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

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1 **Abstract**

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

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

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23 **Introduction**

## Neural correlates of social comparison

1           The perception of physical beauty can have far-ranging implications (Kedia et al.,  
2 2014). For example, attractive individuals are perceived to possess several positive  
3 characteristics (e.g., more intelligent, honest, kind, sociable, dominant, talented, and mentally  
4 healthy), and were shown to be treated more favourably (e.g., paid higher salaries, milder  
5 criminal sentences) compared to less attractive individuals (Dion et al., 1972; Efran, 1974;  
6 Feingold, 1992; Hamermesh & Biddle, 1993; Kaplan, 1978; Langlois et al., 2000; Moss &  
7 Page, 1972; Piliavin et al., 1975; Sigall & Ostrove, 1975; Thorndike, 1920). Given the  
8 importance of attractiveness, prior work examined the psychological and neurobiological  
9 mechanisms by which humans judge the appearance of others. Correlational and  
10 experimental methods that mainly assessed attractiveness judgements in response to human  
11 physical attributes demonstrated the involvement of several factors in the formation of beauty  
12 judgments, such as symmetry, averageness, youthfulness, waist-to-hip ratio, and external or  
13 internalized standards (Brown et al., 1992; Hamermesh & Biddle, 1993; Langlois &  
14 Roggman, 1990; Perrett et al., 1999; Pettijohn II & Tesser, 1999; Rhodes & Zebrowitz, 2002;  
15 Sigall & Ostrove, 1975; Singh, 1993).

16           Neuroimaging studies highlighted the importance of three brain networks during  
17 beauty judgments. The first network involves reward-related areas such as the nucleus  
18 accumbens and the orbitofrontal cortex, whereby attractive faces elicit greater activity within  
19 these regions (Bray & O'Doherty, 2007; Bzdok et al., 2011; Cloutier et al., 2008; Kawabata  
20 & Zeki, 2008; Kim et al., 2007). The second network is the frontoparietal control network,  
21 which among other functions subserves mental comparison processes, which are at the heart  
22 of beauty judgments (Kedia et al., 2014). A classic effect in the literature that applies in the  
23 context of the frontoparietal control network is the distance effect, which states that the closer  
24 the two compared magnitudes (e.g. two numbers), the more difficult the comparison, and the  
25 greater the activity of this frontoparietal control network (Cohen Kadosh et al., 2005; Nieder

1 & Dehaene, 2009). In the context of physical beauty, the distance effect was observed when  
2 comparing the beauty of two unknown people (Kedia et al., 2014). In particular, low-distance  
3 beauty comparisons elicited longer reaction times, lower accuracy and greater recruitment of  
4 the frontoparietal control network compared to high-distance beauty comparisons (Kedia et  
5 al., 2014). The same behavioural effect was observed with other types of beauty comparisons,  
6 for example when comparing ourselves to an unknown person (i.e., self-other beauty  
7 comparison) or when comparing the beauty of a familiar person to that of an unknown person  
8 (i.e., familiar-other beauty comparison) (Kedia et al., 2019). At the brain level, these types of  
9 judgments involved a third network of supplementary motor area/dorsomedial prefrontal  
10 cortex frontal and anterior insula, where the effect of distance was stronger for the self-other  
11 than the familiar-other comparisons (Kedia et al., 2019). This predilection for self-other  
12 comparisons is compatible with the recognized role of these areas in self-referential  
13 processing. These studies showed that the engagement of the fronto-striatal “reward”, the  
14 frontoparietal control “comparison” and the mediofrontal–insular “self” network varied  
15 according to the nature of the beauty judgment.

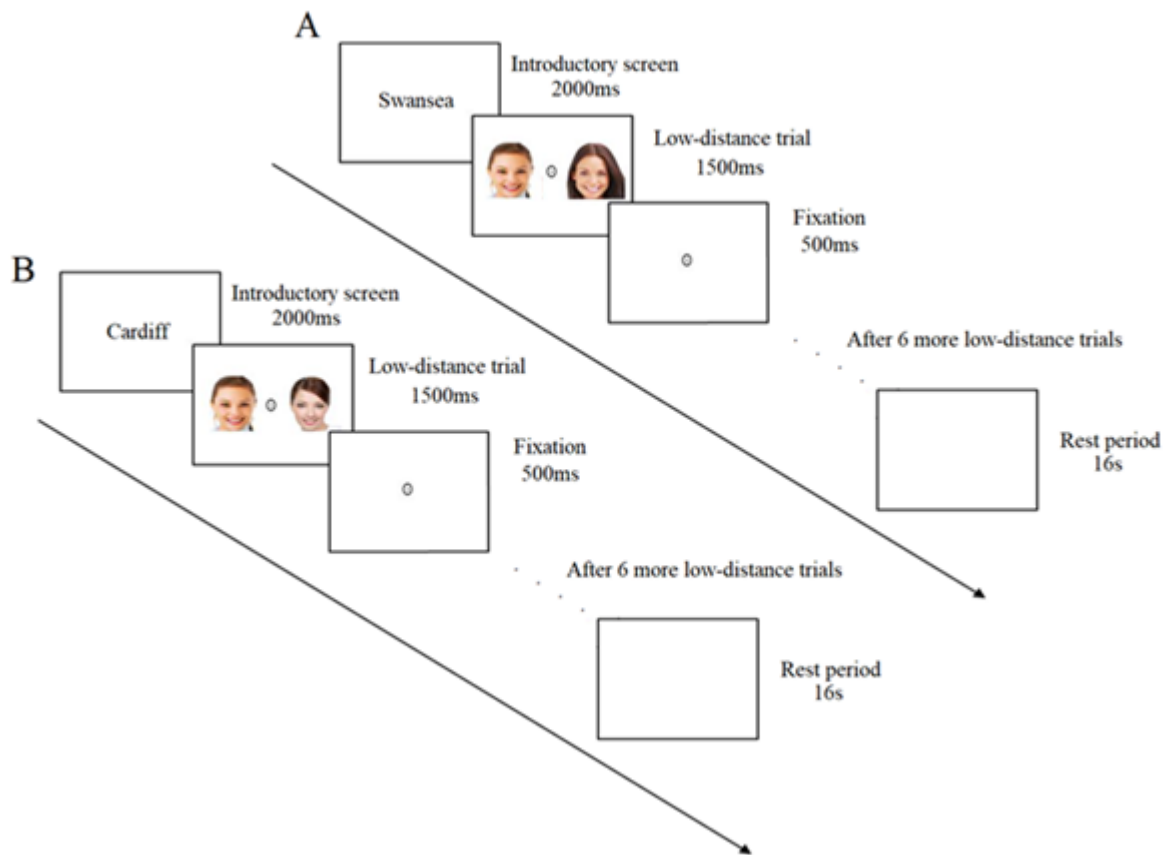
16         Membership in a social group is a crucial factor influencing beauty judgments. For  
17 example, individuals have more favourable mental representations (including more attractive  
18 faces) of ingroup vs outgroup members (Hong & Ratner, 2021; Ratner et al., 2014),  
19 subordinates rate the leaders of their ingroups as significantly more physically attractive than  
20 comparably familiar outgroup leaders (Kniffin et al., 2014), and facial appearance predicts  
21 inclusion into the ingroup (Bjornsdottir et al., 2022). Nevertheless, the extent to which the  
22 activation of the above-outlined neural networks is modulated by the ingroup-outgroup status  
23 of the target person has not been investigated thus far. One important factor potentially  
24 influencing beauty judgments of outgroup versus ingroup members is outgroup homogeneity,  
25 which is the tendency to view members of social outgroups as interchangeable, which has

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1 long been considered a core component of intergroup bias and a precursor to stereotyping and  
2 discrimination (Hughes et al., 2019; Quattrone & Jones, 1980). For example, perceiving  
3 outgroup members in categorical terms and consequently being unable to distinguish between  
4 them constitutes a crucial element of stereotyping, which can have life-changing real-world  
5 effects such as faulty eyewitness testimony (Allport et al., 1954; Fiske & Neuberg, 1990;  
6 Hughes et al., 2019). However, our knowledge on the extent to which the activation of these  
7 networks is shaped by differences in the perception of the outgroup is still limited.

8         Our present study has two aims: (i) to elucidate the brain networks engaged in ingroup  
9 and outgroup beauty comparisons in a classic distance effect paradigm, and (ii) to identify  
10 whether the activation of these networks is shaped by perceptions of outgroup homogeneity.  
11 To this end, we conducted an fMRI study (**Fig 1**) where we asked participants to compare the  
12 beauty of pairs of unknown women ostensibly from the participants' ingroup (ingroup  
13 comparison condition) or from an outgroup (outgroup comparison condition). Moreover, in  
14 some blocks the beauty difference between the target women was high (high-distance  
15 condition) or low (low-distance condition), producing a 2 (group: ingroup vs outgroup) x 2  
16 (distance: high vs low) design. Lastly, we additionally assessed via a questionnaire  
17 participants' perceptions about the ingroup and outgroup, including a measure of outgroup  
18 homogeneity. We used membership of the largest universities of two urban centres in South  
19 Wales, Cardiff and Swansea, as "in- "vs. "outgroup" manipulation. Cardiff and Swansea,  
20 which are approximately 45 miles apart, are the two biggest cities in Wales based on  
21 population size. These two cities represent distinct social identities spanning several social  
22 dimensions, including the rugby and football rivalry within and beyond sports stadiums  
23 between the "Jacks" of Swansea and the "Bluebirds" of Cardiff. For example, the South  
24 Wales derby is a local derby between Welsh association football clubs Cardiff City and  
25 Swansea City. Moreover, it is common practice to use university identities as group

1 membership (Bernstein et al., 2007), and minimal group memberships were shown to induce  
2 biases in even early visual processing (Hong et al., 2022). Therefore, we believe that an  
3 explicit tag of university membership is sufficient to elicit processes related to  
4 ingroup/outgroup affiliation given the absence of perceptual or implicit cues of  
5 ingroup/outgroup affiliation such as skin colour, gender and age.



6

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

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14 **Material and Methods**

## 1 **Participants**

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

## 8 **Materials and Methods**

9           The stimulus set used in the present study consisted of 148 coloured images of female  
10 faces used in previous fMRI and EEG research (Kedia et al., 2014; Ohmann et al., 2016).  
11 These images were pretested for beauty ratings in a separate female sample (Kedia et al.,  
12 2014) which enabled the formation of three distinct categories: faces of high beauty, of  
13 moderate beauty, and of low beauty. These three groups (i.e, faces of high beauty, of  
14 moderate beauty, and of low beauty) were determined before the start of the current study.  
15 They were specifically based on pre-test and post-test (ANOVA and t-test) validation  
16 analyses the results of which are published in the **Supplementary Material** of our prior work  
17 (Kedia et al., 2014). To create high-distance pairs, we matched faces that were judged as  
18 being of high and low beauty. Low-distance pairs consisted of moderately attractive faces,  
19 combined with faces that were either high or low in beauty. In sum, we created 294 pairs, half  
20 of them being of high and half of them being of low distance, whose mean beauty levels did  
21 not differ,  $t(292)=-.061$ ,  $p=.951$ , Cohen's  $d=.07$ . Of note, we defined accuracy or correctness  
22 of behavioural responses based on these normative ratings.

23           To avoid any confounding influence of facial expressions, we created pairs of female  
24 faces who either both smiled or both looked neutral. We also equated the distribution of



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1 smiling and non-smiling pairs across the low and the high distance condition. Moreover, to  
2 rule out that any differences between the conditions arise from differences in low-level visual  
3 properties of the stimuli, we calculated mean scores concerning luminance, colour, and local  
4 frequency for each pair of images. Our analysis revealed no significant differences between  
5 the high and low distance beauty conditions in any of these properties,  $t_s(292) < 1.45$ ,  $p_s >$   
6  $.148$ ,  $d_s < .20$ . There are several reasons for the suitability of this face database selection.  
7 First, the stimulus set consisted of female faces the physical characteristic (tone, shape etc.)  
8 of which match the ones of the target (i.e., Welsh) population; therefore, it was believable  
9 that the target stimuli represented people from Cardiff and Swansea University students.  
10 Second, we used this face database because there were no differences in low-level visual  
11 properties (luminance, colour, and local frequency) for each pair of images which could have  
12 confounded our analyses. Third, the stimulus set used in the current study (i.e., female faces)  
13 was used in previous neuroimaging (fMRI and EEG) research (Kedia et al., 2014; Ohmann et  
14 al., 2016).

### 15 **Cover Story**

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

### 24 **Questionnaire**

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1           To assess individual differences in participants' degree of identification with the  
2 group, we created a questionnaire that assessed participants' attitudes towards Cardiff and  
3 Swansea University. On a rating scale from 1 (*=not at all*) to 7 (*=very*), one item assessed  
4 participants' degree of identification with Cardiff University, three items assessed perceived  
5 similarity ((i) "In your opinion: How similar are students from Cardiff University and the  
6 University of Swansea?", (ii) "In your opinion: How similar are the students at Cardiff  
7 University?") and the outgroup homogeneity measure ("In your opinion: How similar are the  
8 students at the University of Swansea?"). The outgroup homogeneity score for each  
9 participant, was a single score that was assessed with a single item ("In your opinion: How  
10 similar are the students at Swansea University?") on a rating scale from 1 (*=not at all*) to 7  
11 (*=very*). Please note that assessing social psychological constructs (e.g., outgroup  
12 homogeneity) using a single item has been utilized in several prior studies for a wide range of  
13 constructs including political attitudes, life satisfaction, religiosity, self-esteem, and self-  
14 efficacy (Gebauer et al., 2017; Hanel et al., 2019; Wolf et al., 2021; Zacharopoulos et al.,  
15 2022). Furthermore, this questionnaire contained two items assessing participants'  
16 willingness to pay for a calendar displaying female faces from either Cardiff or Swansea  
17 University, to measure the degree of identification with the ingroup (How much money  
18 would you be willing to pay for a calendar that shows the faces of the female students from  
19 Cardiff University?) relative to the outgroup (How much money would you be willing to pay  
20 for a calendar that shows the faces of the female students from Swansea University?), in that  
21 the more someone is willing to pay for the "ingroup" vs the "outgroup" calendar the more  
22 he/she is identified with the ingroup relative to the outgroup. Lastly, the questionnaire  
23 featured some demographic variables, such as age, sex, and field of study.

24

## 25 **Procedure**

1           Prior to scanning, all participants underwent an MRI safety screening, were  
2 familiarized with the scanning environment and performed a ten-trial training session with  
3 different stimuli as those used in the fMRI session. The scanning session comprised three  
4 functional runs and the acquisition of a structural image, leading to a total scanning time of  
5 approximately 30 minutes. A single run comprised 14 active blocks and 14 blocks of rest. In  
6 each active block, an introductory screen was presented for 2000 milliseconds indicating the  
7 following targets' group membership (Cardiff vs Swansea) and was succeeded by seven trials  
8 (1500 milliseconds each) of simultaneously presented women that were either all of high or  
9 all of low distance. Trials were separated by a fixation cross lasting 500 milliseconds. Stimuli  
10 were presented via a 45° angled mirror positioned above the head coil reflecting the  
11 projection of a computer screen. Participants indicated on each trial whether they regarded  
12 the woman presented on the left or the woman presented on the right as more attractive by  
13 pressing a button placed below their left or a button placed below their right hand. Half of the  
14 active blocks consisted of trials that presented women who were ostensibly from Cardiff  
15 University and the other half that were ostensibly from Swansea University, again half of  
16 them being of high and half of them being of low distance (for an example, see **Fig 1**). After  
17 the scanning procedure, participants answered the questionnaire described above, were  
18 debriefed, thanked, and paid £10.

### 19 **MRI Data Acquisition**

20           MRI images were acquired with a General Electric 3T scanner equipped with an 8HR  
21 Brain parallel head coil for radio frequency transmission/reception. Anatomical high-  
22 resolution T1-weighted volume scans (1mm<sup>3</sup>) were acquired using FSPGR 256\*192 3-D  
23 sequence (TR=8.8ms; TE=3.5ms; voxel size=1x1x1mm, 182 slices). Functional images were  
24 acquired with a gradient-echo EPI sequence [TR=2000ms, TE=35ms, flip angle=80 degrees,

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1 slice thickness=3mm, gap=1mm). Each volume consisted of 34 slices obtained in an  
2 ascending interleaved order.

### 3 **fMRI data pre-processing and analyses**

4         Imaging data were pre-processed in CONN (Whitfield-Gabrieli & Nieto-Castanon,  
5 2012) (a toolbox in SPM12) using the default MNI-space direct normalization pre-processing  
6 pipeline which performs several steps including realignment, slice-timing correction,  
7 structural segmentation and normalization, functional normalization and smoothing  
8 (FWHM=8mm). In the first-level analyses, separate regressors were included for the four  
9 conditions: (i) high-distance ingroup, (ii) low-distance ingroup, (iii) high-distance outgroup,  
10 (iv) low-distance outgroup. To remove variations in signal due to movement artefacts, we  
11 included the movement parameters (6 overall, 3 translations, and 3 rotations, which are  
12 automatically computed during realignment) in the models as parameters of no interest. The  
13 conditions were initially modelled with a boxcar function from the onset to the offset of each  
14 block and the predictors were convolved with a canonical hemodynamic response function to  
15 produce the predicted BOLD signal. Moreover, we excluded all runs where there was >2mm  
16 movement in either of the three translations (x,y,z), overall we excluded 13% of the runs in  
17 this study (i.e., 8 runs from all possible 60). We created three contrasts during the first-level  
18 analyses (examining the effects of distance [.5 -.5 .5 -.5], group [.5 .5 -.5 -.5], and the  
19 distance\*group interaction [.5 -.5 -.5 .5]) and then entered the contrast of parameter estimate  
20 images into a second-level group analysis. Please note that since we utilized a whole-brain  
21 voxel-wise  $P_{FWE} < .05$  threshold the cluster sizes are expected to be smaller relative to using a  
22 cluster-wise threshold, this is because the cluster-wise threshold approach uses a more lenient  
23 voxel-wise correction (i.e., typically  $P_{uncorrected} < .001$ ) compared to the voxel-wise correction  
24 threshold used here ( $P_{FWE} < .05$ ). Statistical analysis was conducted with the SPM toolbox

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1 Statistical Non-Parametric Mapping (SnPM, <http://warwick.ac.uk/snpm>) which uses the  
2 GLM to construct *t*-statistic images, which are then assessed for significance using a standard  
3 non-parametric procedure based on randomization/permutation testing. Our approach is  
4 consistent with current guidelines on the reporting of whole-brain MRI data (Roiser et al.,  
5 2016). Throughout the manuscript, the xyz coordinates of each region are in MNI space. The  
6 error bars in **Fig 3** represented the 95% confidence intervals in raw beta-weights calculated  
7 based on our sample. After completing the second-level analyses, raw beta-weights were  
8 extracted from the four regions of interest in response to the relevant contrast of interest using  
9 the MarsBar toolbox (Brett et al., 2002) within the SPM package yielding 20 (number of  
10 participants) raw beta-weights for every region. We then performed regression analyses (**Fig**  
11 **4A**) with bootstrapping (bootstrapped P-values denoted as  $P_{BO}$ ) between the individual  
12 variation in these raw beta-weights (i.e., 20 values, 1 per participant per region) per region  
13 and the corresponding values of the questionnaire items (i.e., 20 values, 1 per participant per  
14 questionnaire item). For visualization purposes, we also extracted the raw beta-weights of  
15 each of the four conditions separately from the four regions of interest using the MarsBar  
16 toolbox (Brett et al., 2002), which we plot in **Fig 3A-D** and **Fig 4B-E**. Of note, apart from the  
17 left IFG/insula cluster (**Fig 3C**), three more clusters reached statistical significance during our  
18 neuroimaging analyses (see, **Results** section). However, we believe that the cluster in Fig 3A  
19 which seems to be within the ventricles may be in response to the smoothing effect, and the  
20 patterns in Fig 3B and Fig 3D are difficult to explain in the context of the present study.

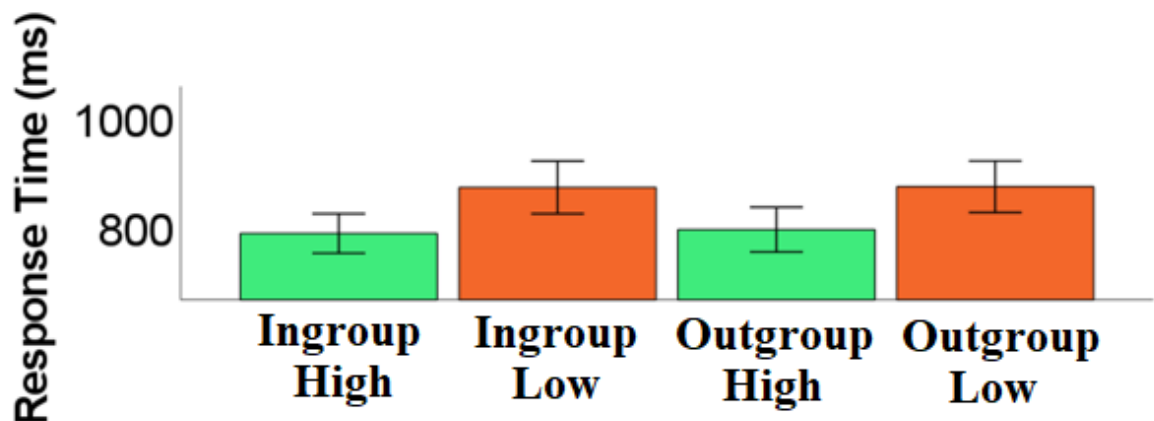
## 21 **Results**

### 22 **Behavioural data**

23 As a first step, we calculated mean reaction times for every participant in each condition  
24 and submitted these means to a 2 (group: ingroup vs outgroup) x 2 (distance: high vs low)

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1 ANOVA. We observed a strong main effect of distance on the mean reaction time, ( $F(1,$   
2  $19)=87.03, P<.001, \eta^2=.821$ ), whereby, low-distance trials led to longer response times  
3 ( $M=867\text{ms}$ ) than high-distance trials ( $M=784\text{ms}$ ; **Fig 2**), and on accuracy ( $F(1,19)=157.6,$   
4  $P<.001, \eta^2=.892$ ), whereby, low distance trials led to reduced accuracy ( $M=79\%$ ) than high  
5 distance trials ( $M=92\%$ ). We observed no additional main or interaction effects ( $ps>.05$ )  
6 either in our mean reaction time or accuracy analyses.



8

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

## 12 Neuroimaging analyses

13 We examined the effect of distance (high vs low), the effect of group (ingroup vs  
14 outgroup) as well as the distance\*group interaction at the neural level (for details, see  
15 **Materials and Methods** section). The high-distance conditions elicited higher activation in a  
16 region neighbouring the right hippocampus ( $T=5.46, P_{\text{FWE}}=.022, x=30, y=-40, z=4, k=6, \text{Fig}$   
17 **3A**) compared to the low-distance conditions. No significant effect was identified for the  
18 contrast ingroup vs outgroup.

## Neural correlates of social comparison

1           We found three clusters with a significant interaction effect. Low-distance ingroup  
2 processing and high-distance outgroup processing elicited a negative correlation with the  
3 BOLD within the precentral/postcentral gyrus ( $T=5.78$ ,  $P_{FWE}=.029$ ,  $x=-12$ ,  $y=-32$ ,  $z=68$ ,  $k=3$ ,  
4 **Fig 3B**) compared to the high-distance ingroup processing and the low-distance outgroup  
5 processing. The interaction effect in the left IFG/ anterior insula was driven by higher  
6 activation for the low-distance ingroup condition ( $T=6.78$ ,  $P_{FWE}=.006$ ,  $x=-36$ ,  $y=20$ ,  $z=14$ ,  
7  $k=12$ , **Fig 3C**) and in the right IFG/ anterior insula BOLD signal was negatively correlated  
8 with the low-distance outgroup condition ( $T=6.06$ ,  $P_{FWE}=.016$ ,  $x=36$ ,  $y=8$ ,  $z=12$ ,  $k=5$ , **Fig**  
9 **3D**).

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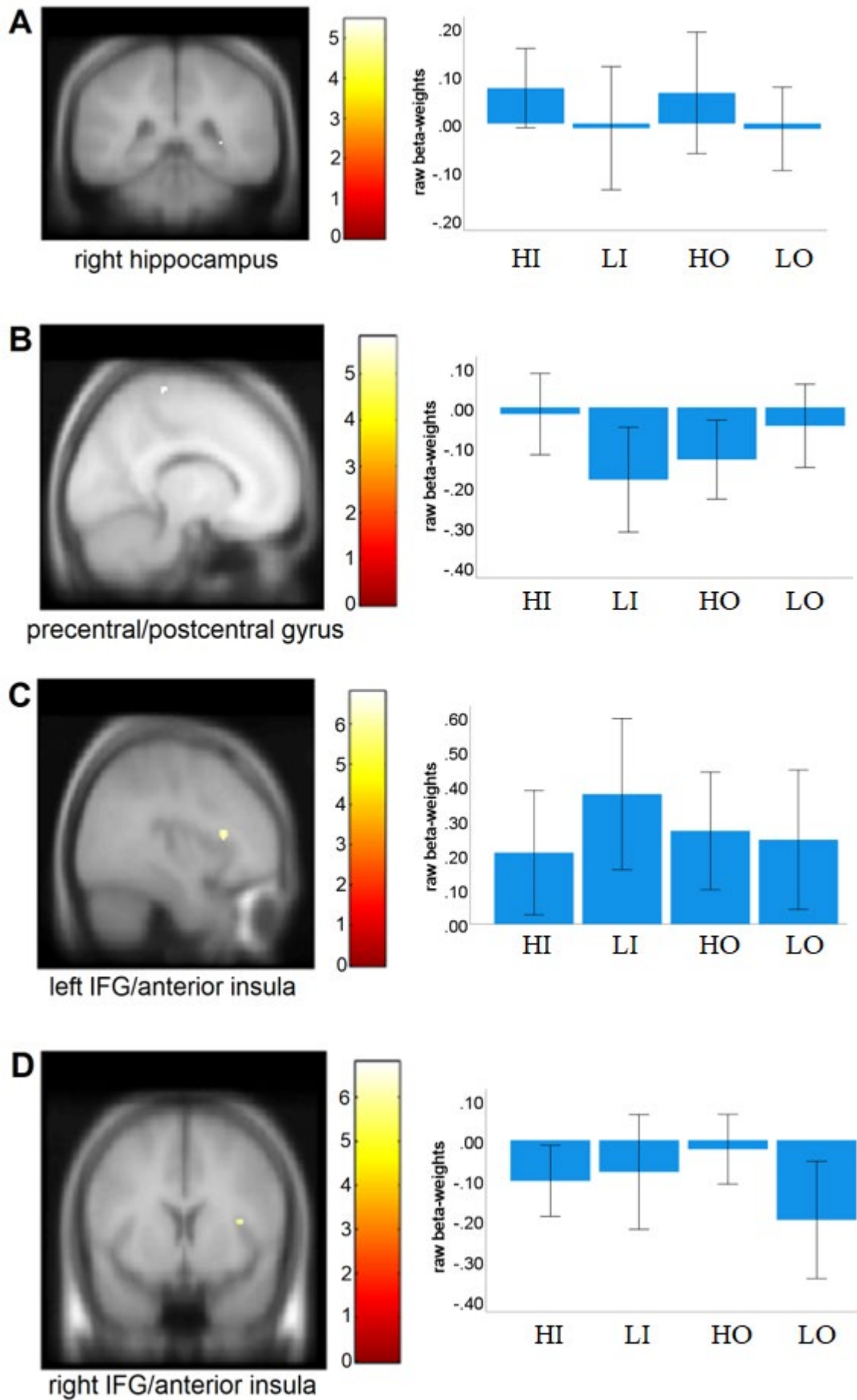
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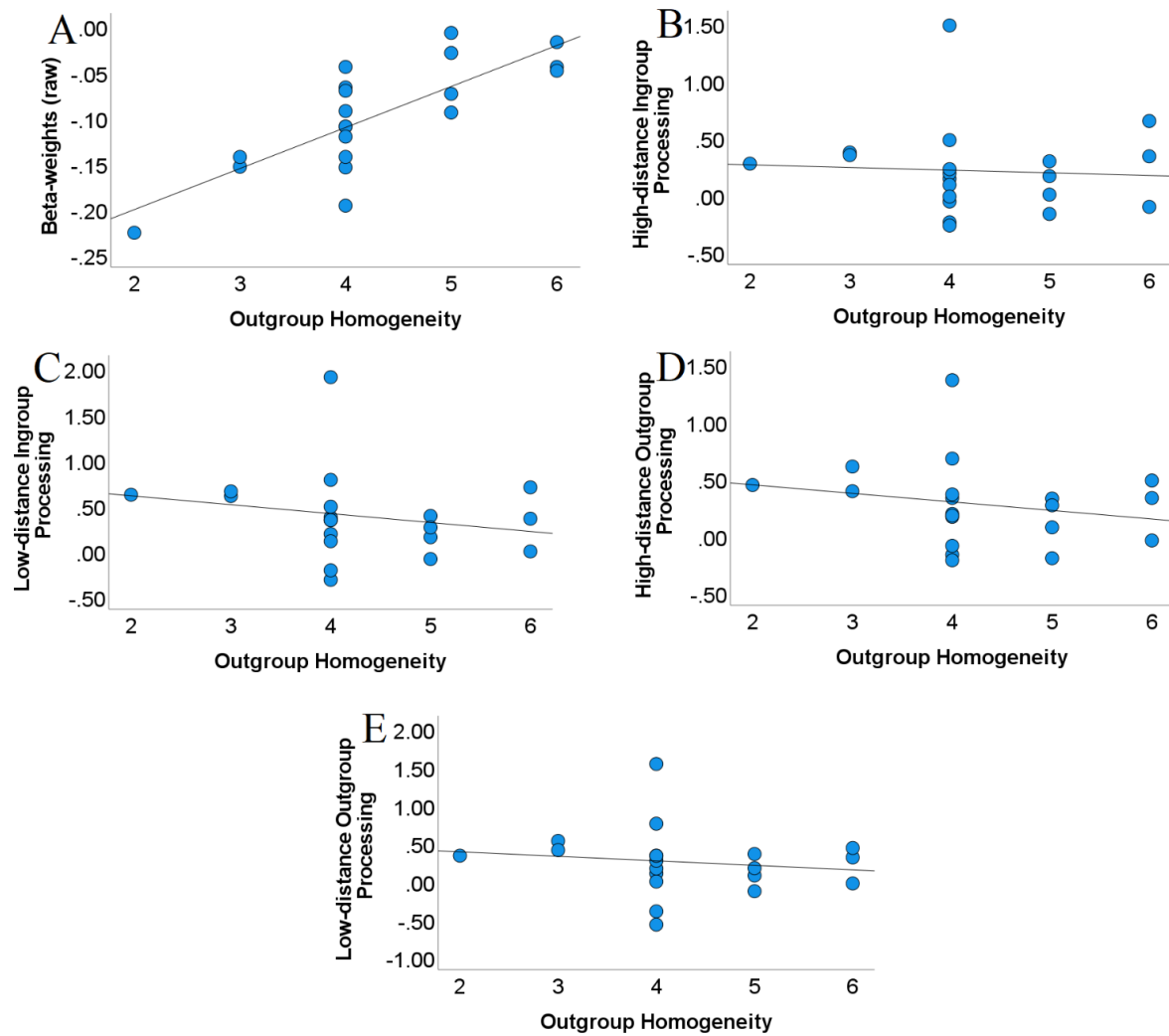
1 **3.** Neuroimaging results in response to the effect of distance (Panel **A**) and the  
2 distance\*group interaction (Panels **B**, **C**, **D**), and the corresponding raw beta weights (y-axis,  
3 error bars represent 95% confidence intervals of means) in each of the four conditions  
4 (H=high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

### 6 **Neuroimaging-behaviour analyses**

7       After assessing the neuroimaging results, we examined whether interindividual  
8 variation in behavioural scores modulated the activity within the four regions identified in the  
9 neuroimaging analyses (**Fig 3**). To this end, we extracted the beta-weights of each of the four  
10 regions, and from the 20 comparisons (4 [brain regions]\*5 [questionnaire measures]) re ran,  
11 one comparison survived the FDR correction. Namely, we identified a significant association  
12 in the left IFG/ anterior insula, the cluster depicted in **Fig 3C** (**Fig 4A**) and outgroup  
13 homogeneity (i.e., raw beta-weights of **Fig 3C**,  $\beta=.779$ ,  $t(18)=5.27$ ,  $CI=[.555\ 1.000]$ ,  
14  $P_{BO}<.001$ ,  $P_{FDR}=0.00104$ ).

15       As a next step, we discerned the extent to which perceptions of outgroup homogeneity  
16 shape the four individual brain measures that make up the interaction effect (i.e., high-  
17 distance ingroup processing, low-distance ingroup processing, high-distance outgroup  
18 processing, low-distance outgroup processing) independently, which was not the case.  
19 Namely, outgroup homogeneity scores were not significantly associated with any of the four  
20 brain measures independently: high-distance ingroup processing (**Fig 4B**,  $\beta=-.062$ ,  $t(18)=-$   
21  $.265$ ,  $CI=[-.423\ .271]$ ,  $P_{BO}=.712$ ), low-distance ingroup processing (**Fig 4C**,  $\beta=-.215$ ,  $t(18)=-$   
22  $.934$ ,  $CI=[-.525\ .086]$ ,  $P_{BO}=.178$ ), high-distance outgroup processing (**Fig 4D**,  $\beta=-.212$ ,  
23  $t(18)=-.921$ ,  $CI=[-.546\ .107]$ ,  $P_{BO}=.195$ ), low-distance outgroup processing (**Fig 4E**,  $\beta=-.141$ ,  
24  $t(18)=-.606$ ,  $CI=[-.449\ .122]$ ,  $P_{BO}=.280$ ).

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1

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

7

## 8 Discussion

9 In the present study, we (i) examined the neural mechanisms of ingroup and outgroup  
10 beauty comparisons using an adaptation of a classical magnitude comparison paradigm  
11 (Cohen Kadosh et al., 2005; Kedia et al., 2019; Kedia et al., 2014), and (ii) discerned how  
12 interindividual variation in outgroup homogeneity relates to these neural mechanisms. Three  
13 main findings emerge from this study: (i) low-distance beauty comparisons produced longer

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1 reaction times and lower accuracy compared to high-distance beauty comparisons, and this  
2 distance effect was found both for the ingroup judgments as well as for outgroup judgments;  
3 (ii) the left IFG/anterior insula encoded the group\*distance interaction effect, and (iii)  
4 interaction-specific activity within this region correlated with outgroup homogeneity assessed  
5 via a questionnaire.

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

21 Our study did not show a general involvement of the frontoparietal control network in  
22 response to the low-distance vs high-distance conditions found in some (Kedia et al., 2014)  
23 but not all previous studies (Kedia et al., 2019). However, a closer examination of the  
24 interaction effects shows that the left IFG/anterior insula encoded the classic distance effect

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1 for the ingroup (higher activity in the low-distance compared to the high-distance conditions)  
2 but not for the outgroup (no significant differences in activity between the outgroup low-  
3 distance and outgroup high-distance conditions). Previous research suggested that the anterior  
4 insula is important in identifying relevant/salient stimuli from the overall stimuli in the  
5 environment (Menon & Uddin, 2010) and it was also shown to track the distance effect in the  
6 context of attractiveness among social conditions (Kedia et al., 2019). Notably, the left  
7 IFG/anterior insula cluster found in this study in response to the group\*distance interaction  
8 overlaps with the left anterior insula cluster identified previously where the authors found  
9 that this cluster tracked the distance effect more strongly for self-other than familiar-other  
10 comparisons (Kedia et al., 2019). In the present study, the ingroup conditions are  
11 hypothesized to be most relevant/salient rather than the outgroup conditions, and indeed the  
12 left IFG/anterior insula was shown to track the distance effect only in the salient (ingroup)  
13 but not the not-salient (outgroup) conditions. However, we appreciated that the sample size  
14 was small, particularly for documenting individual differences at the behavioural or at the  
15 neuroimaging level, thus, these results should be interpreted with caution. Replication and  
16 extension of the current findings need to be investigated in larger sample sizes in future work.

17 Our study also addresses the link between perceptions of outgroup homogeneity and  
18 brain activity. Despite the considerable knowledge of the psychological building blocks of  
19 prejudice (e.g., processes of social categorization, prejudice formation, and intergroup  
20 emotion and perception), our understanding of the neurocomputational bases of outgroup  
21 homogeneity is only beginning to emerge (Amodio & Cikara, 2021). An fMRI study revealed  
22 outgroup homogeneity effects in early face-selective cortex suggesting that outgroup  
23 deindividuation emerges at some of the earliest stages of face perception in the form of  
24 reduced neural sensitivity to variability among other-race faces (Hughes et al., 2019).  
25 Moreover, the human brain uses different neural systems to sort people into different groups

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1 and dynamic neural responses within these systems predicted racial biases in face recognition  
2 and altruistic intention (Zhou et al., 2020). Here we extend these findings by showing that  
3 perceptions of outgroup homogeneity are not confined to sensory areas, but also found in the  
4 frontal cortex. Specifically, interaction-specific activity within the left IFG/anterior insula  
5 was related to perceptions of outgroup homogeneity. Notably, outgroup homogeneity scores  
6 were not significantly associated with any of the four conditions independently (**Fig 4**). This  
7 finding suggests that perceptions of outgroup homogeneity exert an effect beyond solely the  
8 perceptions of outgroup processing. Instead, our perceptions of an outgroup may shape the  
9 relative difference between the ingroup vs outgroup conditions depending on the distance  
10 effect. We speculate that the underlying psychological mechanisms at play here may involve  
11 ingroup-outgroup comparison processes. Namely, perceptions of outgroup homogeneity seem  
12 to shape the left IFG/anterior insula activity in the context of beauty processing via an  
13 ingroup-outgroup comparison process.

14         In the present study, we choose to equate visual input by keeping the stimuli (i.e.,  
15 pictures of female faces) identical between the ingroup vs outgroup conditions. This was  
16 done as we deliberately aimed to isolate the effects of our manipulation on later processing  
17 stages and establish a clear effect of outgroup homogeneity by not conflating earlier (visual)  
18 stages of processing that have been studied elsewhere (Hughes et al., 2011; Zhou et al.,  
19 2020). Moreover, we have chosen this design as in many real-life situations the ingroup and  
20 outgroup members are indeed physically indistinguishable (e.g., members of a different  
21 sexual orientation or a political ideology). However, there are also cases where outgroup  
22 members are visually distinct from ingroup members (e.g., skin tone), and it is currently an  
23 open question whether the findings of this study generalize to these scenarios.

24         As mentioned above, we indicated that the ingroup conditions are hypothesised to be  
25 most relevant/salient rather than the outgroup conditions, and indeed the left IFG/anterior

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

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1           As summarised elsewhere, prior social neuroscience studies demonstrated the effects  
2 of group membership on perceptual processes (Van Bavel & Cunningham, 2009). The current  
3 study did not find significant ingroup vs outgroup brain activation differences in beauty  
4 comparison. Besides the relatively small sample size, this lack of significant effect may  
5 primarily result from the fact that the current study equated visual stimuli in the ingroup and  
6 outgroup conditions which reduces the likelihood of inducing low-level (e.g., visual) brain  
7 activation differences.

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

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

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