greater activity in response to low-distance ingroup processing and high-distance outgroup processing relative to high-distance ingroup processing and low-distance outgroup processing. Notably, outgroup homogeneity scores were not significantly associated with any of the four conditions independently (**Fig 4**). This finding suggests that perceptions of outgroup homogeneity exert an effect beyond solely the perceptions of outgroup processing. Instead, our perceptions of an outgroup may extend beyond outgroup processing in that they shape the relative difference between the ingroup vs outgroup conditions depending on the distance effect. We speculate that the underlying psychological mechanisms at play here may involve ingroup-outgroup comparison processes. Namely, perceptions of outgroup homogeneity seem to shape the left IFG/anterior insula activity in the context of beauty processing via an ingroup-outgroup comparison process.

In the present study, we choose to equate visual input by keeping the stimuli (i.e., pictures of female faces) identical between the ingroup vs outgroup conditions. This was done as we deliberately aimed to isolate the effects of our manipulation on later processing stages and establish a clear effect of outgroup homogeneity by not conflating earlier (visual) stages of processing that have been studied elsewhere (Hughes et al., 2011; Zhou et al., 2020). Moreover, we have chosen this design as in many real-life situations the ingroup and outgroup members are indeed physically indistinguishable (e.g., of a different sexual orientation or a political ideology). However, there are also cases where outgroup members are visually distinct from ingroup members (e.g., skin tone), and it is currently an open question whether the findings of this study generalize to these scenarios.

As mentioned above, we indicated that the ingroup conditions are hypothesised to be most relevant/salient rather than the outgroup conditions, and indeed the left IFG/anterior insula was shown to track the distance effect only in the salient (ingroup) but not the non-salient (outgroup) conditions. A closer examination of the four left IFG/anterior insula (**Fig 3C**) error bars suggests that high and low-distance outgroup targets are processed similarly where the distance effect does not seem apparent between the two Swansea conditions (post-hoc paired sample t-test: t(19)=.83, P=.42), compared to the ingroup targets where the distance effect does seem evident between the two Cardiff conditions (post-hoc paired sample t-test: t(19)=-4.83, P<.001). However, we did not find evidence for such differentiations at the behavioural level. First, we did not find a group*distance interaction effect at the behavioural level in that there was no differentiation between low and high-distance processing as a function of group membership (**Fig 2**). Second, even though one would predict that outgroup homogeneity would mean that high and low-distance outgroup (vs ingroup) targets would be processed similarly, we found this was not the case in the behavioural analyses. Outgroup homogeneity was not significantly correlated with this contrast (High Cardiff=.5, Low Cardiff=-.5, High Swansea=-.5, Low Swansea=.5) at the behavioural level. Similarly, outgroup homogeneity did not significantly correlate with the (accuracy or reaction time) behavioural measure [(High Cardiff-Low Cardiff)-(High Swansea-Low Swansea)], suggesting that outgroup homogeneity does not have a behavioural impact in shaping the processing of high and low-distance outgroup (vs ingroup) targets more similarly. One potential factor that may explain this discrepancy between neural and behavioural effects is statistical power. Namely, for neuronal analyses, we utilised a blocked design which generally has a more robust detection compared to event-related designs (Huettel et al., 2004) and thus allows us to detect interaction effects, and while behavioural analyses were calculated by aggregating behavioural data per participant, the number of trials may not have been adequate to detect a potentially smaller behavioural interaction effect.

The finding of the interaction-specific activity within the left IFG/anterior insula was related to outgroup homogeneity may have some implications for the similarity between the distance effect and the other-race effect. The other-race effect is the finding that recognition memory for same-race faces is generally more accurate than for other-race faces and it can have substantial consequences as it constitutes one of the classical biases that eyewitness testimony (Eysenck & Keane, 2015). Our findings may suggest that the increased homogeneity of social outgroups may be due to top-down modulation rather than perceptual experience in interacting with individuals of a different appearance. Therefore, these implication have the potential to broaden the impact of the current study for other researchers in the field of social prejudice\facial attractiveness.

In sum, the present research (i) demonstrated that low-distance beauty comparisons produced longer reaction times and lower accuracy compared to high-distance beauty comparisons, and this distance effect was found both for the ingroup judgments as well as for the outgroup judgments; (ii) it provides tentative evidence that the left IFG/anterior insula encodes a group*distance interaction and (iii) interaction-specific activity within this region was related to outgroup homogeneity. These findings pave the way for further studies into the mechanisms underlying group biases and their effect on social judgments.

References

Allport, G. W., Clark, K., & Pettigrew, T. (1954). The nature of prejudice.

Amodio, D. M., & Cikara, M. (2021). The social neuroscience of prejudice. *Annual Review of Psychology*, *72*, 439-469.

Bray, S., & O'Doherty, J. (2007). Neural coding of reward-prediction error signals during classical conditioning with attractive faces. *Journal of neurophysiology*, *97*(4), 3036-3045.

Brown, J. D., Novick, N. J., Lord, K. A., & Richards, J. M. (1992). When Gulliver travels: Social context, psychological closeness, and self-appraisals. *Journal of personality and social psychology*, *62*(5), 717.

Bzdok, D., Langner, R., Caspers, S., Kurth, F., Habel, U., Zilles, K., Laird, A., & Eickhoff, S. B. (2011). ALE meta-analysis on facial judgments of trustworthiness and attractiveness. *Brain Structure and Function*, *215*(3), 209-223.

Cloutier, J., Heatherton, T. F., Whalen, P. J., & Kelley, W. M. (2008). Are attractive people rewarding? Sex differences in the neural substrates of facial attractiveness. *Journal of cognitive neuroscience, 20*(6), 941-951.

Cohen Kadosh, R., Henik, A., Rubinsten, O., Mohr, H., Dori, H., Van De Ven, V., Zorzi, M., Hendler, T., Goebel, R., & Linden, D. E. (2005). Are numbers special?: The comparison systems of the human brain investigated by fMRI. *Neuropsychologia*, *43*(9), 1238-1248.

Dion, K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of personality and social psychology*, *24*(3), 285.

Efran, M. G. (1974). The effect of physical appearance on the judgment of guilt, interpersonal attraction, and severity of recommended punishment in a simulated jury task. *Journal of Research in Personality*, *8*(1), 45-54.

Feingold, A. (1992). Good-looking people are not what we think. *Psychological bulletin, 111*(2), 304.

Fiske, S. T., & Neuberg, S. L. (1990). A continuum of impression formation, from category-based to individuating processes: Influences of information and motivation on attention and interpretation. In *Advances in experimental social psychology* (Vol. 23, pp. 1-74). Elsevier.

Gebauer, J. E., Sedikides, C., Schönbrodt, F. D., Bleidorn, W., Rentfrow, P. J., Potter, J., & Gosling, S. D. (2017). The religiosity as social value hypothesis: A multi-method replication and extension across 65 countries and three levels of spatial aggregation. *Journal of Personality and Social Psychology, 113*(3), e18.

Hamermesh, D. S., & Biddle, J. E. (1993). Beauty and the labor market. In: National Bureau of Economic Research Cambridge, Mass., USA.

Hanel, P. H., Zarzeczna, N., & Haddock, G. (2019). Sharing the same political ideology yet endorsing different values: Left-and right-wing political supporters are more heterogeneous than moderates. *Social Psychological and Personality Science, 10*(7), 874-882.

Hughes, A. J., Denney, D. R., & Lynch, S. G. (2011). Reaction time and rapid serial processing measures of information processing speed in multiple sclerosis: Complexity, compounding, and augmentation. *Journal of the International Neuropsychological Society*, *17*(6), 1113-1121.

Hughes, B. L., Camp, N. P., Gomez, J., Natu, V. S., Grill-Spector, K., & Eberhardt, J. L. (2019). Neural adaptation to faces reveals racial outgroup homogeneity effects in early perception. *Proceedings of the National Academy of Sciences*, *116*(29), 14532-14537.

Kaplan, R. M. (1978). Is beauty talent? Sex interaction in the attractiveness halo effect. *Sex Roles*, *4*(2), 195-204.

Kawabata, H., & Zeki, S. (2008). The neural correlates of desire. *Plos one, 3*(8), e3027.

Kedia, G., Mussweiler, T., Adam, R., Ischebeck, A., Ihssen, N., & Linden, D. E. (2019). So pretty! The neural correlates of self-other vs familiar-other attractiveness comparisons. *Social Neuroscience*, *14*(1), 41-52.

Kedia, G., Mussweiler, T., Mullins, P., & Linden, D. E. (2014). The neural correlates of beauty comparison. *Social cognitive and affective neuroscience*, *9*(5), 681-688.

Kim, H., Adolphs, R., O'Doherty, J. P., & Shimojo, S. (2007). Temporal isolation of neural processes underlying face preference decisions. *Proceedings of the National Academy of Sciences*, *104*(46), 18253-18258.

Kniffin, K. M., Wansink, B., Griskevicius, V., & Wilson, D. S. (2014). Beauty is in the in-group of the beholded: Intergroup differences in the perceived attractiveness of leaders. *The Leadership Quarterly*, *25*(6), 1143-1153.

Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., & Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychological bulletin*, *126*(3), 390.

Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological science*, *1*(2), 115-121.

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: a network model of insula function. *Brain structure and function*, *214*(5), 655-667.

Moss, M. K., & Page, R. A. (1972). Reinforcement and Helping Behavior 1. *Journal of Applied Social Psychology*, *2*(4), 360-371.

Nieder, A., & Dehaene, S. (2009). Representation of number in the brain. *Annual review of neuroscience*, *32*, 185-208.

Ohmann, K., Stahl, J., Mussweiler, T., & Kedia, G. (2016). Immediate relativity: EEG reveals early engagement of comparison in social information processing. *Journal of Experimental Psychology: General*, *145*(11), 1512.

Perrett, D. I., Burt, D. M., Penton-Voak, I. S., Lee, K. J., Rowland, D. A., & Edwards, R. (1999). Symmetry and human facial attractiveness. *Evolution and human behavior*, *20*(5), 295-307.

Pettijohn II, T. F., & Tesser, A. (1999). Popularity in environmental context: Facial feature assessment of American movie actresses. *Media Psychology*, *1*(3), 229-247.

Piliavin, I. M., Piliavin, J. A., & Rodin, J. (1975). Costs, diffusion, and the stigmatized victim.

Rhodes, G. E., & Zebrowitz, L. A. (2002). *Facial attractiveness: Evolutionary, cognitive, and social perspectives*. Ablex Publishing.

Roiser, J., Linden, D., Gorno-Tempinin, M., Moran, R., Dickerson, B., & Grafton, S. (2016). Minimum statistical standards for submissions to Neuroimage: Clinical. *NeuroImage: Clinical*, *12*, 1045.

Sigall, H., & Ostrove, N. (1975). Beautiful but dangerous: effects of offender attractiveness and nature of the crime on juridic judgment. *Journal of personality and social psychology*, *31*(3), 410.

Singh, D. (1993). Adaptive significance of female physical attractiveness: role of waist-to-hip ratio. *Journal of personality and social psychology*, *65*(2), 293.

Thorndike, E. L. (1920). A constant error in psychological ratings. *Journal of applied psychology*, *4*(1), 25.

Whitfield-Gabrieli, S., & Nieto-Castanon, A. (2012). Conn: a functional connectivity toolbox for correlated and anticorrelated brain networks. *Brain connectivity*, *2*(3), 125-141.

Wolf, L. J., Hanel, P. H., & Maio, G. R. (2021). Measured and manipulated effects of value similarity on prejudice and well-being. *European Review of Social Psychology*, *32*(1), 123-160.

Zacharopoulos, G., Hertz, U., Kanai, R., & Bahrami, B. (2022). The effect of feedback valence and source on perception and metacognition: An fMRI investigation. *Cognitive neuroscience*, *13*(1), 38-46.

Zhou, Y., Gao, T., Zhang, T., Li, W., Wu, T., Han, X., & Han, S. (2020). Neural dynamics of racial categorization predicts racial bias in face recognition and altruism. *Nature human behaviour*, *4*(1), 69-87.

Citation on deposit: Zacharopoulos, G., Ohmann, K., Ihssen, N., Kedia, G., Mussweiler, T., & Linden, D. E. (2023). The role of outgroup homogeneity and the neurodynamics of the frontal cortex during beauty comparisons. Social Neuroscience, 18(6), 382-392. https://doi.org/10.1080/17470919.2023.2242098