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Supplemental Information

Spatial Heterogeneity

in the Perception

of Face and Form Attributes

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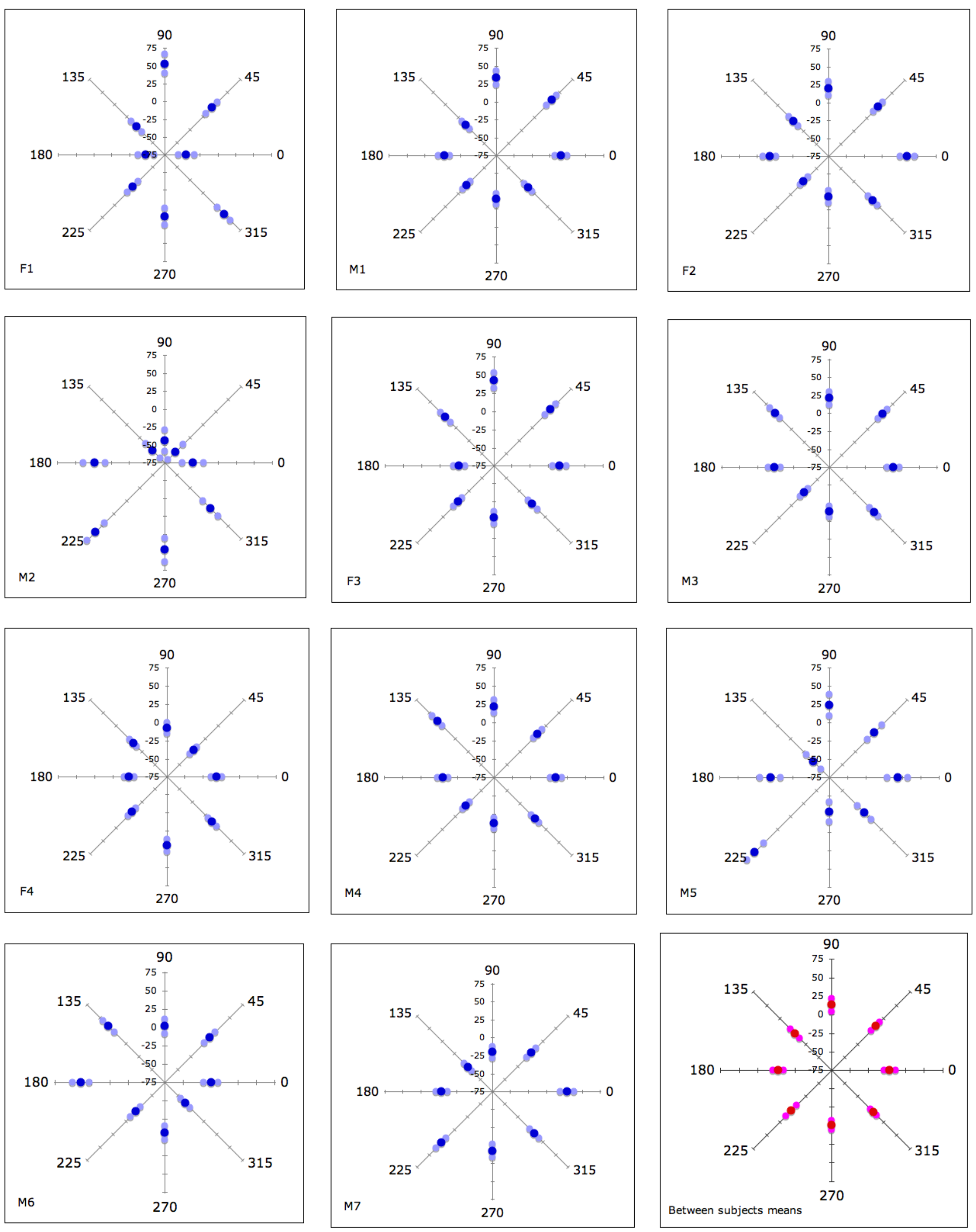
A)



B)

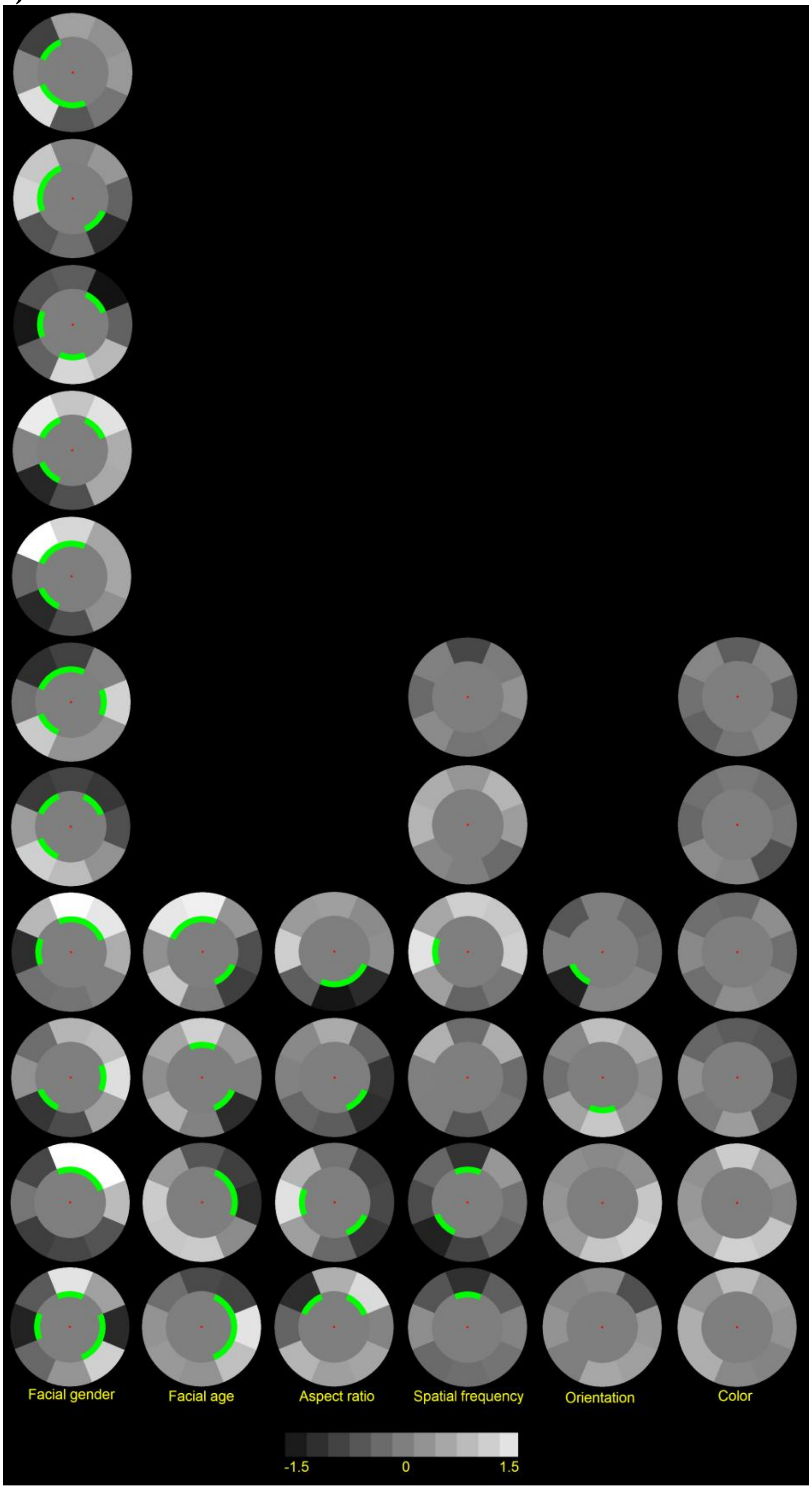
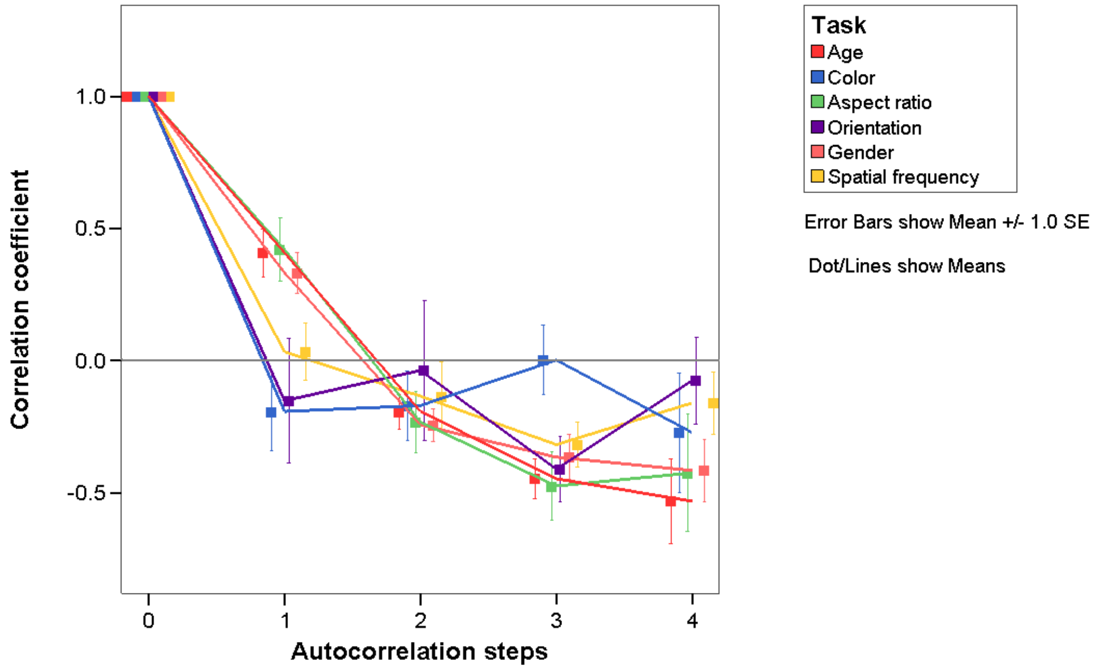

Facial gender
Facial age
Aspect ratio
Spatial frequency
Orientation
Color
-1.5
0
1.5

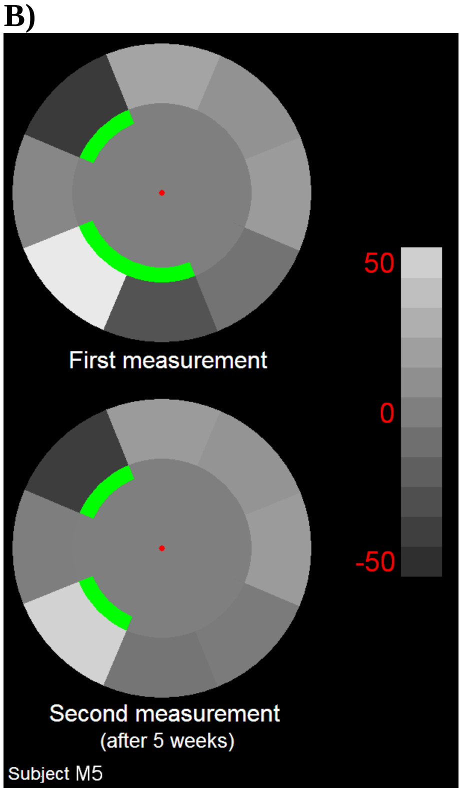
Figure S1.
(A) PSE polar plots for facial gender task showing within subject and between subjects variability. The polar angle on each plot represents the angular retinotopic position. The radius of each plot spans the morphing spectrum from negative values for male signal to positive values for female signal. The dark blue spots represent the PSE for each subject/location. The light blue spots indicate ±1 SE of mean. The plot at the bottom-right corner demonstrates between subjects variance. The red spots show the average PSE of all subjects at each location. . The pink spots indicate ±1 SE of mean.
(B) PSE mosaics for the five visual tasks for all of the subjects. Each row contains the results of a subject and each column indicates a visual task. To make it possible to compare the heterogeneity magnitude across five different tasks, PSEs of each task are normalized to the corresponding JND. The color map indicates PSE/JND.

A)



Correlation coefficient
1.0
0.5
0.0
-0.5
0
1
2
3
4
Autocorrelation steps
Task
Age
Color
Aspect ratio
Orientation
Gender
Spatial frequency
Error Bars show Mean +/- 1.0 SE
Dot/Lines show Means

B)



50
0
-50
First measurement
Second measurement
(after 5 weeks)
Subject M5

C)

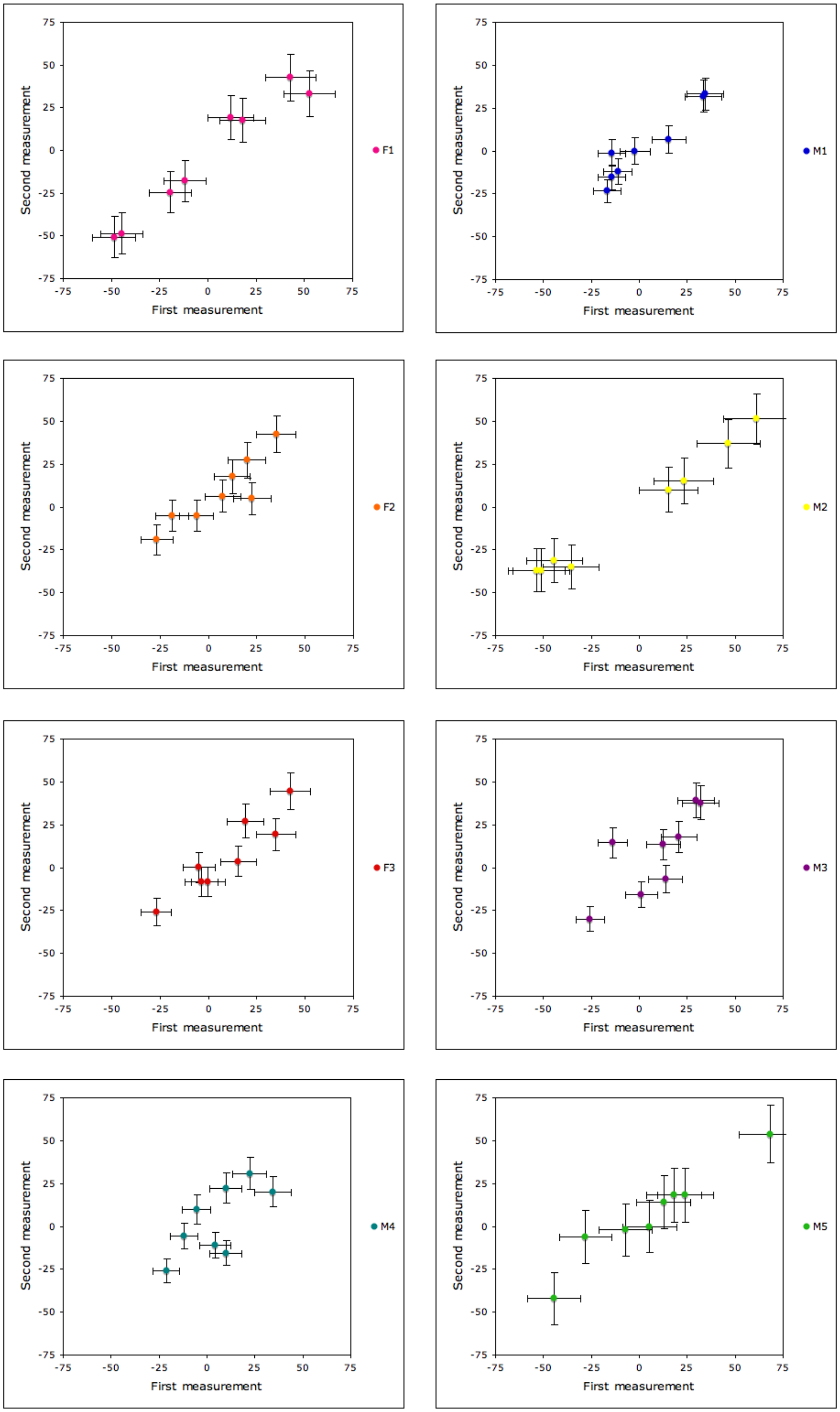
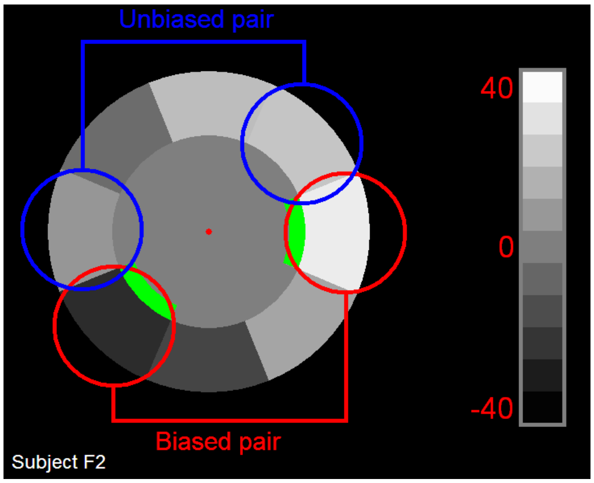
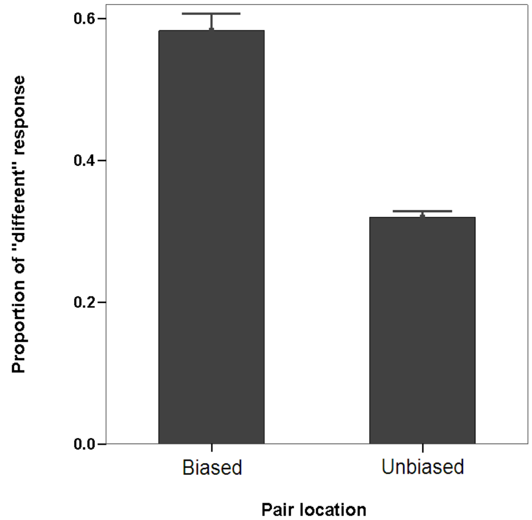


Figure S2.
(A) Autocorrelogram of PSE patterns. To reveal the spatial scale of the local biases, PSE values were autocorrelated for each subject/task independently. Each radial PSE mosaic was circularly shifted from 0 to ±4 steps and correlated with the original mosaic. The results were collapsed then across all subjects to provide autocorrelograms for the six visual tasks. The vertical axis shows the correlation coefficient (Pearson r) and the horizontal axis indicates the autocorrelation step. Step zero is the correlation of the pattern with itself and step N indicate the correlation of the pattern with itself shifted N steps circularly. Note higher correlation coefficients at step 1 for the gender, age and ellipse aspect ratio tasks than for the spatial frequency, color and orientation tasks. Error bars show ±1 SE of mean.
(B) Stability of the gender bias mosaic over time. An example of the PSE mosaic for the two measurements from a subject across a 5 week period.
(C) Scatter plots comparing the first and second measurements of PSEs for 8 subjects at each of the 8 locations. It is the same data as show in Figure 2.a., this time plotted separately for each subject.

A)



B)



C)

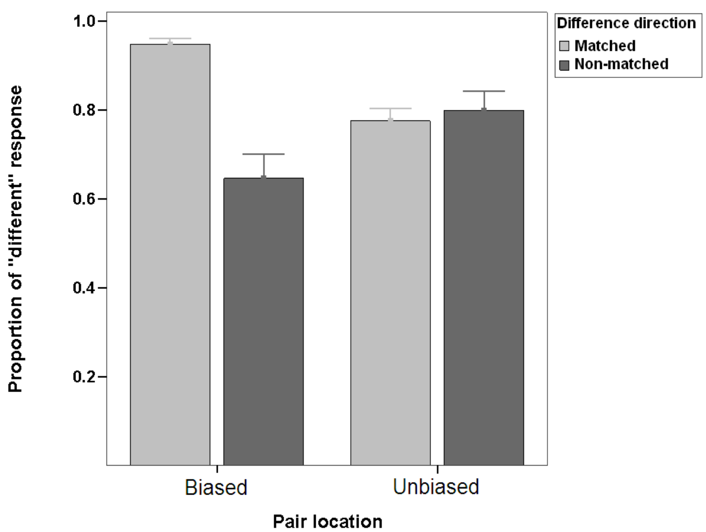


Figure S3. Simultaneous Presentation of Two Faces

(A) Two pairs of locations were selected for each individual based on his/her own gender bias pattern. The pair of locations with maximally different PSEs (biased to opposite directions) was named the **biased pair**. The pair of locations with minimal PSE difference was called the **unbiased pair**.

(B) The results for trials in which two identical faces were presented. The proportion of “different” responses was significantly higher when they were presented at the **biased pair** of locations.

(C) The results for trials in which the two faces were physically different. Light gray shade indicates the condition when the physical difference between the two faces matched the direction of the local bias difference. Dark gray shade stands for the condition when the difference between the two faces was opposite to the natural bias difference of the selected pair. Bar plots show the results pooled from all subjects. Error bars show ±1 SE of mean.

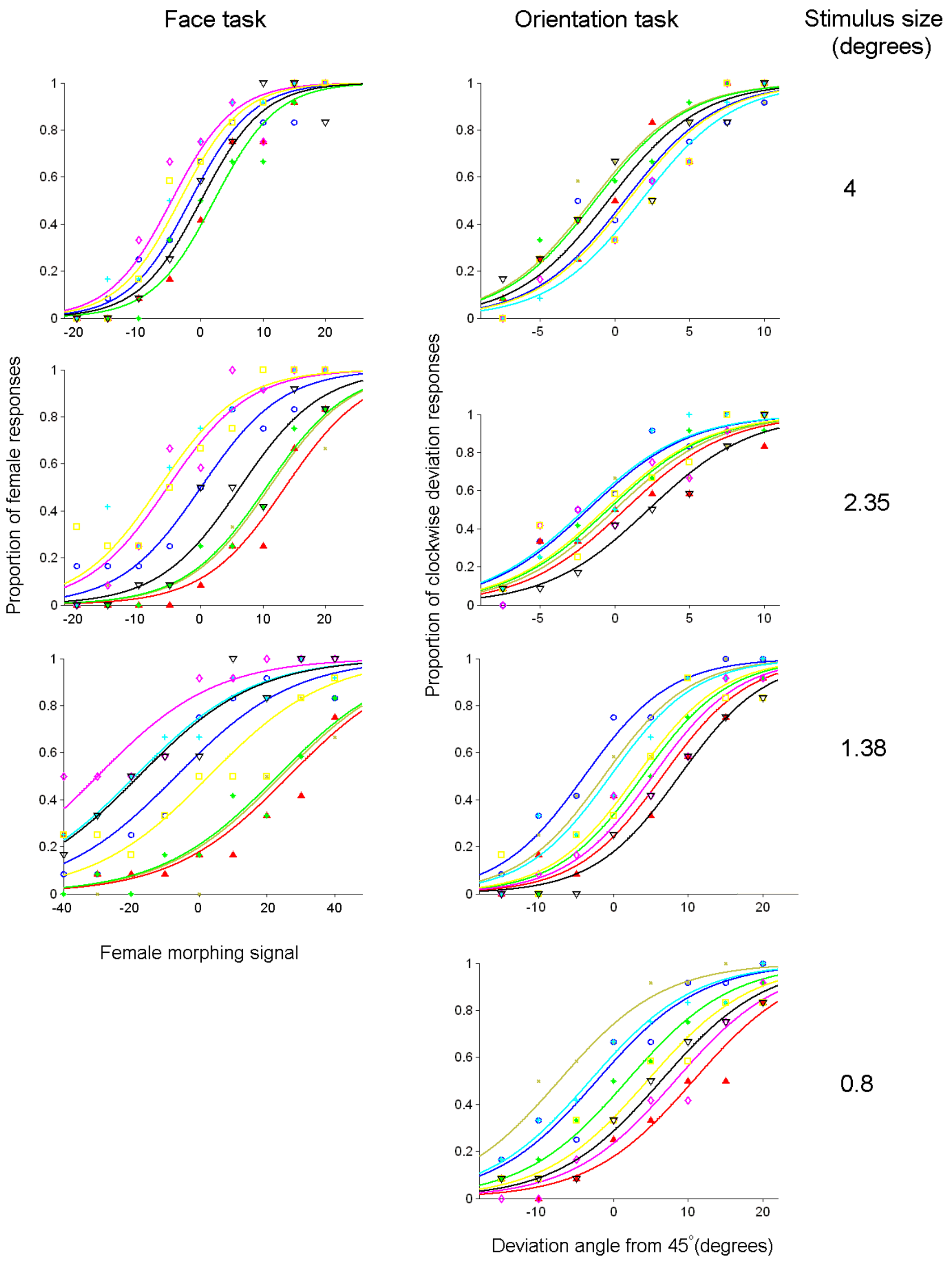


Figure S4. The Effect of Stimulus Size on Perceptual Heterogeneity
Psychometric functions are shown for a typical subject for orientation and face tasks with various stimulus sizes. As the size of the stimulus decreases, the slope of the psychometric curves becomes smoother, also the separation between the curves for the eight tested locations (the eight colors, the same color code as figure 1) increases. Further analysis reveals that the separation between the curves increases for smaller stimulus sizes, even in JND units. See the text also figure 3 for more information.

Supplemental Experimental Procedures

Psychophysical Procedure

Seven males and four females (22 to 34 years old) with normal or corrected to normal vision participated in the first experiment. Eight of these subjects were retested in this experiment after 3 to 5 weeks. Six of the original 11 subjects, including two of the authors, were tested in the other experiments. In all experiments subjects rested their head on a chin and forehead rest in a dark room and viewed the stimuli binocularly (except for the monocular viewing control experiment) on a CRT from 57 cm distance. For all experiments except experiment two (simultaneous face presentation), subjects were trained to identify the stimuli in the fovea for each task prior to the experimental sessions. Experimental sessions started after subjects reached 85% performance level on each task. The initial training task included the whole range of stimulus signal values (e.g. various morphing levels for faces) to familiarize subjects with the main task in the center of fixation. Subjects were given feedback for their correct and incorrect key presses at this stage. They could never reach 100% performance because there were very difficult stimuli in the set as well as stimuli with strong visual signal. 1728 trials were collected from each of the subjects for each task. Trials from the different conditions of the experiment were randomly ordered in each experiment. Stimulus presentation procedures were controlled by a PC processor using MATLAB psychtoolbox (version 2.54) and displayed on a 60 Hz 17 in. CRT. Stimuli used in all experiments (except for experiment two) spanned nine levels of signal strength. Each trial started with appearance of a small red fixation point in the middle of the screen. After 500ms the test stimulus was displayed for 50 ms (see Fig.1.a). The size of all stimuli was ~2° of visual angle in diameter and they were presented randomly in one of the eight possible locations at 3° of visual angle eccentricity around the fixation point. Pilot experiments suggested that presentations at 3° supported reasonably good face/color/orientation/aspect- ratio recognition and also gave enough space to test various retinal locations for the main purpose of the experiment. Subjects responded by pressing one of the two keys on the computer keyboard.

The face stimuli were made with Singular Inversion's FaceGen which produces facial prototypes based on 3D scans of numerous faces (based on methods developed by Blanz, V. & Vetter, T. A morphable model for the synthesis of 3D faces. In 1999 Symposium on Interactive 3D Graphics-Proceedings of SIGGRAPH'99, W. Waggenspack, ed. (pp. 187–194). New York: ACMPress.). For the gender face, the stimuli spanned morphing levels between 50% male and 50% female prototypes. The facial structure varied across morphing level but the identical texture was mapped onto the structure for all faces. For the facial age, subjects reported whether test faces looked older or younger than 40. The stimuli spanned the range between 30 to 50 year old neutral-gender face prototypes.. For the aspect ratio task, subjects judged whether the test ellipse was vertically or horizontally oriented. Ellipses varied in aspect ratio from 0.9 for vertical to 1.1 for horizontal ellipses chosen in a way to produce the same surface area for ellipses with all stimuli. In the spatial frequency discrimination task, subjects reported whether the spatial frequency of the grating patch was above or below the foveally learned value of 1.6 cycle/degree, a standard on which they were they were trained until they reached 85% correct. For this task horizontal Gabor patches of 3° size were used, spanning the spatial frequency range of 1.6±0.32 cycle/degree. In the orientation discrimination task, subjects reported whether the grating patch was oriented clockwise or counterclockwise of 45°. For this task Gabor patches of 3° size and 1.6 cycle/degree spatial frequency were used, spanning the orientation range of 45°±20°. For the color discrimination, subjects reported whether the test patch color was reddish or greenish with test colors centered on the neutral skin tone from the forehead of the average of our face stimuli. Circular uniform equiluminant color patches 2.1° in diameter were used for this task. The color range varied from a reddish tone (CIE *x*, *y* = 0.423, 0.324) to the neutral skin tone from the forehead of the averaged face stimulus (CIE *x*, *y* = 0.401, 0.335) to a greenish tone of (CIE *x*, *y* = 0.378, 0.347), all with luminance of 28.8 cd/m^2.

For experiment two, a pair of faces was used. In half of the trials two identical neutral faces were shown. In the other half, the two faces were slightly different, one of them 37.5% morphed toward the female prototype and the other was morphed 37.5% toward the male prototype. This stimulus strength difference was chosen to support ~75% performance in the unbiased pair of locations.

For the size experiment, the same faces and Gabors as the previous experiments were used. The stimuli were presented this time at 5° eccentricity. The tested sizes were: 4, 2.35, and 1.38 degrees of visual angle. For the Gabors we also tested the smaller size of 0.8° to confirm the systematic increase in the heterogeneity as the stimulus size decreases. The heterogeneity was not tested for 0.8° size because face discrimination was impossible for the subjects at that size at 5° eccentricity. However, the face heterogeneity seems to saturate even at the larger size of 2.35° (see Fig. 3).

Data Analysis

Data obtained from the eight tested locations for each subject/task were fit with a logistic function to calculate the PSE for each location.

$$p(x) = \frac{1}{1 + e^{-(\alpha x + \sum_{j=1}^{8} \beta_j I_j)}}$$

Where x is the stimulus signal value (e.g. morphing value for faces or the color patch hue for the color task) and P(x) is the probability of one of the two possible responses (e.g. probability of female response for the gender task or probability of "greenish" report for the color task). I is a binary variable, set to either 1 or 0 to indicate the presence or absence of a location condition while j was set from 1 to 8 to indicate all eight tested locations. α and β are free parameters that were fit using the maximum likelihood fitting procedure (Meeker, W. Q., & Escobar, L. A. *American Statistician* 1995: 49, 48–53.).

The Just Noticeable Difference (JND) was defined as the change in the stimulus signal that increases the psychometric performance 25% up (or down) from the psychometric threshold. "Heterogeneity index" was defined as the standard deviation of PSEs of the eight tested location in JND units for each subject/task. JND units were used to provide a standard measure for cross-task comparisons. For autocorrelation analysis (figure 4.c), each radial PSE mosaic was circularly shifted from 0 to ±4 steps and correlated with the original mosaic. The correlation coefficients were averaged for negative and positive values of each step for each subject/task. The resulting coefficients were collapsed across subjects to produce autocorrelograms (supplementary figure 2.a) for the six tasks.