Familiarity Affects Early Perceptual Stages of Face Processing

Katharina Dobs (katharina.dobs@gmail.com)
CBMM; Dept. of Brain and Cognitive Sciences; CSAIL; McGovern Institute for Brain Research; Massachusetts Institute of Technology, 43 Vassar Street, Cambridge, MA 02139, US

Leyla Isik (lisik@mit.edu)
CBMM; Dept. of Brain and Cognitive Sciences; McGovern Institute for Brain Research; Massachusetts Institute of Technology, 43 Vassar Street, Cambridge, MA 02139, US

Dimitrios Pantazis (pantazis@mit.edu)
Dept. of Brain and Cognitive Sciences; CSAIL; McGovern Institute for Brain Research; Massachusetts Institute of Technology, 43 Vassar Street, Cambridge, MA 02139, US

Nancy Kanwisher (ngk@mit.edu)
CBMM; Dept. of Brain and Cognitive Sciences; McGovern Institute for Brain Research; Massachusetts Institute of Technology, 43 Vassar Street, Cambridge, MA 02139, US

Abstract:

From a brief glimpse of a face, we extract not just the presence of a person, but their gender, age, familiarity and specific identity. How quickly are these specific dimensions of face information represented, and which dimensions are affected by familiarity? To find out, we used Magnetoencephalography (MEG) and representational similarity analysis (RSA) to measure the time course of extraction of each of these dimensions of face information and their modulation by familiarity. Subjects viewed 80 face images, 5 of each of 16 celebrities, varying in lightning, pose, expression, and eye gaze. Celebrities varied orthogonally in familiarity, gender and age. Subjects (*n* = 16) performed a 1-back task on upright and inverted images in separate sessions. RSA analyses showed that we could decode identity, gender and age of face images at similar latencies within 130 ms after stimulus onset. We further found that familiarity enhanced face representations even at this early stage. Importantly, when identity decoding was analyzed within age and gender, early identity decoding remained significant only for familiar faces, suggesting qualitatively different early processing for familiar versus unfamiliar faces.

Keywords: Face perception; Familiarity; MEG; RSA; Vision

Introduction

Considerable evidence from behavioral and neural studies indicates that faces are detected rapidly (e.g. Crouzet, Kirchner, & Thorpe, 2010). However, a face reveals not just the presence of a person, but many different kinds of information about that person, such as their gender, age, familiarity and specific identity.

Here we ask two questions. First, how quickly are these specific dimensions of face information extracted, and do some arise before others? Second, given the considerable evidence that familiar faces are processed differently than unfamiliar faces (e.g. Jenkins, White, Van Montfort, & Burton, 2011; Landi & Freiwald, 2017), which of these dimensions are affected by familiarity, and how early in processing does familiarity affect face processing?

Methods

To answer these questions, we used Magnetoencephalography (MEG) and representational similarity analysis (RSA) to measure the time course of extraction of each of these dimensions of face information and their modulation by familiarity. Subjects (*n* = 16) viewed 80 different face images (Fig. 1a; 5 images of each of 16 different celebrities), while monitoring for consecutive repetitions of identical images (Fig. 1b; 1-back task). Each of the 80 images was presented 28 times upright and 28 times inverted in separate sessions (in counterbalanced order). Images within the same celebrity varied in lightning, pose, expression and eye gaze. Half of the celebrities were familiar (US actors) and half unfamiliar (German actors), half young (< 36 years) and half old (> 59 years), and half female and half male.

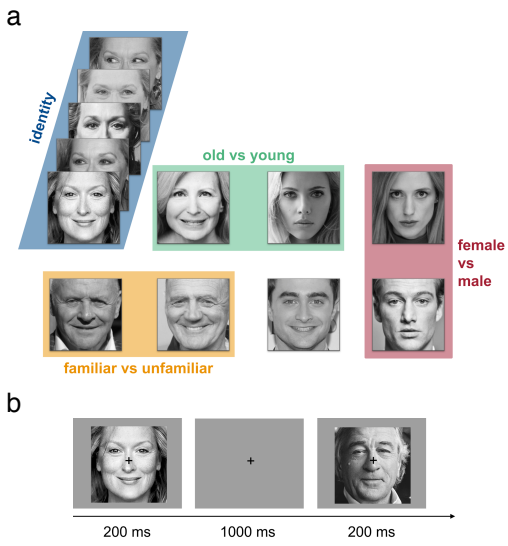

Figure 1: Stimuli and task design. a. Stimuli consisted of 80 face images, 5 images of each of 16 celebrities. Celebrities varied orthogonally in familiarity, gender and age. b. Subjects performed a 1-back task on upright and inverted images in separate sessions.

Results

RSA analyses showed significant decoding of identity, gender and age of face images within 130 ms after stimulus onset. Decoding accuracy of these dimensions reached their maximum significantly later than image decoding (i.e. discriminating any pair of stimulus images; $p < 0.05$), which occurred ~100 ms after stimulus onset. To further exclude the contribution of low-level stimulus features, we computed correlations between representational dissimilarity matrices derived from candidate models (identity, gender and age) and MEG neural data, while partialling out the correlation between similarity patterns based on physical stimulus features (e.g. image pixels or early layers of a deep neural network trained on faces). All model correlations remained significant (Fig. 2a, left panel; $p < 0.05$; sign permutation test) suggesting that this decoding is unlikely to be accounted for by low-level image properties, a conclusion further supported by the fact that decoding accuracy was significantly reduced by face inversion ($p < 0.05$; peak analysis).

To assess whether familiar faces were processed differently than unfamiliar faces, we ran the same RSA analysis described above separately for familiar versus unfamiliar faces. We found that familiarity significantly enhanced the decoding accuracy of all three face dimensions (age, gender, and identity), and did so at similar latencies for each dimension (~120 ms after stimulus onset; Fig. 2a, right panel).

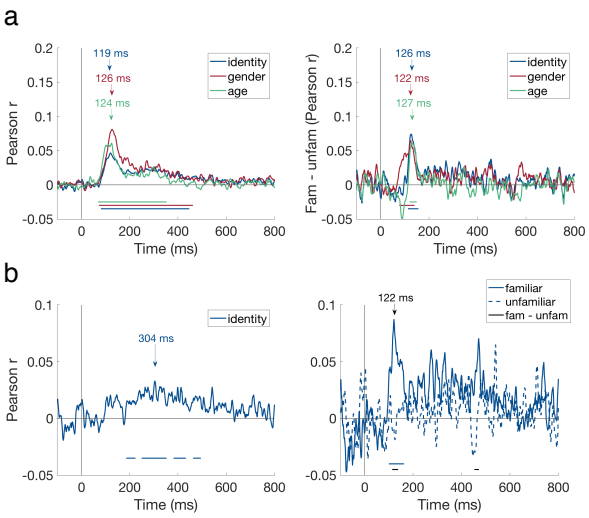

Figure 2: RSA analysis. a. Correlations of MEG RDM remain significant (horizontal bars) for all models (identity, gender and age) when low-stimulus features are partialled out (left). Familiarity enhances early face encoding (right). b. Latency for identity decoding within same gender and same age starts only at ~200 ms (left). However, a familiarity analysis suggests early decoding at ~120 ms for familiar faces (right).

To analyze face identity information unconfounded from differences in age or gender, we restricted the RSA analysis to same gender and same age identities (e.g. young females). For this restricted analysis, we find that identity decoding occurs at later stages of processing (~200 ms; Fig. 2b left panel) suggesting that early identity decoding was driven primarily by gender and age information. However, when further separating the faces into familiar and unfamiliar identities, we find early identity decoding (~120 ms; Fig. 2b right panel) for familiar but not for unfamiliar faces.

Conclusions

Overall, our results indicate that different kinds of face information become available extremely rapidly, within 130 ms of stimulus onset, and that familiarity enhances representations of face dimensions already at this early stage. This very early decoding of identity is consistent with findings from other decoding studies based on EEG/MEG (Nemrodov, Niemeier, Patel, & Nestor, 2018; Vida, Nestor, Plaut, & Behrmann, 2017) and intracranial electrocorticography (Ghuman et al., 2014). Importantly, we find early identity decoding within same age and gender for familiar but not unfamiliar faces, suggesting qualitatively different and earlier processing for familiar than unfamiliar faces.

Acknowledgments

This work was supported by a Feodor-Lynen fellowship to K.D., NIH grant DP1HD091947 to N.K. and the Center for Brain, Minds, and Machines.

References

Crouzet, S. M., Kirchner, H., & Thorpe, S. J. (2010). Fast saccades toward faces: Face detection in just 100 ms. *Journal of Vision*, *10*(4), 1–17.

Ghuman, A. S., Brunet, N. M., Li, Y., Konecky, R. O., Pyles, J. A., Walls, S. A., et al. (2014). Dynamic Encoding of Face Information in the Human Fusiform Gyrus. *Nature Communications*, *5*, 1–10.

Jenkins, R., White, D., Van Montfort, X., & Burton, A. M. (2011). Variability in photos of the same face. *Cognition*, *121*(3), 313–323.

Landi, S. M., & Freiwald, W. A. (2017). Two areas for familiar face recognition in the primate brain. *Science*, 1–6.

Nemrodov, D., Niemeier, M., Patel, A., & Nestor, A. (2018). The Neural Dynamics of Facial Identity Processing: insights from EEG-Based Pattern Analysis and Image Reconstruction. *eNeuro*, *5*(1), e0358-17.2018, 1-17.

Vida, M. D., Nestor, A., Plaut, D. C., & Behrmann, M. (2017). Spatiotemporal dynamics of similarity-based neural representations of facial identity. *Proceedings of the National Academics of Sciences*, 388–393.