1 Idiosyncratic, retinotopic bias in face identification
2 modulated by familiarity

3 Abbreviated title: Retinotopic bias in face identification

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31

Abstract

The perception of gender and age of unfamiliar faces is reported to vary idiosyncratically across retinal locations such that, for example, the same androgynous face may appear to be male at one location but female at another. Here we test spatial heterogeneity for the recognition of the *identity* of personally familiar faces. We found idiosyncratic biases that were stable within subjects and that varied more across locations for low as compared to high familiar faces. These data suggest that like face gender and age, face identity is processed, in part, by independent populations of neurons monitoring restricted spatial regions and that the recognition responses vary for the same face across these different locations. Moreover, repeated exposure to the same face in different portions of the visual field due to repeated and varied social interactions appears to lead to adjustment of these independent face recognition neurons so that the same familiar face is eventually more likely to elicit the same recognition response across widely separated regions.

Significance statement

In this work we tested spatial heterogeneity for the recognition of personally familiar faces. We found retinotopic biases that varied more across locations for low as compared to highly familiar faces. The retinotopic biases were idiosyncratic and stable within subjects. Our data suggest that, like face gender and age, face identity is processed by independent populations of neurons

55 monitoring restricted spatial regions and that recognition may vary for the same

56 face at these different locations. Unlike previous findings, our data show how

57 the effect of learning modifies the representation of face identity in

58 retinotopically-organized visual cortex. This new perspective has broader

59 implications for understanding how learning optimizes visual processes for

60 socially salient stimuli.

61 ## Introduction

62 We spend most of our days interacting with acquaintances, family and close

63 friends. Because of these repeated and protracted interactions, the

64 representation of personally familiar faces is rich and complex, as reflected by

65 stronger and more widespread neural activation in the distributed face

66 processing network, as compared to responses to unfamiliar faces (Gobbini and

67 Haxby, 2007; Taylor et al., 2009; Gobbini, 2010; Natu and O'Toole, 2011; Bobes

68 et al., 2013; Sugiura, 2014; Ramon and Gobbini, 2017; Visconti di Oleggio

69 Castello et al., 2017a). Differences in representations of familiar as compared to

70 unfamiliar faces is also reflected in faster detection of familiar faces and more

71 robust recognition (Burton et al., 1999; Gobbini et al., 2013; Ramon et al., 2015;

72 Visconti di Oleggio Castello and Gobbini, 2015; Visconti di Oleggio Castello et

73 al., 2017b). Thus, despite the subjective feeling of expertise with faces in general

74 (Diamond and Carey, 1986), our visual system seems to be optimized for the

75 processing of familiar faces. The mechanisms underlying the prioritized

76   processing of familiar faces are still a matter of investigation (Guntupalli and

77   Gobbini, 2017; Ramon and Gobbini, 2017; Young and Burton, 2017).

78   The advantage for familiar faces could originate at different stages of the visual

79   processing stream. In a study measuring saccadic reaction time, correct and

80   reliable saccades to familiar faces were recorded as fast as 180 ms when

81   unfamiliar faces were distractors (Visconti di Oleggio Castello and Gobbini,

82   2015). At such short latencies it is unlikely that a viewpoint-invariant

83   representation of an individual face's identity drives the saccadic response. To

84   account for facilitated, rapid detection of familiarity, we have previously

85   hypothesized that personally familiar faces may be recognized quickly based on

86   diagnostic, idiosyncratic features, which become highly learned through

87   extensive personal interactions (Visconti di Oleggio Castello and Gobbini, 2015;

88   Visconti di Oleggio Castello et al., 2017b). In a study of perception of gaze

89   direction and head angle, changes in eye gaze were detected around 100ms

90   faster in familiar than in unfamiliar faces (Visconti di Oleggio Castello and

91   Gobbini, 2015). These data provide support for the hypothesis that facial

92   features that are diagnostic for identity are processed more efficiently for familiar

93   as compared to unfamiliar faces. Detection of these features may occur early in

94   the visual hierarchy, allowing an initial, fast differential processing for personally

95   familiar faces.

96   Processes occurring at early stages of the visual system can show idiosyncratic

97   retinotopic biases (Greenwood et al., 2017). Afraz et al. (2010) reported

98   retinotopic biases for perceiving face gender and age that vary depending on

99   stimulus location in the visual field and were specific to each subject. These

100   results suggest that neurons in higher-order face areas have restricted receptive

101   fields or, equivalently, that diagnostic facial features for gender and age are

102   encoded in retinotopic visual cortices. Here we reasoned that diagnostic visual

103   features that play a role in visual processes for individuating faces may show

104   idiosyncratic retinotopic biases and that these biases may be tuned by repeated

105   interactions with personally familiar faces. Such biases may affect recognition of

106   the identities presented in different parts of the visual field and may be

107   modulated by the familiarity of those identities.

108   We tested this hypothesis by presenting participants with morphed stimuli of

109   personally familiar individuals that were briefly shown at different retinal

110   locations. In two separate experiments we found that participants showed

111   idiosyncratic biases for specific identities in different visual field locations, and

112   these biases were stable on retesting after weeks. Importantly, the range of the

113   retinal biases was inversely correlated with the reported familiarity of each target

114   identity, suggesting that prolonged personal interactions with the target

115   individuals reduced retinal biases. These findings provide additional support for

116   the hypothesis that asymmetries in the processing of personally familiar faces

117   can arise at stages of the visual processing hierarchy where there is still

118   retinotopic coding.
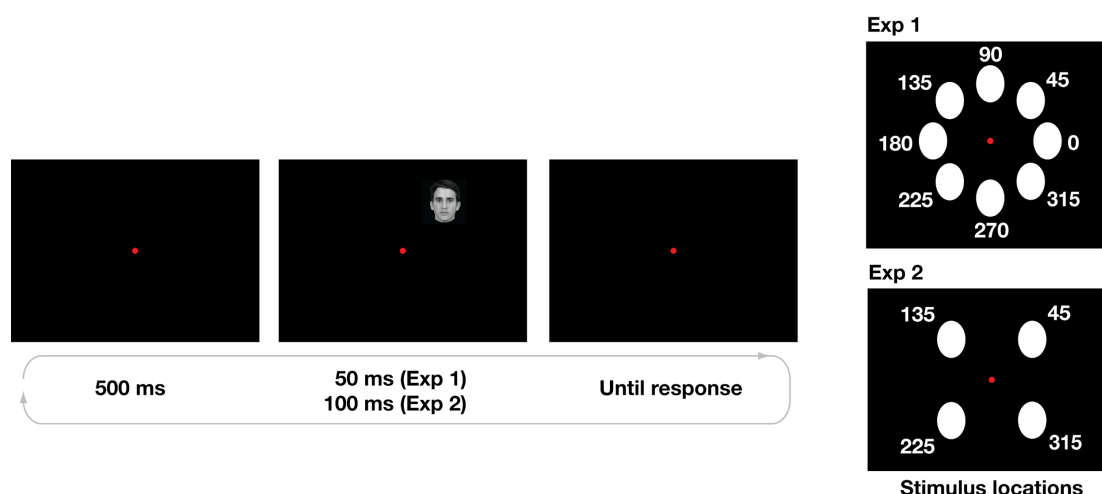
Materials and Methods

Figure 1. Experimental paradigm. The left panel shows an example of the experimental paradigm, while the right panel shows the angular locations used in Experiment 1 (eight locations, top panel) and in Experiment 2 (four locations, bottom panel).

Stimuli

Pictures of the faces of individuals who were personally familiar to the participants (graduate students in the same department) were taken in a photo studio room with the same lighting condition and the same camera. Images of two individuals were used for Experiment 1, and images of three individuals were used for Experiment 2. All individuals portrayed in the stimuli signed written informed consent to use their pictures for research and in publications.

The images were converted to grayscale, resized and centered so that the eyes were aligned in the same position for the three identities, and the background was manually removed. These operations were performed using ImageMagick and Adobe Photoshop CS4. The resulting images were matched in luminance

131   (average pixel intensity) using the SHINE toolbox (function *lumMatch*)

132   (Willenbockel et al., 2010) after applying an oval mask, so that only pixels

133   belonging to the face were modified. The luminance-matched images were then

134   used to create morph continua (between two identities in Experiment 1, see

135   Figure 2; and among three identities in Experiment 2, see Figure 3) using

136   Abrosoft Fantamorph (v. 5.4.7) with seven percentages of morphing: 0, 17, 33,

137   50, 67, 83, 100 (see Figures 2, 3).

138   **Experiment 1**

139   *Paradigm*

140   The experimental paradigm was similar to that by (Afraz et al., 2010). In every

141   trial participants would see a briefly flashed image in one of eight locations at

142   the periphery of their visual field (see Figure 1). Each image was shown for 50

143   ms at a distance of 7° of visual angle from the fixation point, and subtended

144   approximately 4° x 4° of visual angle. The images could appear in one of eight

145   locations evenly spaced by 45 angular degrees. For Experiment 1, only the

146   morph *ab* was used (see Figure 1). Participants were required to maintain fixation

147   on a central red dot subtending approximately 1° of visual angle.

148   After the image disappeared, participants reported which identity they saw using

149   the left (identity *a*) and right (identity *b*) arrow keys. There was no time limit for

150   responding, and participants were asked to be as accurate as possible. After

151   responding, participants had to press the spacebar key to continue to the next

152   trial.

153   Participants performed five blocks containing 112 trials each, for a total of 560

154   trials. In each block all the images appeared twice for every angular location (8

155   angular locations x 7 morph percentages x 2 = 112). This provided ten data

156   points for each percentage morphing at each location, for a total of 70 trials at

157   each angular location.

158   Before the experimental session participants were shown the identities used in

159   the experiment (corresponding to 0% and 100% morphing, see Figure 2), and

160   practiced the task with 20 trials. These data were discarded from the analyses.

161   Participants performed two identical experimental sessions at least four weeks

162   apart.

163   Participants sat at a distance of approximately 50 cm from the screen, with their

164   chin positioned on a chin-rest. The experiment was run using Psychtoolbox

165   (Kleiner et al., 2007) (version 3.0.12) in MATLAB (R2014b). The screen operated

166   at a resolution of 1920x1200 and a 60Hz refresh rate.

167   *Subjects*

168   We recruited six subjects for this experiment (three males, including one of the

169   authors, MVdOC). The sample size for Experiment 1 was not determined by

170   formal estimates of power, and was limited by the availability of participants

171   familiar with the stimulus identities. After the first experimental session, two

172 participants (one male, one female) were at chance level in the task, thus only

173 data from four subjects (two males, mean age 27.50 ± 2.08 SD) were used for

174 the final analyses.

175 All subjects had normal or corrected-to-normal vision, and provided written

176 informed consent to participate in the experiment. The study was approved by

177 the Dartmouth College Committee for the Protection of Human Subjects.

178 ***Experiment 2***

179 *Paradigm*

180 Experiment 2 differed from Experiment 1 in the following parameters (see

181 Figures 1, 3): 1. three morph continua (*ab*, *ac*, *bc*) instead of one; 2. images

182 appeared in four angular locations (45°, 135°, 225°, 315°) instead of eight; 3.

183 images were shown for 100 ms instead of 50 ms to make the task easier.

184 All other parameters were the same as in Experiment 1. Participants had to

185 indicate which of the three identities they saw by pressing the left (identity *a*),

186 right (identity *b*), or down (identity *c*) arrow keys.

187 Participants performed ten blocks containing 84 trials each, for a total of 840

188 trials. In each block all the images appeared once for every angular location (4

189 angular locations x 7 morph percentages x 3 morphs = 84). We used 70 data

190 points at every angular location to fit the model for each pair of identities. Thus,

191   we used the responses to different unmorphed images for each pair of identities,

192   ensuring independence of the models.

193   Before the experimental session participants were shown the identities used in

194   the experiment (corresponding to 0% and 100% morphing, see Figure 3), and

195   practiced the task with 20 trials. These data were discarded from the analyses.

196   Participants performed two experimental sessions at least four weeks apart.

197   *Subjects*

198   Ten participants (five males, mean age 27.30 ± 1.34 SD) participated in

199   Experiment 2, five of which were recruited for Experiment 1 as well. No authors

200   participated in Experiment 2. The sample size (n = 10) was determined using

201   G*Power3 (Faul et al., 2007, 2009) to obtain 80% power at α = 0.05 based on

202   the correlation of the PSE estimates across sessions in Experiment 1, using a

203   bivariate normal model (one-tailed).

204   All subjects had normal or corrected-to-normal vision, and provided written

205   informed consent to participate in the experiment. The study was approved by

206   the Dartmouth College Committee for the Protection of Human Subjects.

207   **Familiarity and contact scales**

208   After the two experimental sessions, participants completed a questionnaire

209   designed to assess how familiar each participant was with the identities shown

210   in the experiment. Participants saw each target identity, and were asked to

211   complete various scales for that identity. The questionnaire comprised the

212   "Inclusion of the Other in the Self" scale (IOS) (Aron et al., 1992; Gächter et al.,

213   2015), the "Subjective Closeness Inventory" (SCI) (Berscheid et al., 1989), and

214   the "We-scale" (Cialdini et al., 1997). The IOS scale showed two circles

215   increasingly overlapping labeled "You" and "X", and participants were given the

216   following instructions: *Using the figure below select which pair of circles best*

217   *describes your relationship with this person. In the figure "X" serves as a*

218   *placeholder for the person shown in the image at the beginning of this section,*

219   *and you should think of "X" being that person. By selecting the appropriate*

220   *number please indicate to what extent you and this person are connected (Aron*

221   *et al., 1992; Gächter et al., 2015)*. The SCI scale comprised the two following

222   questions: *Relative to all your other relationships (both same and opposite sex)*

223   *how would you characterize your relationship with the person shown at the*

224   *beginning of this section?*, and *Relative to what you know about other people's*

225   *close relationships, how would you characterize your relationship with the person*

226   *shown at the beginning of this section?* Participants responded with a number

227   between one *(Not close at all)* and seven *(Very close) (Berscheid et al., 1989)*.

228   The We-scale comprised the following question: *Please select the appropriate*

229   *number below to indicate to what extent you would use the term "WE" to*

230   *characterize you and the person shown at the beginning of this section.*

231   Participants responded with a number between one *(Not at all)* and seven *(Very*

232   *much so).* For each participant and each identity we created a composite

233   "familiarity score" by averaging the scores in the three scales.

234   We also introduced a scale aimed at estimating the amount of interaction or

235   contact between the participant and the target identity. The scale was based on

236   the work by (Idson and Mischel, 2001), and participants were asked to respond

237   Yes/No to the following six questions: *Have you ever seen him during a*

238   *departmental event?*, *Have you ever seen him during a party?*, *Have you ever*

239   *had a group lunch/dinner/drinks with him?*, *Have you ever had a one-on-one*

240   *lunch/dinner/drinks with him?*, *Have you ever texted him personally (not a group*

241   *message)?*, and *Have you ever emailed him personally (not a group email)?* The

242   responses were converted to 0/1 and for each participant and for each identity

243   we created a "contact score" by summing all the responses.

244   For each subject separately, to obtain a measure of familiarity and contact

245   related to each morph, we averaged the familiarity and contact scores of each

246   pair of identities (e.g., the familiarity score of morph *ab* was the average of the

247   scores for identity *a* and identity *b*).

248   ***Psychometric fit***

249   For both experiments we fitted a group-level psychometric curve using Logit

250   Mixed-Effect models as implemented in *lme4 (Bates et al., 2015)*. For each

251   experiment and each session, we fitted a model of the form

252
$$y^k = \text{logit}\left(\beta_0 x + \sum_{i=1}^{n} (\beta_i + z_i^k) I_i \right)$$

253   where k indicates the subject, n is the number of angular locations ($n = 8$ for the

254   first experiment, and $n = 4$ for the second experiment), I_i is an indicator variable

255   for the angular location, β_i are the model fixed-effects, and z_i are the subject-

256   level random-effects (random intercept). From this model, we defined for each

257   subject the Point of Subjective Equality (PSE) as the point x such that logit(x) =

258   0.5, that is for each angular location

259
$$PSE_i^k = -\frac{\beta_i}{\beta_0} - \frac{z_i^k}{\beta_0} = PSE_i^p + \Delta PSE_i^k$$

260   Thus, the PSE for subject k at angular location i can be decomposed in a

261   population-level PSE and a subject-specific deviation from the population level,

262   indicated with PSE^p and ΔPSE^k respectively.

263   In Experiment 2 we fitted three separate models for each of the morph continua.

264   In addition, prior to fitting we removed all trials in which subjects mistakenly

265   reported a third identity. For example, if an image belonging to morph ab was

266   presented, and subjects responded with c, the trial was removed.

267   ***Code and data availability***

268   Code and data for both experiments are available at [link removed: will be made

269   public after publication].

13

270 # Results

271 ### *Experiment 1*

272 In this experiment, participants performed a two-alternative forced-choice (AFC)

273 task on identity discrimination. In each trial they saw a face presented for 50 ms,

274 and were asked to indicate which of the two identities they just saw. Each face

275 could appear in one of eight stimulus locations. Participants performed the same

276 experiment with the same task a second time, at least 33 days after the first

277 session (average 35 days ± 4 days standard deviation).

278 Participants showed stable and idiosyncratic retinal heterogeneity for

279 identification. The PSE estimates for the two sessions were significantly

280 correlated (see Table 1 and Figure 2B), showing stable estimates, and the within-

281 subject correlations of ΔPSEs (see Methods) was significantly higher than the

282 between-subject correlation (correlation difference: 0.87 [0.64, 1.10], 95% BCa

283 confidence intervals (Efron, 1987); see Table 2), showing that the biases were

284 idiosyncratic (see Figure 2A for example fits for two different subjects).

285

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Table 1. Correlation of parameter estimates across sessions for the two experiments.				
Parameter	r	t	df	p
Experiment 1				
PSE	0.89 [-0.23, 1]	4.86**	6	0.002831
ΔPSE	0.71 [0.47, 0.84]	5.47***	30	6.106e-06
Experiment 2				
PSE	0.98 [0.93, 0.99]	15.22***	10	3.042e-08
ΔPSE	0.64 [0.5, 0.75]	9.02***	118	3.997e-15
Note: *All confidence intervals are 95% BCa with 10,000 repetitions.* *p < .05. ** p < .01. *** p < .001				

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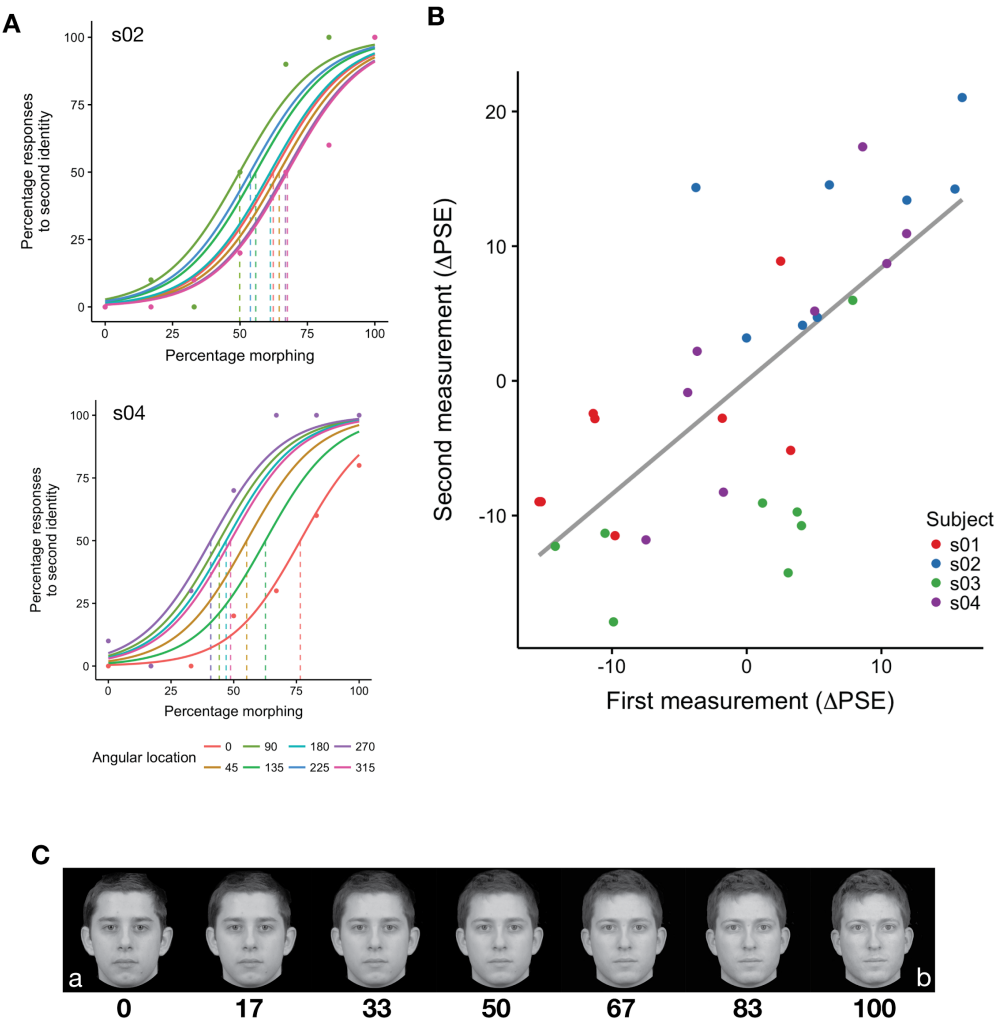| Table 2. Comparison of within-subjects correlations of parameter estimates across sessions with between-subjects correlations.			
Morph	Within-subjects r	Between-subjects r	Difference
Experiment 1			
ab	0.65† [0.57, 0.8]	-0.22 [-0.41, -0.01]	0.87† [0.63, 1.1]
Experiment 2			
ab	0.32 [-0.10, 0.62]	-0.02 [-0.15, 0.11]	0.34 [-0.07, 0.69]
ac	0.62† [0.35, 0.79]	-0.07 [-0.21, 0.08]	0.68† [0.41, 0.92]
bc	0.85† [0.61, 0.95]	-0.08 [-0.27, 0.12]	0.92† [0.68, 1.15]
Note: *All confidence intervals are 95% BCa with 10,000 repetitions.* † *indicates that the CIs do not contain 0.*			

288

Figure 2. Stable and idiosyncratic biases in identification in Experiment 1. A) Psychometric fit for two subjects from one of the two sessions. Colors indicate angular location; actual data (points) are shown only for the extreme locations to avoid visual clutter. B) The parameter estimates across sessions (at least 33 days apart) were stable (r = 0.71 [0.47, 0.84], see Table 1). C) Example morphs used in the experiment. Note that the morphs depicted here are shown for illustration only, and participants saw morphs of identities that were personally familiar to them.

289

290

291 ***Experiment 2***

292 In this experiment, participants performed a similar task as in Experiment 1, with

293 the following differences. First, each face was presented for 100 ms instead of

294 50 ms in order to make the task easier; second, each face could belong to one

295 of three morphs, and participants were required to indicate which of three

296 identities the face belonged to; third, each face could appear in four retinal

297 locations instead of eight (see Figure 1). Each participant performed another

298 experimental session at least 28 days after the first session (average 33 days ±

299 8 days SD).

300 We found that participants exhibited stable biases across sessions for the three

301 morphs (see Table 1 and Figure 3). Interestingly, within-subjects correlations

302 were higher than between-subjects correlations for the two morphs that

303 included the identity *c* (morphs *ac* and *bc*), but not for morph *ab* (see Table 2),

304 suggesting stronger differences in spatial heterogeneity caused by identity *c*. To

305 test this further, we performed a two-way ANOVA on the PSE estimates across

306 sessions with participants and angular locations as factors. The ANOVA was run

307 for each pair of morphs containing the same identity (e.g., for identity *a* the

308 ANOVA was run on data from morphs *ab* and *ac*), and the PSE estimates were

309 transformed to be with respect to the same identity (e.g., for identity *b* we

310 considered PSE_{bc} and 100 - PSE_{ab}). We found significant interactions between

311 participants and angular locations for identity *b* ($F(27, 120) = 1.77, p = 0.01947$)

312 and identity *c* ($F(27, 120) = 3.34, p = 3.229e-06$), but not identity *a* ($F(27, 120) = $

313   1.17, p = 0.2807), confirming that participants showed increased spatial

314   heterogeneity for identities *b* and *c*. Moreover, inspecting the ΔPSE estimates

315   for each individual subjects (Figure 4A) revealed lower variance across retinal

316   locations of the biases for morph *ab* than the other two morphs.

317   The variance of the average ΔPSE estimates across sessions for each subject

318   was significantly correlated with the reported familiarity of the identities

319   (r = -0.56 [-0.71, -0.30], t(28) = -3.59, p = 0.001248), showing that the strength

320   of the retinal bias for identities was inversely modulated by personal familiarity

321   (see Figure 4B). Because the amount of personal familiarity was correlated with

322   the amount of contact with a target identity (r = 0.45 [0.17, 0.68], t(28) = 2.65,

323   p = 0.01304), we tested whether a linear model predicting ΔPSE with both

324   contact and familiarity as predictors could fit the data better. Both models were

325   significant, but the model with two predictors explained more variance as

326   indicated by higher R^2: R^2 = 0.45, adjusted R^2 = 0.40 for the model with both

327   Familiarity and Contact scores (F(2, 27) = 10.82, p = 0.0003539), and R^2 = 0.32,

328   adjusted R^2 = 0.29 for the model with the Familiarity score only (F(1, 28) = 12.88,

329   p = 0.001248). Importantly, both predictors were significant (see Table 3),

330   indicating that familiarity modulated the variance of the ΔPSE estimates in

331   addition to modulation based on the amount of contact with a person. After

332   adjusting for the contact score, the variance of the ΔPSE estimates and the

333   familiarity score were still significantly correlated (r_p = -0.42 [-0.61, -0.16], t(28) =

334   -2.42, p = 0.02235).

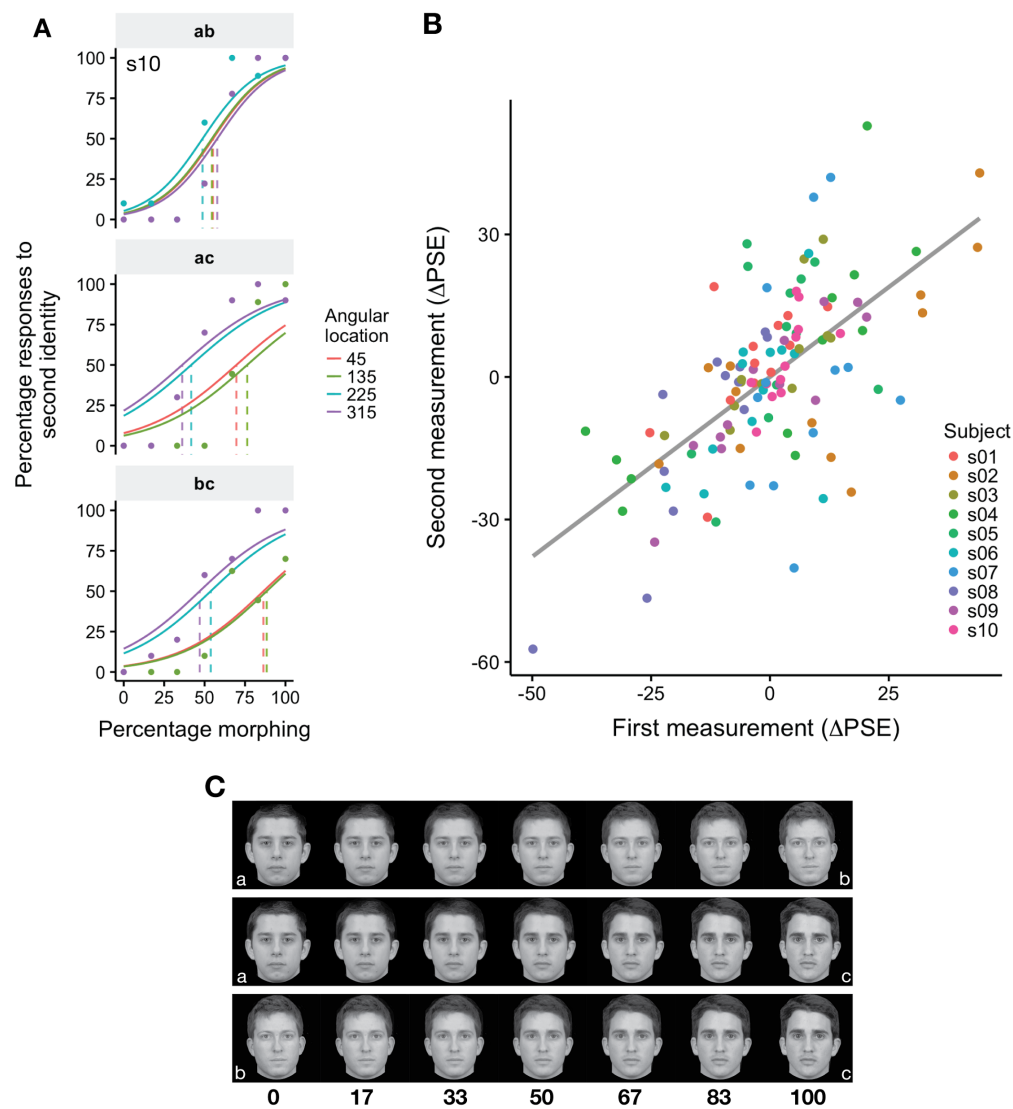| Table 3. Models predicting variance of the ΔPSE estimates across angular locations in Experiment 2.						
Model	**R^2**	**Score**	**β**	**η_p^2**	**t**	**p**
1	0.32	Familiarity	-0.0574	0.32	-3.59	0.0013
2	0.45	Familiarity	-0.0390	0.17	-2.38	0.0249
		Contact	-0.0452	0.19	-2.512	0.0183

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Figure 3. Stable and idiosyncratic biases in identification in Experiment 2. A) Psychometric fit for one subject from one of the two sessions for each of the morphs. Colors indicate angular location; actual data (points) are shown only for the extreme locations to avoid visual clutter. B) The parameter estimates across sessions (at least 28 days apart) were stable ($r = 0.64$ [0.5, 0.75], see Table 1). C) Example morphs used in the experiment. Note that the morphs depicted here are shown only for illustration (participants saw morphs of identities who were personally familiar).
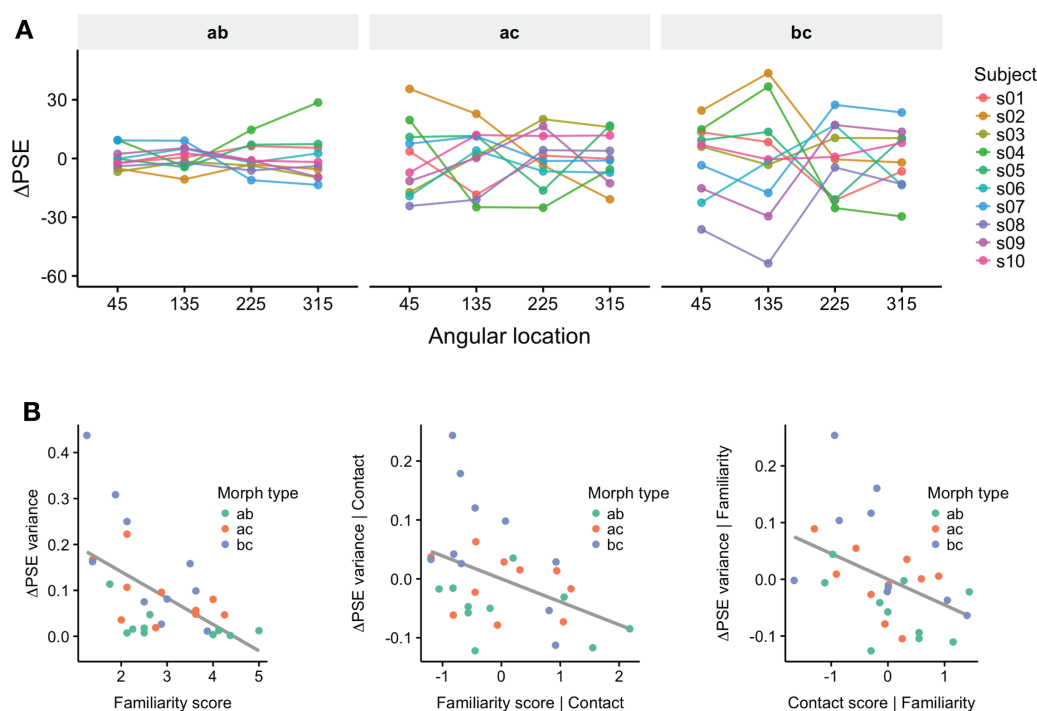
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Figure 4. The strength of idiosyncratic biases was modulated by personal familiarity. A) Individual subjects' ΔPSE for each morph, averaged across sessions. Note the difference in variance across angular locations for the three different morphs (left to right)). B) The variance across angular locations of ΔPSE estimates was inversely correlated with the reported familiarity of the identities (left panel; r = -0.56 [-0.71, -0.30]), even when adjusting for the Contact score (middle panel; r_p = -0.42 [-0.61, -0.16]). The right panel shows the scatterplot between the Contact score and the ΔPSE variance, adjusted for the Familiarity score, which were significantly correlated as well (r_p = -0.44 [-0.62, -0.17]). See Methods for definition of the Familiarity score and the Contact score.

338

339

Discussion

340

341　Afraz et al. (2010) reported spatial heterogeneity for recognition of facial

342　attributes such as gender and age, suggesting that relatively independent neural

343　populations tuned to facial features might sample different regions of the visual

344　field. Prolonged social interactions with personally familiar faces lead to

345　facilitated, prioritized processing of those faces. Here we wanted to investigate

346　if this learning of face identity through repeated social interactions also affects

347　these local visual processes, by measuring spatial heterogeneity of identity

348　recognition. We measured whether face identification performance for

349　personally familiar faces differed according to the location in the visual field

350　where face images were presented. We found that participants exhibited

351　idiosyncratic, retinotopic biases for different face identities that were stable

352　across experimental sessions. Importantly, the variability of the retinotopic bias

353　was reduced with increased familiarity with the target identities. These data

354　support the hypothesis that familiarity entails learning visual features that affect

355　processing in visual areas with a retinotopic organization (Visconti di Oleggio

356　Castello et al., 2017a).

357　These results extend the reports of spatial heterogeneity in visual processing to

358　face identification. Similar biases exist for high-level judgments such as face

359　gender and age (Afraz et al., 2010), as well as shape discrimination (Afraz et al.,

360　2010), crowding, and saccadic precision (Greenwood et al., 2017). Afraz et al.

361　(2010) suggested that neurons in IT exhibit biases that are dependent on retinal

22

362 location because their receptive field sizes are not large enough to provide

363 complete translational invariance, and stimuli in different locations will activate

364 a limited group of neurons. In this work, we show that these perceptual biases

365 for face processing not only exist for gender and age judgments (Afraz et al.,

366 2010), but also for face identification and that these biases are affected by

367 learning. Retinotopic organization is stronger in earlier visual areas, suggesting

368 that high-level judgments of gender, age, and identity may be biased by

369 variability of feature detectors in visual areas such as the occipital face area, or

370 even earlier.

371 In this work, we showed that the extent of variation in biases across retinal

372 locations was inversely correlated with the reported familiarity with individuals,

373 suggesting that a history of repeated interaction with a person may tune the

374 responses of neurons to that individual in different retinal locations, generating

375 more homogeneous responses. Repeated exposure to the faces of familiar

376 individuals during real-life social interactions results in a detailed representation

377 of the visual appearance of a personally familiar face. Our results showed that

378 both ratings of familiarity and ratings of amount of contact were strong

379 predictors for reduced retinotopic bias. This supports our hypothesis that

380 facilitated processing might be mediated by the development or tuning of

381 detectors for diagnostic fragments of personally familiar faces that may exist in

382 the visual pathway in areas that still have localized analyses and have a

383   retinotopic organization (Gobbini et al., 2013; Visconti di Oleggio Castello et al.,

384   2014, 2017b; Visconti di Oleggio Castello and Gobbini, 2015).

385   Future research can investigate the mechanism that generates these biases and

386   how learning reduces them. However, our results suggest that prioritized

387   processing for personally familiar faces may exist at relatively early stages of the

388   visual processing hierarchy, as shown by the local biases reported here. We

389   hypothesize that these differences may be one of the mechanisms that underlies

390   the known behavioral advantages for perception of personally familiar faces

391   (Burton et al., 1999; Gobbini and Haxby, 2007; Gobbini, 2010; Gobbini et al.,

392   2013; Visconti di Oleggio Castello et al., 2014, 2017b; Ramon et al., 2015;

393   Visconti di Oleggio Castello and Gobbini, 2015; Chauhan et al., 2017; Ramon

394   and Gobbini, 2017).

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Legends

Figure 1. Experimental paradigm. The left panel shows the experimental paradigm, while the right panel shows the angular locations used in Experiment 1 (eight locations, top panel) and in Experiment 2 (four locations, bottom panel).

Figure 2. Stable and idiosyncratic biases in identification in Experiment 1. A) Psychometric fit for two subjects from one of the two sessions. Colors indicate angular location; actual data (points) are shown only for the extreme locations to avoid visual clutter. B) The parameter estimates across sessions (at least 33 days apart) were stable (r = 0.71 [0.47, 0.84], see Table 1). C) Example morphs used in the experiment. Note that the morphs depicted here are shown for illustration only, and participants saw morphs of identities that were personally familiar to them.

Figure 3. Stable and idiosyncratic biases in identification in Experiment 2. A) Psychometric fit for one subject from one of the two sessions for each of the morphs. Colors indicate angular location; actual data (points) are shown only for the extreme locations to avoid visual clutter. B) The parameter estimates across sessions (at least 28 days apart) were stable (r = 0.64 [0.5, 0.75], see Table 1). C) Example morphs used in the experiment. Note that the morphs depicted here are shown only for illustration (participants saw morphs of identities who were personally familiar).

Figure 4. The strength of idiosyncratic biases was modulated by personal familiarity. A) Individual subjects' ΔPSE for each morph, averaged across sessions. Note the difference in variance across angular locations for the three different morphs (left to right)). B) The variance across angular locations of ΔPSE estimates was inversely correlated with the reported familiarity of the identities (left panel; r = -0.56 [-0.71, -0.30]), even when adjusting for the Contact score (middle panel; r_p = -0.42 [-0.61, -0.16]). The right panel shows the scatterplot between the Contact score and the ΔPSE variance, adjusted for the Familiarity score, which were significantly correlated as well (r_p = -0.44 [-0.62, -0.17]). See Methods for definition of the Familiarity score and the Contact score.

Table 1. Correlation of parameter estimates across sessions for the two experiments.

Table 2. Comparison of within-subjects correlations of parameter estimates across sessions with between-subjects correlations.

Table 3. Models predicting variance of the ΔPSE estimates across angular locations in Experiment 2.

Tables

Table 1.
Correlation of parameter estimates across sessions for the two experiments.

Parameter	r	t	df
Experiment 1			
PSE	0.89 [-0.23, 1]	4.86**	6
ΔPSE	0.71 [0.47, 0.84]	5.47***	30
Experiment 2			
PSE	0.98 [0.93, 0.99]	15.22***	10
ΔPSE	0.64 [0.5, 0.75]	9.02***	118
Note: *All confidence intervals are 95% BCa with 10,000 repetitions.* ** p < .05. ** p < .01. *** p < .001*			

Table 2.
Comparison of within-subjects correlations of parameter estimates across sessions with between-subjects correlations.

Morph	Within-subjects r	Between-subjects r	Difference
Experiment 1			
ab	$0.65^{\dagger}$ [0.57, 0.8]	-0.22 [-0.41, -0.01]	$0.87^{\dagger}$ [0.63, 1.1]
Experiment 2			
ab	0.32 [-0.10, 0.62]	-0.02 [-0.15, 0.11]	0.34 [-0.07, 0.69]
ac	$0.62^{\dagger}$ [0.35, 0.79]	-0.07 [-0.21, 0.08]	$0.68^{\dagger}$ [0.41, 0.92]
bc	$0.85^{\dagger}$ [0.61, 0.95]	-0.08 [-0.27, 0.12]	$0.92^{\dagger}$ [0.68, 1.15]
Note: *All confidence intervals are 95% BCa with 10,000 repetitions.* *† indicates that the CIs do not contain 0.*			

Table 3. Models predicting variance of the ΔPSE estimates across angular locations in Experiment 2.						
Model	**R^2**	**Score**	**β**	**η_p^2**	**t**	**p**
1	0.32	Familiarity	-0.0574	0.32	-3.59	0.0013
2	0.45	Familiarity	-0.0390	0.17	-2.38	0.0249
		Contact	-0.0452	0.19	-2.512	0.0183

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