Supplementary Materials

1. - Methods

1.1 - Eye-tracking

We used an EyeLink II headmounted eye-tracker (SR Research, Mississauga, ON, Canada), and sampled pupil centroid at 500 Hz. The default nine point calibration and validation sequences were repeated throughout the experiment. Both eyes were calibrated and validated, but only the eye with the lowest maximum error was recorded for the trials following a particular calibration. Calibration was repeated when maximum error at validation was more than 1° of visual angle. Before each trial, a drift correction was performed. Default criteria for fixations, blinks, and saccades as implemented in the Eyelink system were used.

1.2 - Stimuli

Grayscale neutral expression frontal-view face images were used in both the Other-Race and Face Orientation experiments. Each face was scaled to have a forehead width subtending 10 degrees of visual angle at presentation and was rotated to correct for any tilt of the head. Images were cropped to remove most of the background, but not the hair or other external features, and all images were equated for overall luminance. At presentation, images were centered on a black background. To eliminate any possible stimulus bias as the source of any laterality effects, half of the faces were randomly left-right flipped across the vertical midline of the image for each participant separately for each combination of stimulus face gender and either race of face or face orientation condition, depending on whether it was the Other-Race or Face Orientation Experiment.

Other-Race Experiment

For the experiment in which Race of Face and Start Position were manipulated, we collected 32 Caucasian-American, 32 African-American, and 32 Chinese face images (16 male and 16 female for each race), for a total of 96 grayscale neutral expression frontal-view face images. All Caucasian faces were taken from the neutral expression 18 to 29 age group of the Productive Aging Lab Face Database established by the University of Texas at Dallas (http://vitallongevity.utdallas.edu/stimuli/facedb/categories/neutral-faces.html) (Minear & Park, 2004). African-American faces were taken from the neutral expression 18 to 29 age group of the Productive Aging Lab Face Database, from the MacBrain ("NimStim") Face Stimulus Set made by the MacArthur Foundation Research Network on Early Experience and Brain Development (http://www.macbrain.org/resources.htm), and from the Color FERET Database (http://www.nist.gov/itl/iad/ig/colorferet.cfm) (Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998) established by the United States Department of Defense (DOD) Counterdrug Technology Program. All Chinese faces were taken from the CAS-PEAL Face Database (http://www.jdl.ac.cn/peal/index.html) (Gao et al., 2008) established by the ICT-ISVISION Joint Research and Development Laboratory

(JDL) for Face Recognition.

The website of the Productive Aging Lab Face Database states: “This [database] contains a range of face of all ages which are suitable for use as stimuli in face processing studies. Releases have been signed by the participants we photographed and the faces may be included in publications or in media events.” Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set. Portions of the research in this paper use the FERET database of facial images collected under the FERET program, sponsored by the DOD Counterdrug Technology Development Program Office. The research in this paper use the CAS-PEAL-R1 face database collected under the sponsor of the Chinese National Hi-Tech Program and ISVISION Tech. Co. Ltd.

Face Orientation Experiment

For the experiment in which Face Orientation and Start Position were manipulated, we used 80 grayscale neutral expression face images (40 male). These images were of Caucasians between the ages of 18 and 29 again from the Productive Aging Lab Face Database at the University of Texas at Dallas (http://vitallongevity.utdallas.edu/stimuli/facedb/categories/neutral-faces.html). Inverted faces were created by simply reflecting each image around the horizontal axis.

1.3 - Areas of Interest (AOIs)

To aid alignment of the face images and positioning relative to the fixation starting position, rectangular areas-of-interest (AOIs) were drawn for each face around the right and left eyes, bridge of nose (i.e. middle of eye region), right and left half of nose, and right and left half of mouth using EyeLink Data Viewer software. These AOIs were never visible to participants during the experiment.

1.4 - Design

The paradigms of the face orientation experiment and the other-race experiment were highly similar. Each experiment was comprised of two phases: study and test. During the study phase, one face was presented per trial and participants were instructed to remember the faces for later recognition. They were allowed to advance study phase trials in a self-paced manner (up to 10 seconds per trial, self-terminating trials with a button press). The test phase began immediately after the study phase. In each trial of the test phase, participants viewed a face for a limited duration (one second only) and indicated with a button press whether or not they recognized each face as one presented during study (old/new task). Participants were instructed to respond within two seconds following stimulus onset, as soon as they thought they knew the answer.

In both the study and test phases, there were equal proportions of trials for each combination of levels of the factors of stimulus type (race of face or face orientation, depending on the experiment), face gender, and start position (i.e. the pre-stimulus fixation location). The particular subset of faces used in the study phase was randomized across participants. Of the faces presented in both study and test phase, half of the faces were presented with the same start position at study and test and for the other half, the start position on the other side of the face was used (e.g. left to right start position between study and test).

We systematically varied the pre-stimulus fixation location ("Start Position") because fixation patterns are affected by visuomotor factors (e.g. start position) in addition to stimulus factors (face) (J. Arizpe, Kravitz, Yovel, & Baker, 2012; J. M. Arizpe, Walsh, & Baker, 2015). Further, we were interested in this factor as a potential modulator of individual differences. The start positions of interest were either left of or right of the internal features of the upcoming face stimulus. Coordinates for a given start position were calculated uniquely for each face stimulus to be equidistant from all of the nearest internal facial features. Specifically, this was the unique coordinate that was equidistant from the centers of the nearest eye, nearest half-nose, and nearest half-mouth AOI was calculated numerically for each face. As the data from these experiments were originally collected for different purposes than the present study, there were also other start positions either above, below, or (only in the Face Orientation experiment) centered on the internal features of the upcoming face stimulus throughout the experiment; however, due to the number of comparisons necessary among the start positions and because left and right start position conditions are the most ecological, only left and right start position conditions were ultimately analyzed.

Before the onset of each stimulus, participants fixated at the start position, indicated by a standard Eyelink II calibration target (0.17° diameter black circle overlaid on a 0.75° diameter white circle) on the black screen. Participants initiated the trial by pressing a button while looking at the fixation target. In this action, a drift correction was performed. A colored dot (0.5° diameter) remained after drift correction, and the stimulus appeared only after a participant had fixated at the dot for an accumulated total of 1500 ms. This requirement ensured that drift correction and fixation were stable prior to stimulus onset. If more than 1500 ms of fixation off the start position accumulated before the trial could be initiated, drift correction was repeated. A fixation was considered off the start position if it landed more than 0.5° from the center of the dot. Dot color changed successively from red to yellow to green in order to signal to the participant that a maintained fixation was successfully detected at the start position.

Other-Race Experiment

In the other-race experiment, we varied Race of Face (Caucasian, African, Chinese) and Start Position across trials. During the study phase, participants viewed 48 faces (16 of each race, 8 male for each race). During the test phase, participants viewed 96 faces (the 48 study phase faces plus 48 new faces).

Face Orientation Experiment

In the face orientation experiment, we varied face Orientation (upright or inverted) and Start Position across trials. For each participant, a random half of the faces were inverted in each phase, with the orientation of a given face being identical in both phases. In the study phase, participants viewed 40 faces (20 male). In the test phase, participants viewed 80 faces (the 40 study phase faces plus 40 new faces).

1.5 – Split-half analysis table

Analysis	Experimental data	Trial condition levels pooled before calculating correlation	Trial condition levels averaged after calculating correlation	Trial condition levels excluded	Split half 1 trial condition level	Split half 2 trial condition level
Race of Face: Discriminability	Other-Race Experiment	N/A	left and right start positions	test phase; upper and lower start positions; time windows 2 - 5; African and Chinese faces	Caucasian	Caucasian
				test phase; upper and lower start positions; time windows 2 - 5; Caucasian and Chinese faces	African	African
				test phase; upper and lower start positions; time windows 2 - 5; Caucasian and African faces	Chinese	Chinese
Race of Face: Individual Consistency	Other-Race Experiment	N/A	left and right start positions	test phase; upper and lower start positions; time windows 2 - 5; Chinese faces	Caucasian	African
				test phase; upper and lower start positions; time windows 2 - 5; African faces	Caucasian	Chinese
				test phase; upper and lower start positions; time windows 2 - 5; Caucasian faces	African	Chinese
Start Position: Discriminability	Other-Race Experiment	Caucasian, African, and Chinese faces	N/A	test phase; right, upper, and lower start positions; time windows 2 - 5	left start position	left start position
				test phase; left, upper, and lower start positions; time windows 2 - 5	right start position	right start position
Start Position: Individual Consistency	Other-Race Experiment	Caucasian, African, and Chinese faces	N/A	test phase; upper and lower start positions; time windows 2 - 5	left start position	right start position
Phase: Discriminability	Other-Race Experiment	Caucasian, African, and Chinese faces	left and right start positions	test phase; upper and lower start positions; time windows 2 - 5	study phase	study phase
				study phase; upper and lower start positions; time windows 2 - 5; "old" faces in test phase	test phase	test phase
Phase: Individual Consistency	Other-Race Experiment	Caucasian, African, and Chinese faces	left and right start positions	upper and lower start positions; time windows 2 - 5; "old" faces in test phase	study phase	test phase
Time Window: Discriminability	Other-Race Experiment	Caucasian, African, and Chinese faces	left and right start positions	test phase; upper and lower start positions; time windows 2 - 5	time window 1	time window 1
				test phase; upper and lower start positions; time windows 1, and 3 - 5	time window 2	time window 2
				test phase; upper and lower start positions; time windows 1, 2, 4, and 5	time window 3	time window 3
				test phase; upper and lower start positions; time windows 1 - 3, and 5	time window 4	time window 4
				test phase; upper and lower start positions; time windows 1 - 4	time window 5	time window 5
Time Window: Individual Consistency	Other-Race Experiment	Caucasian, African, and Chinese faces	left and right start positions	test phase; upper and lower start positions, time windows 2 - 4	time window 1	time window 5
Orientation: Discriminability	Orientation Experiment	N/A	left and right start positions	test phase; upper, lower, and center start positions, inverted orientation	upright orientation	upright orientation
				test phase; upper, lower, and center start positions, upright orientation	inverted orientation	inverted orientation
Orientation: Individual Consistency	Orientation Experiment	N/A	left and right start positions	test phase; upper, lower, and center start positions	upright orientation	inverted orientation

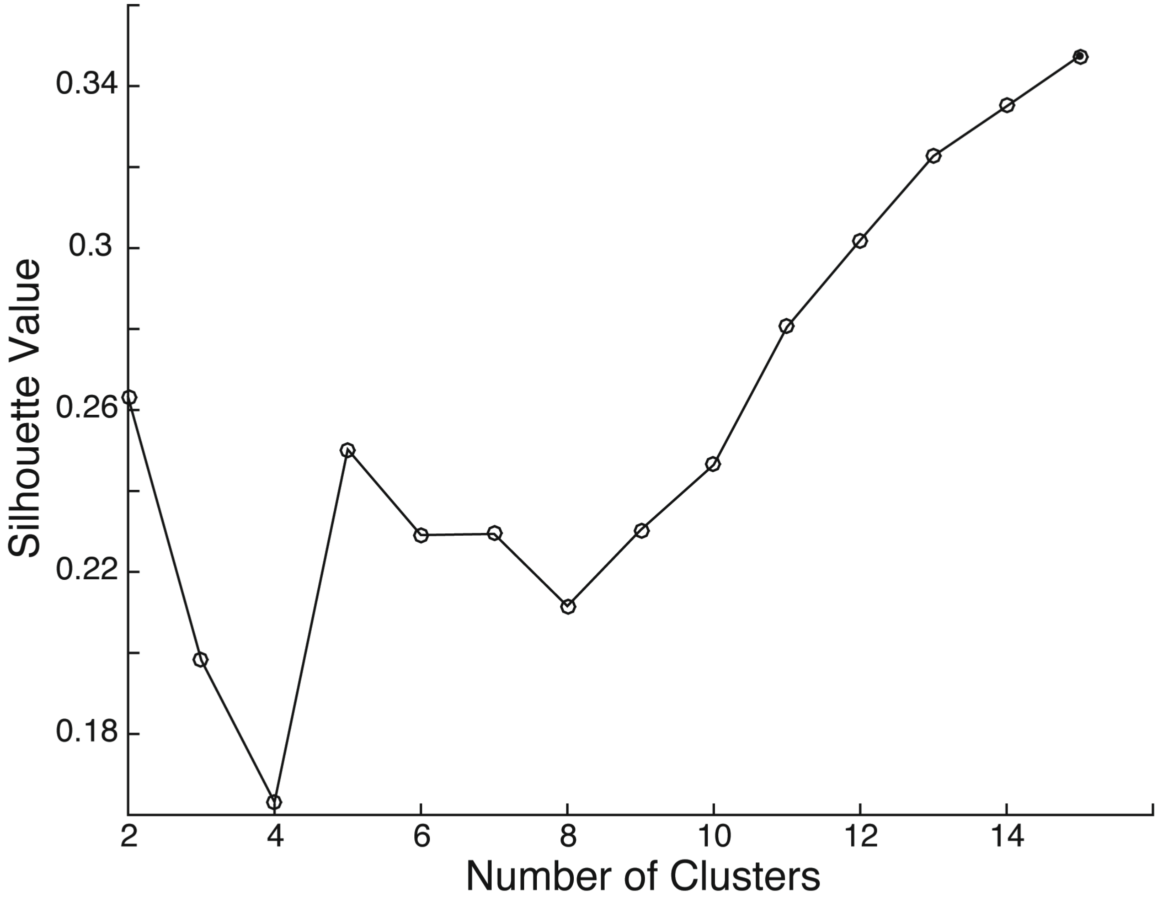
Supplementary Table 1. Details about the subset of trials used for each split-half correlation analysis performed to calculate the discrimination indices.

1.6 - Gap Statistic Clustering Evaluation

Gap statistic evaluations of the cluster solutions for the peaks in eye-movement spatial density were performed with the Matlab function ‘evalclusters’ with the clustering algorithm set to ‘linkage’, the evaluation criterion set to ‘gap, the range of cluster numbers to evaluate set to 2 to 15 clusters, and the distance metric set to squared Euclidean distance.

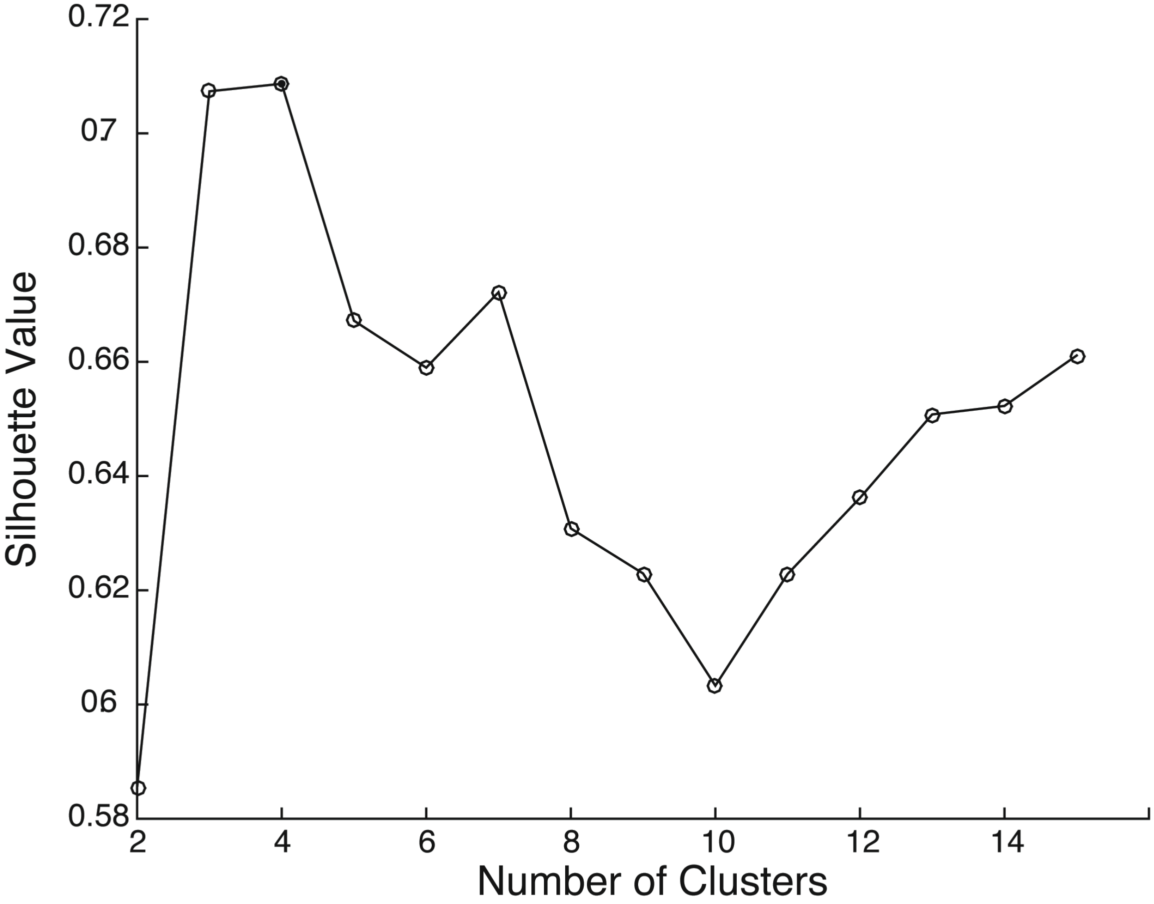
2. - Results

2.1 - Evaluation of Clustering in Eye-movement Density Patterns

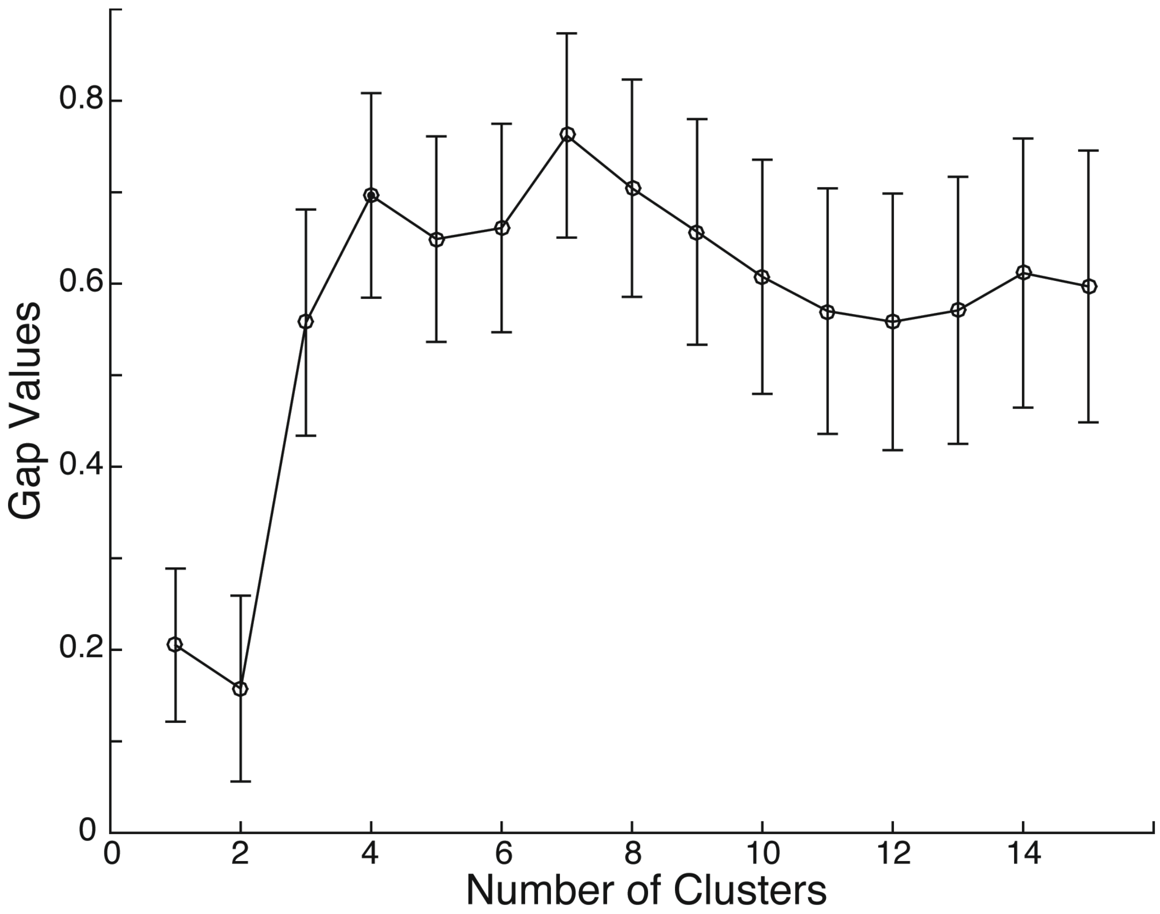


Supplementary Figure 1. Evaluation of clustering among eye-movement spatial density patterns. Plotted are the average Silhouette values of the solutions for the various numbers of clusters resulting from UPGMA hierarchical clustering using the Spearman correlation dissimilarities among participant spatial density maps. Average Silhouette values were overall quite low, suggesting that no optimal number of clusters can be found in this data.

2.2 - Evaluation of Clustering in Eye-movement Density Pattern Peaks

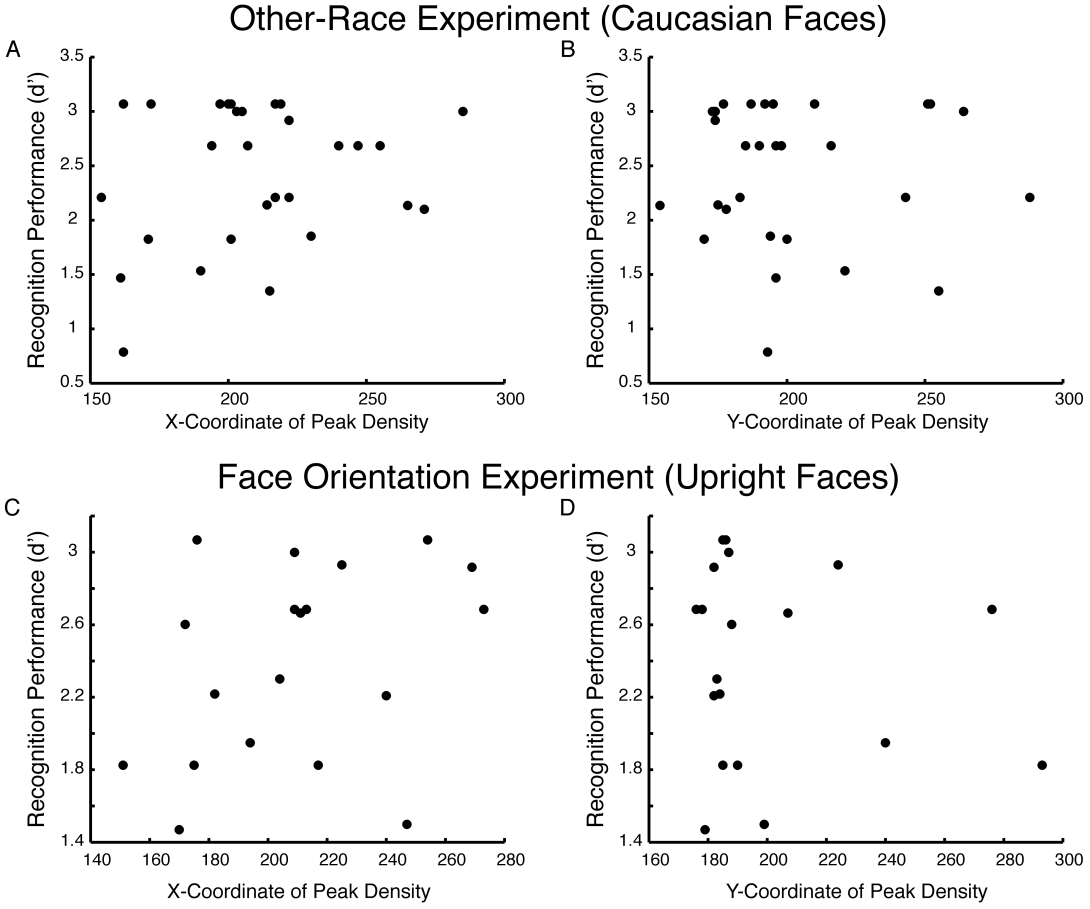


Supplementary Figure 2. Evaluation of clustering among peaks in eye-movement spatial density. Plotted are the average Silhouette values of the solutions for the various numbers of clusters resulting from UPGMA hierarchical clustering on the participant peaks in eye-movement spatial density. The highest average Silhouette value was for the solution for four clusters, suggesting that four is the optimal number of natural clusters.



Supplementary Figure 3. Alternative evaluation of clustering among peaks in eye-movement spatial density. Plotted are the Gap statistic values of the solutions for the various numbers of clusters resulting from UPGMA hierarchical clustering on the participant peaks in eye-movement spatial density. The error bars indicate standard errors. Application of standard Gap evaluation criteria indicates that the optimal natural number of clusters in this data is four, in agreement with the average Silhouette evaluation.

2.3 - Scatter plots of peak spatial density coordinates against recognition performance

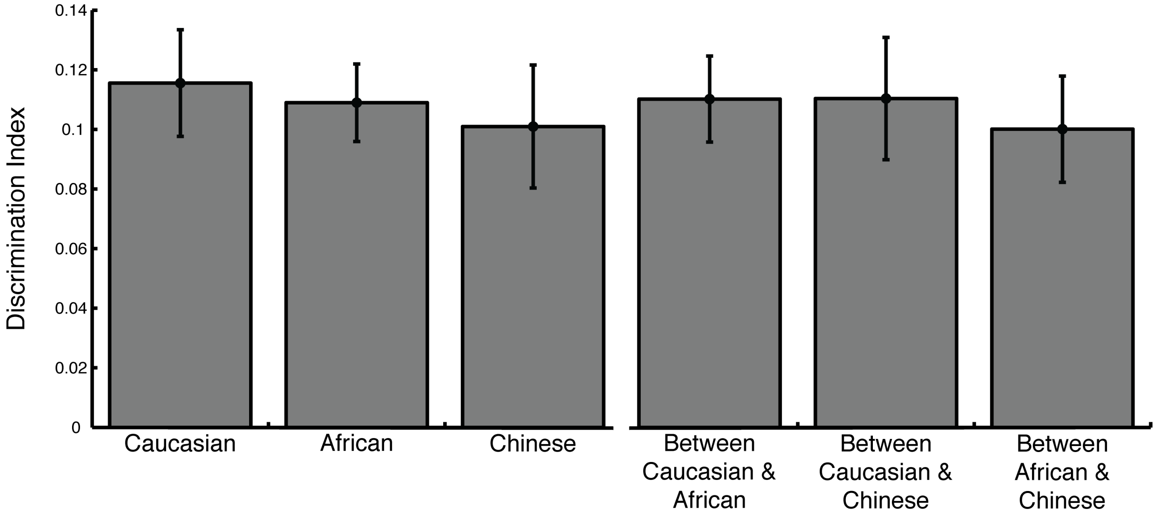


Supplementary Figure 4. Scatter plots of peak spatial density coordinates against recognition performance. Participants' x-coordinates (a) and y-coordinates (b) against recognition performance, measured by d' for Caucasian faces in the Other-Race experiment. Participants' x-coordinates (c) and y-coordinates (d) against recognition performance, measured by d' for upright faces in the Face Orientation experiment. For reference, the coordinates (270, 175) and (155, 175) correspond to the pupils of left and right eyes, respectively, (213, 240) to the tip of the nose, and (213, 305) to the center of the convergence of the lips on the average face.

2.4 - What factors modulate individual differences in eye-movements?

2.4.1 - Race of Face

Race of Face did not significantly modulate the distinctiveness of individual eye-movement patterns, and did not strongly modulate individual eye-movement patterns (Supplementary Figure 5).



Supplementary Figure 5. Discrimination indices within- and between- Race of Face (Caucasian, African, Chinese) for the study phase of the Other-Race experiment. Race of Face did not significantly impact discrimination indices. Discrimination index quantifies the average distinctiveness of eye-movement patterns of the given participants compared to those of the others. Error bars represent ± 1 standard error.

Discriminability. Using the study phase data from the Other-Race Experiment and averaging correlation matrices from both start positions, we found that discriminability indices (see Methods) were significantly greater than zero for each Race of Face (Caucasian, African, Chinese, all $t(28) > 4.8$, $p < 0.00003$, one-tailed). This means that for each race of face condition, there was significant discriminating information in individual eye-movement patterns. Discrimination accuracy (see Methods) for uniquely identifying individual participants' eye-movement patterns across split halves of data was greater than 24%, and thus significantly greater than chance ($p < 0.00005$), for each race of face.

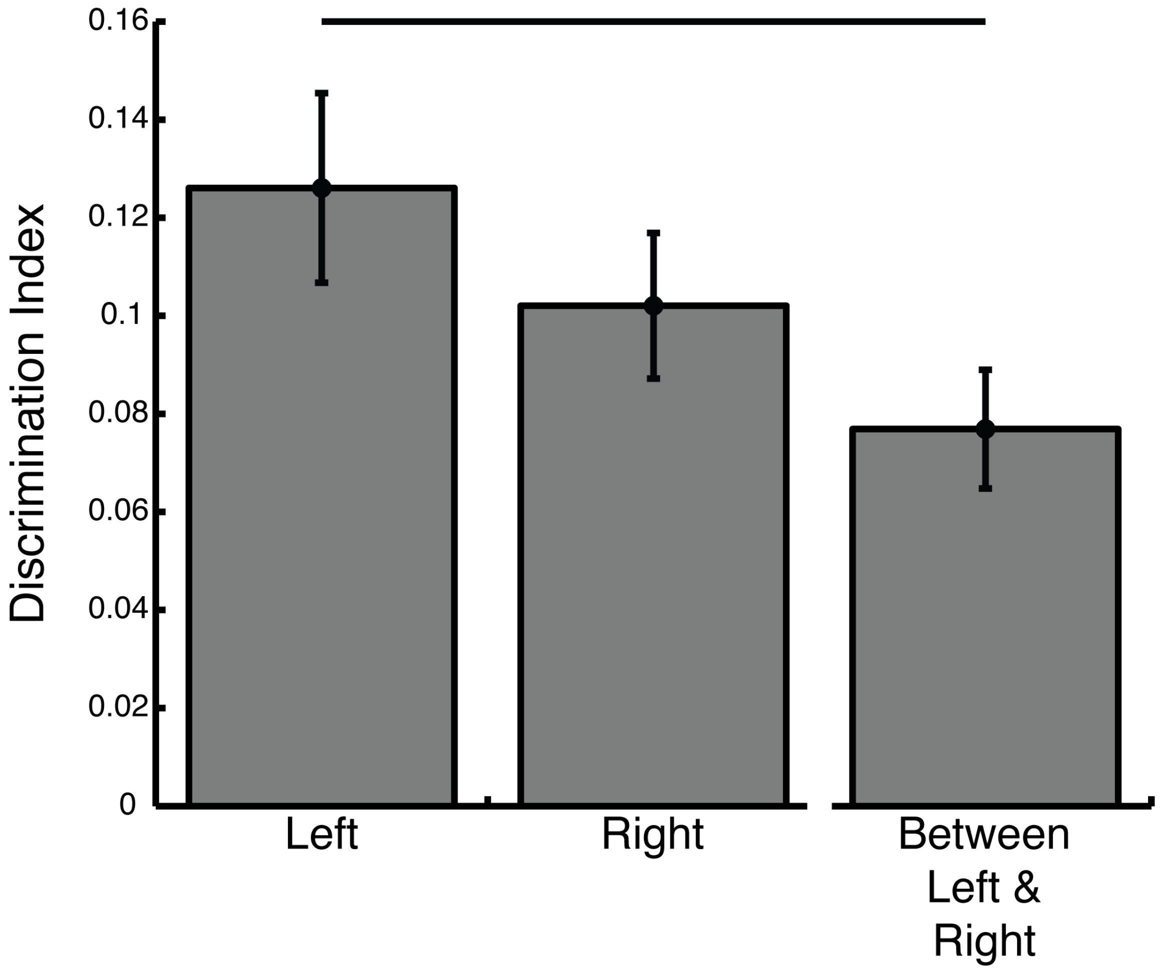
Relative Discriminability. Notably, discriminability indices did not differ significantly among Caucasian, African, and Chinese face conditions (all three comparisons: paired $t(28) <0.96$, $p > 0.34$, two-tailed), which suggests that participants were not differentially discriminable for any of these conditions.

Consistency Across Levels. When individual eye-movement patterns in one Race of Face condition were used to discriminate observers in another Race of Face condition (e.g. discriminate individuals' Chinese condition eye-movement patterns from their Caucasian condition patterns), the discriminability indices for the three possible split halves pairings (i.e. 1. Caucasian discriminating African, 2. Caucasian discriminating Chinese, 3. African discriminating Chinese) differed neither from one another (all three: paired $t(28) < 0.61$, $p > 0.54$, two-tailed) nor from the discrimination indices within Race of Face conditions (all comparisons: paired $t(28) < 0.87$, $p > 0.19$, one-tailed). In accord with these results, discrimination accuracy for the three possible split halves pairings were all greater than 27%, and thus still highly significantly above chance ($p <$ 4.5e-6). These results suggest that our participants' idiosyncratic eye-movement patterns were consistent across changes in Race of Face.

In light of the lack of evidence for Race of Face modulating our participants' idiosyncratic eye-movement patterns, we pooled eye-movement patterns across Race of Face for all remaining analyses involving data from the other-race experiment.

2.4.2 - Start Position

Using the study phase data of Other-Race Experiment and pooling all Race of Face conditions together, we found evidence that pre-stimulus Start Position may have modulated the distinctiveness of individual eye-movement patterns, and, further, that the distinguishing information in individual eye-movement patterns differed across start position conditions (Supplementary Figure 6).



Supplementary Figure 6. Discrimination indices within- and between- Start Position (left, right) conditions for the study phase of the Other-Race experiment (all Race of Face conditions pooled). The between- start position discrimination index was significantly lower than that for within left and marginally lower than that for within right. Error bars represent ± 1 standard error.

Discriminability. Discriminability indices were significantly greater than zero for each Start Position (Left, Right of face both $t(28) > 6.41$, $p < 3.05e-7$). Thus there was significant discriminating information in individual eye-movement patterns for each Start Position condition.

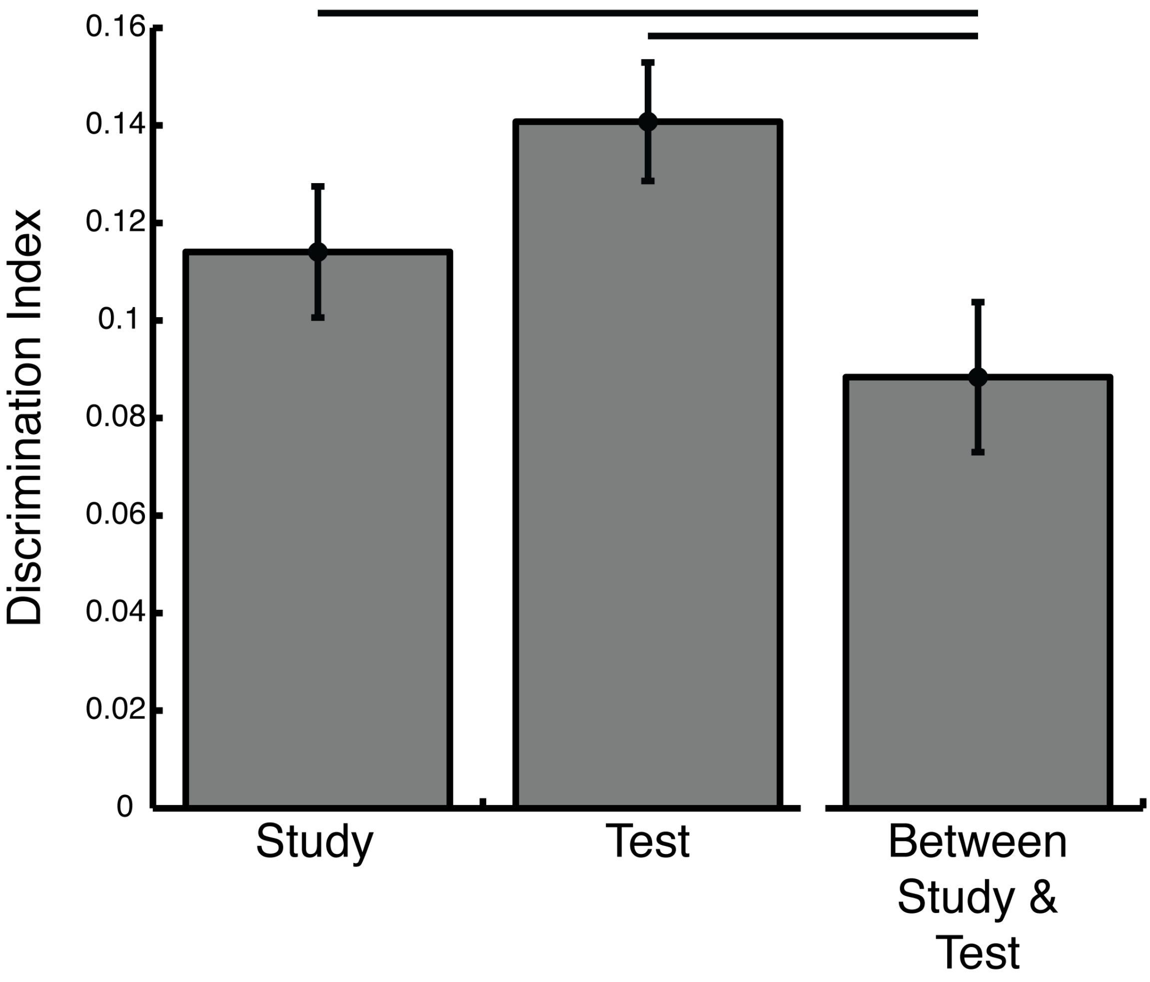
Relative Discriminability. Discriminability indices did not differ significantly between left and right start position conditions (paired $t(28) < 1.098$, $p > 0.28$, two-tailed), suggesting that participants were not differentially discriminable for either condition. Discrimination accuracy was 17.24% for left start position and 48.28% for right start position, both of which are significantly greater than chance ($p < 0.0030$ and $p < 1.59\text{e-}13$, respectively). Given the apparent difference in magnitude of discrimination accuracy between left and right start position conditions, we conducted a post-hoc test calculating the probability that an accuracy greater or equal to than that the of the right start position could be achieved under the assumption that the true probability of correct individuation is equal to the left start position accuracy. The probability is $p < 0.00012$, suggesting that the discrimination accuracies are different between left and right start position. Compared to discrimination index, discrimination accuracy is a more stringent measure of discriminating information and requires uniquely individuating information to be present in patterns to produce high values, so these results suggest that right start position induced patterns which were more highly uniquely discriminating, while average differences in distinctiveness across individuals was not significantly modulated (see "Methodological considerations" in *Discussion*).

Consistency Across Levels. When individual eye-movement patterns in the right start position condition were used to discriminate individuals in the left start position condition, the discriminability indices were significantly greater than zero contrary to our expectation ($t(28) > 5.52$, $p < 3.4\text{e-}6$, one-tailed), and the discrimination accuracy was 10.34%, which is marginally greater than chance ($p < 0.078$). This indicates that discriminating information in eye-movement patterns was at least partially preserved across left and right start position conditions. The between Start Position discrimination index was significantly lower than the within left discrimination index (paired $t(28) > 2.44$, $p < 0.011$, one-tailed) and marginally lower than within right discrimination (paired $t(28) > 1.58$, $p < 0.063$, one-tailed) suggesting that while discriminating information was preserved between left and right start positions, it was degraded. Together, this evidence indicates that our participants' idiosyncratic eye-movement patterns were modulated across Start Position conditions.

In light of the evidence for Start Position modulating our participants' idiosyncratic eye-movement patterns, for all remaining discrimination analyses, we average the correlation matrices from both start positions before calculating discriminability indices and discrimination accuracies, as was done in the analysis investigating discriminability across Race of Face conditions.

2.4.3 - Study and Test Phase

Phase is a factor that marginally significantly modulated the distinctiveness of individual eye-movement patterns, and significantly modulated individual eye-movement patterns (Supplementary Figure 7).



Supplementary Figure 7. Discrimination indices within- and between- Phase (study, test) conditions of the Other-Race experiment (all Race of Face conditions pooled and Start Position conditions averaged). The between-phase discrimination index was significantly lower than the discrimination indices within either phase alone, and within-phase discrimination index for study was marginally lower than for test. Error bars represent ± 1 standard error.

Discriminability. Discriminability indices were significantly greater than zero for both the study and test phases (both $t(28) > 8.33$, $p < 2.31\text{e-}9$, one-tailed) in the other-race experiment, and thus indicate significant discriminating information in individual eye-movement patterns in each phase. Discrimination accuracy was greater than 34%, and thus significantly greater than chance ($p < 2.61\text{e-}8$), for each phase.

Relative Discriminability. There was a marginally significant difference in the discriminability indices between phases (paired $t(28) > 1.88$, $p < 0.070$, two-tailed), which suggests that participants eye-movement patterns may have been more weakly discriminable in the study phase.

Consistency Across Levels. When individual eye-movement patterns in the study phase were used to discriminate individuals in the test phase, the discriminability index was significantly greater than zero (paired $t(28) > 5.65$, $p < 1.17\text{e-}6$, one-tailed) and discrimination accuracy (24.14%) was significantly greater than chance ($p < 0.000046$), but the discrimination index notably was significantly lower than the within-phase discrimination indices (both: paired $t(28) > 1.84$, $p < 0.038$, one-tailed). This suggests that our participants' idiosyncratic eye-movement patterns were modulated across study and test phases.

Given this evidence that our participants' idiosyncratic eye-movement patterns were modulated across study and test phases, and because we cannot rule out that this may have been because of the artificial time restriction to make eye-movements during test phase, we focused only on data from the study phase (which was always self-paced) in all other discrimination analyses.

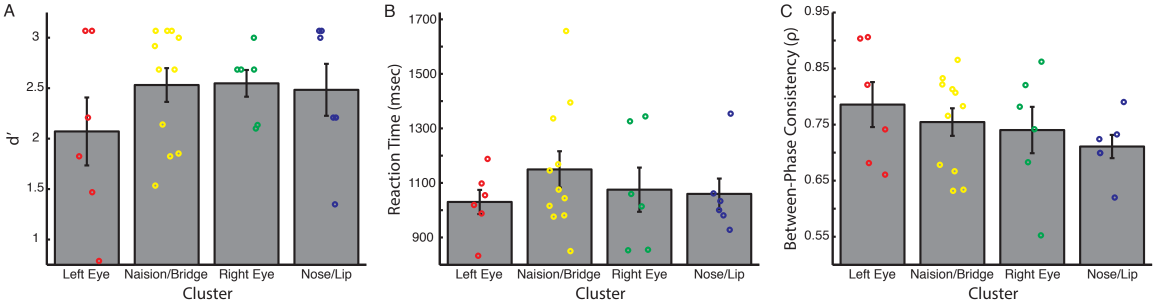
2.4.4 – Face Orientation: Individual Maps

Supplementary Figure 8. Side-by-side upright and inverted face spatial density maps for each participant from the Face Orientation experiment.

2.5 – Orthogonal measures for each cluster

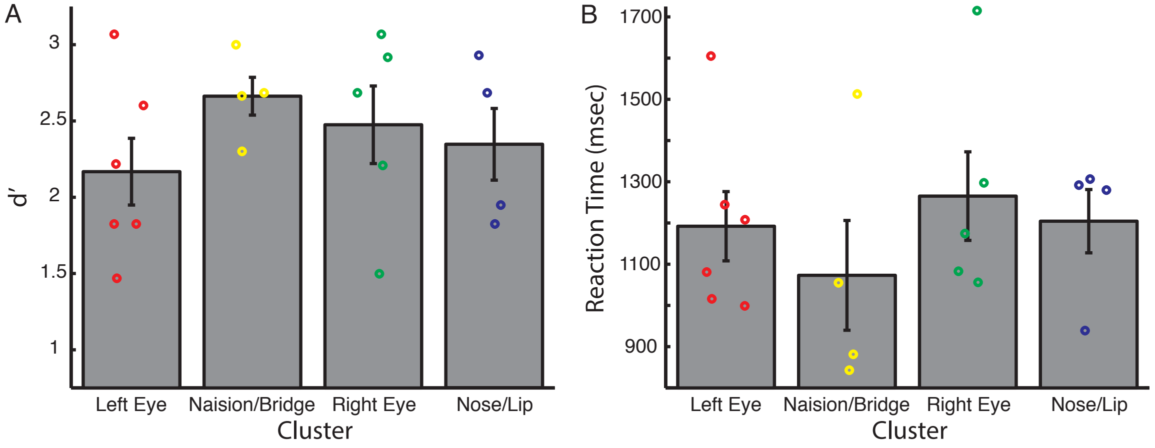
We investigated whether certain measures, such as d' performance or reaction time, differed among the four clusters we discovered. We could not reject the null hypotheses that the measures were equivalent among the clusters; however, low statistical power is also a relevant issue.

One-way ANOVAs did not yield significant effects of cluster for either d' performance ($F(3,25) = 0.78$, $p > 0.51$, $\eta^2 = 0.086$) or for reaction time ($F(3,25) = 0.57$, $p > 0.62$, $\eta^2 = 0.066$) from the Other-Race experiment (Supplementary Figure 9a,b). Additionally, utilizing between-phase consistency values from the diagonal (i.e., within-participant Spearman's ρ) of the between-Phase (study, test) correlation matrix, we also investigated whether between-phase consistency differed among the clusters (Supplementary Figure 9c). No differences in consistency were detected ($F(3,25) = 0.70$, $p > 0.55$, $\eta^2 = 0.078$).



Supplementary Figure 9. Orthogonal measures by cluster for data from the Other-Race experiment. A) d' performance by cluster B) Reaction time by cluster C) Between-phase consistency by cluster. Between-phase consistency values are from the diagonal (i.e., within-participant Spearman's ρ) of the between-Phase (study, test) correlation matrix used to calculate the discrimination indices in Supplementary Figure 7. For all sub-figures, the colored points indicate individual participant data points and the gray bars indicate the means for each cluster. Error bars indicate standard errors of the mean.

Likewise, one-way ANOVAs did not yield significant effects of cluster for either d' performance ($F(3,15) = 0.71$, $p > 0.55$, $\eta^2 = 0.13$) or for reaction time ($F(3,15) = 0.46$, $p > 0.71$, $\eta^2 = 0.083$) from the Face Orientation experiment (Supplementary Figure 10).



Supplementary Figure 10. Orthogonal measures by cluster for data from the Face Orientation experiment. A) d' performance by cluster. B) Reaction time by cluster. For both sub-figures, the colored points indicate individual participant data points and the gray bars indicate the means for each cluster. Error bars indicate standard errors of the mean.

3. - Discussion

3.1 - What factors influenced individual differences?

In our investigation into the influences of experimental factors, we found that for our Western Caucasian participants, Race of Face (Caucasian, African, Chinese) did not significantly modulate the discriminability of eye-movement patterns among participants (i.e. distinguishability arising from the distinctiveness of participants' patterns relative to those of the others) as individuals were discriminable, and equally so, in each Race of Face condition. Further, individual eye-movement patterns were consistent among the Race of Face conditions as we failed to find evidence that they differed strongly between Race of Face conditions (though see J. Arizpe, Kravitz, Walsh, Yovel, & Baker, 2016).

Start Position (left or right of upcoming face) is a factor that showed evidence of modulation of the discriminability of individual eye-movement patterns. Discriminability indices did not significantly differ between left and right start position, though discrimination accuracy did greatly differ such that discrimination accuracy was lower for left start position. Compared to discrimination index, discrimination accuracy is a more stringent measure of discriminating information and requires uniquely individuating information to be present in patterns to produce high values, so these results suggest that right start position induced patterns which were more highly uniquely discriminating, while average differences in distinctiveness across individuals was not significantly modulated. We additionally found that start position modulated individual eye-movement patterns (i.e. individual consistency was reduced between left and right start position conditions compared to within a start position condition), and thus that discriminating information in individual eye-movement patterns was not invariant across start position conditions. This difference in individual eye-movement patterns between start positions can be attributed to the visuomotor influences induced by the start positions that have been characterized in our prior studies (J. Arizpe et al., 2012; J. M. Arizpe et al., 2015).

For Phase (study, test), we observed a trend in our discrimination index ($p < 0.070$, two-tailed) toward higher discriminability in test (i.e. in test, participants patterns were overall more distinct relative to one another). Further, we found evidence that individual eye-movement patterns were modulated between phases, as discrimination between phases was significantly weaker than within phase ($p < 0.038$, one-tailed). Because we cannot rule out that this difference in individual eye-movement patterns between phases may have been due to the artificial time restriction to make eye-movements during test phase, rather than the task difference between phases (encoding during study phase, recognition during test phase), this effect warrants further investigation in future studies.