Image reconstruction reveals how aging impacts face perception

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Introduction

- Face perception can deteriorate due to healthy aging[1-2].
- However, how exactly aging impacts face processing remains unclear. For example, what type of visual information processing is impaired and to what extent?
- Research in healthy adults points to separate mechanisms for shape and surface processing in face perception[3-4].
- This study examines the occurrence of differences in face processing due to impaired shape and/or surface processing by appealing to image reconstruction methodology[5-6].

Methods

- 21 young adults (YA, age 18-31 years, education 12-19 years, 11 female), and 24 older adults (OA, age 62-71 years, education 12-23 years, 11 female) completed two 2h sessions on separate days.
- Participants performed a series of neuropsychological tests as well as a pairwise face similarity rating task with 57 colour images of Caucasian male faces.
- Similarity ratings for each participant provided the input for image reconstruction:
  1) A face space construct was estimated through multidimensional scaling (MDS) applied to to a confusability matrix based on face similarity (on a 7-point scale).
  2) Classification vectors (CVs) for shape, or classification images (CIMs) for surfaces, were synthesized through a method akin to reverse correlation and their significance was assessed via permutation tests.
  3) The target face was reconstructed through a linear combination of significant CVs or CIMs added onto an average shape or a shape-free surface.
  4) Reconstructed shape and surface were combined into a reconstructed face[7].
- The reconstructions were evaluated objectively with regard to fiducial point coordinates or image pixel values, as well as experimentally by an independent group of validators who were demographically matched to the YAs and OAs above.
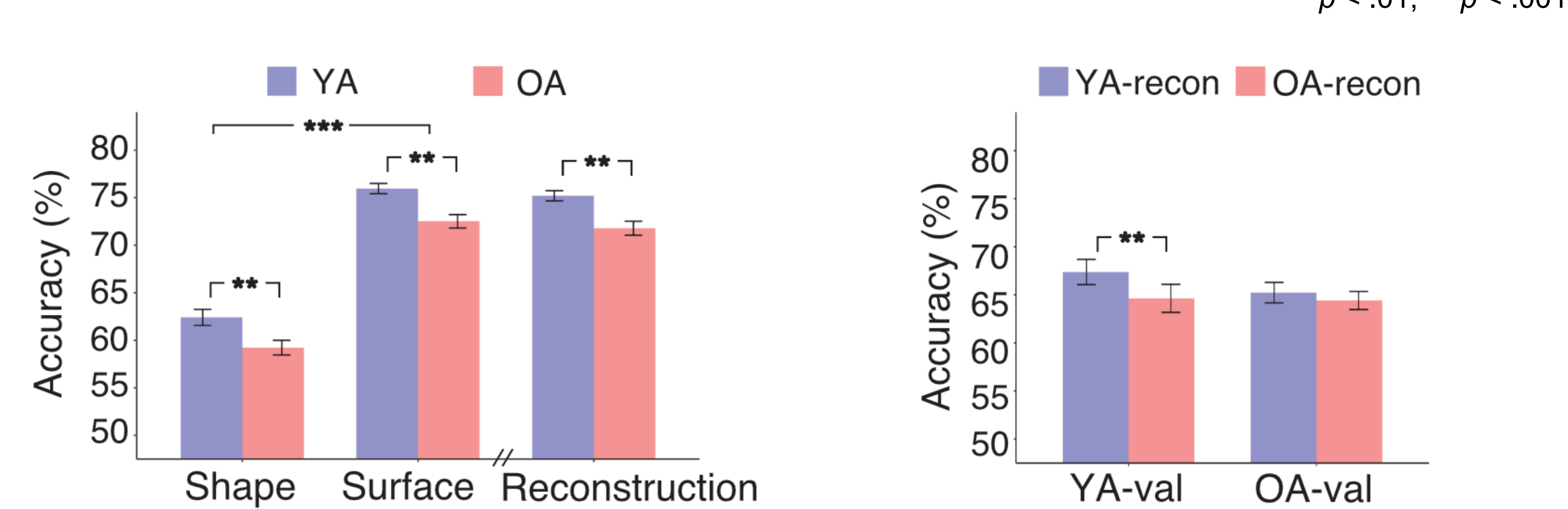
Reconstruction Procedure
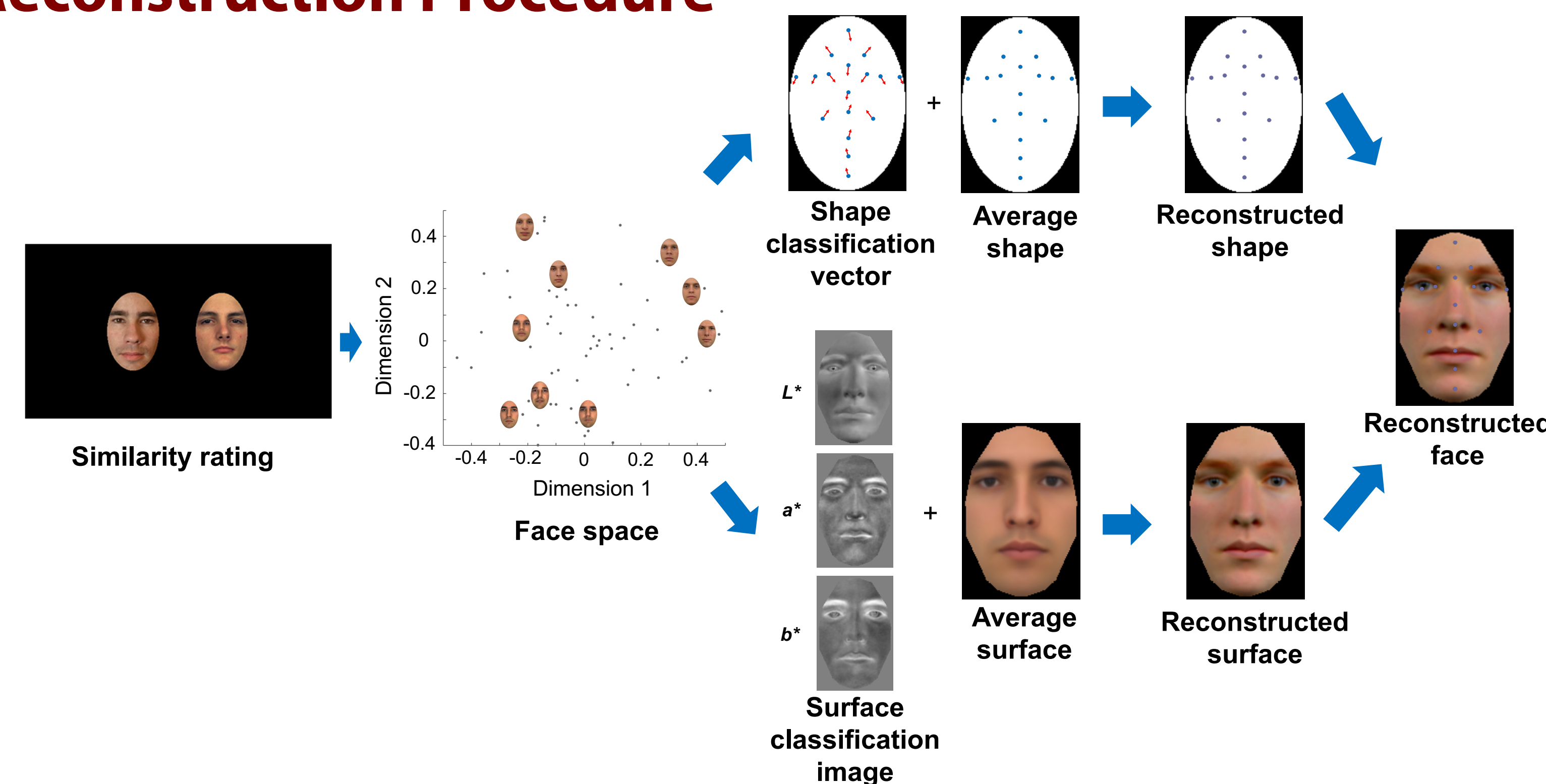
## Examples of Facial Image Reconstructions
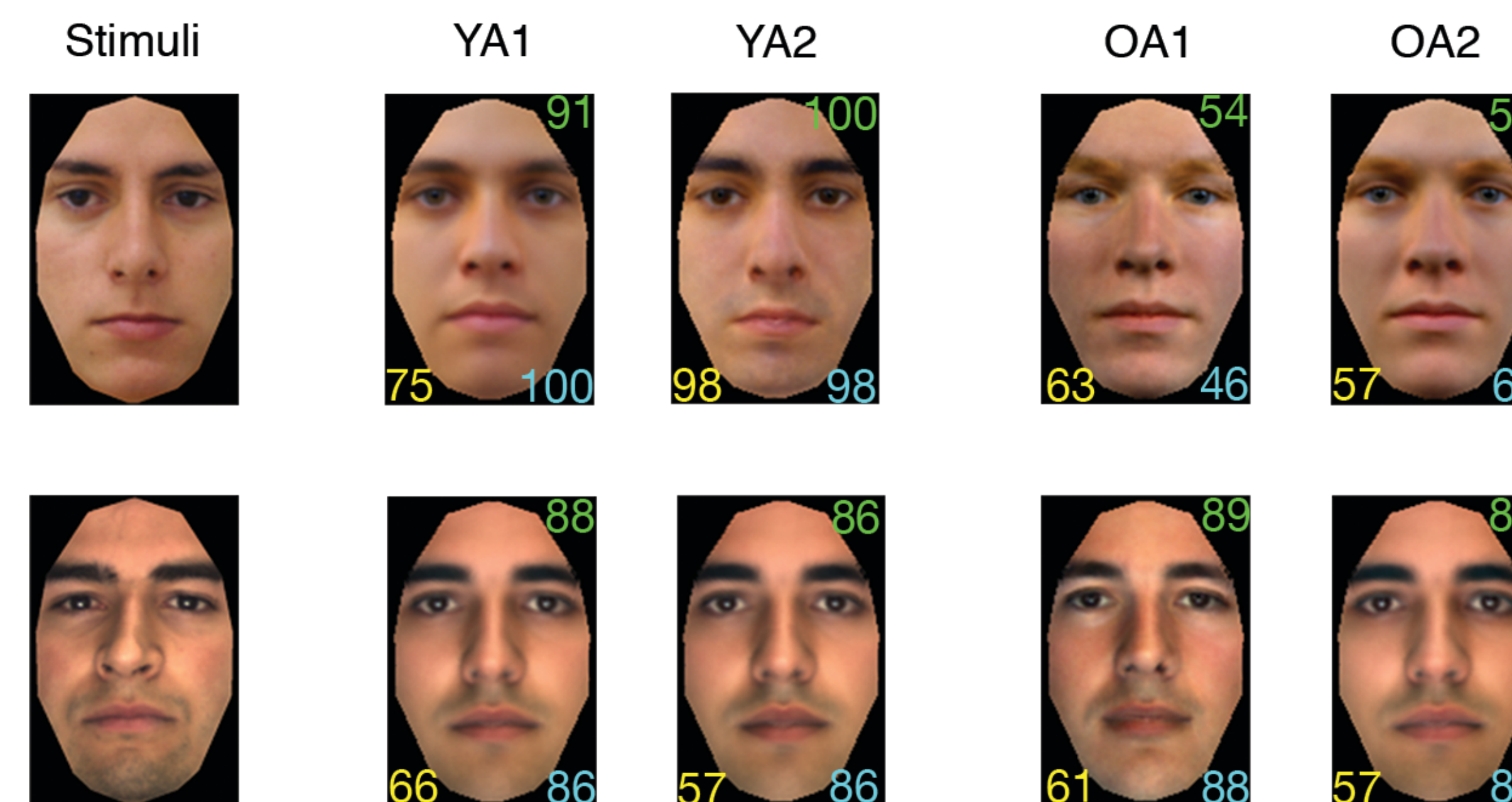
Numbers represent accuracies for: reconstructed faces (top right), only shape (bottom left) and only surface (bottom right).

Results of Reconstruction Accuracies

Error bars: ±1 SE; **p < .01, ***p < .001

- YA data supported higher levels of reconstruction than OA data in all cases.
- Surface information was more accurately retrieved than shape information for both groups of participants.
- Reconstructions derived from YAs were recognized more accurately than those from OAs in both YA and OA validators.

Correlations between Reconstructions and FOJT

*p < .05, **p < .01

r = .42*

r = .48**
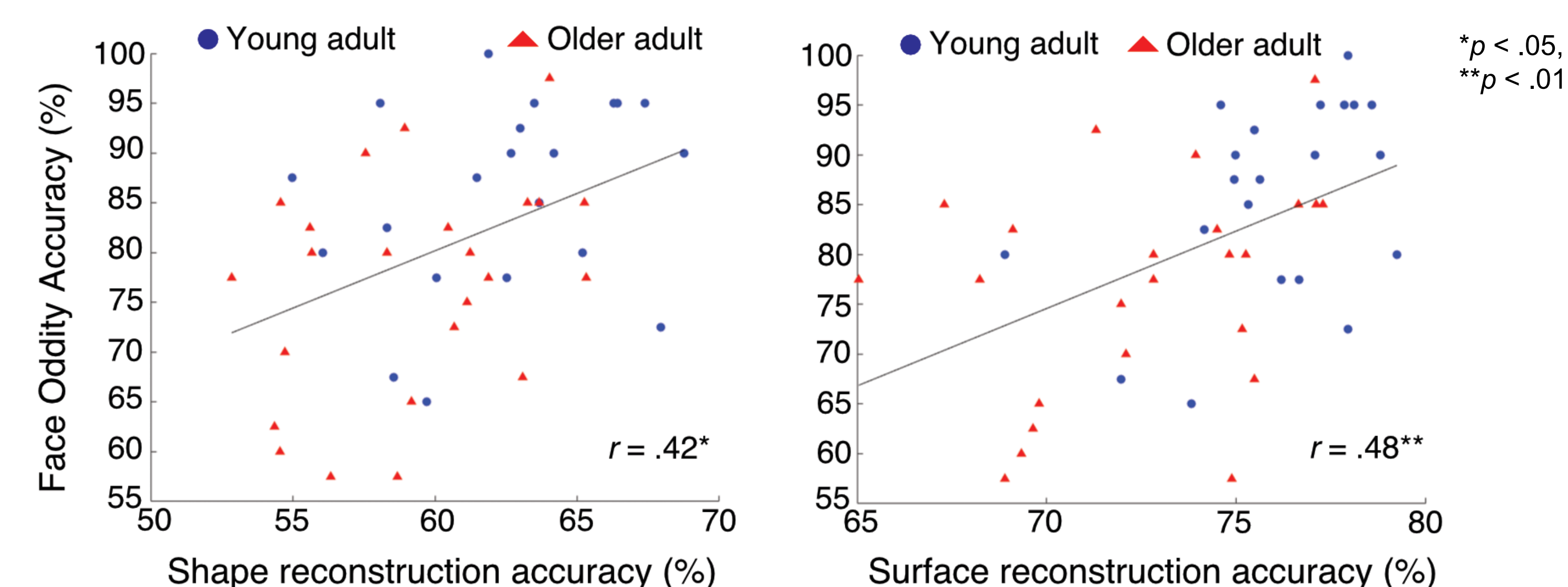
- Reconstruction accuracies for shape and surface were both significantly correlated with the accuracy of the different-view face oddity judgment task (FOJT)[8], in which the performance reflects visual discrimination ability.
- These relationships remained significant even after controlling for age.

Reconstruction Differences Between Age Groups
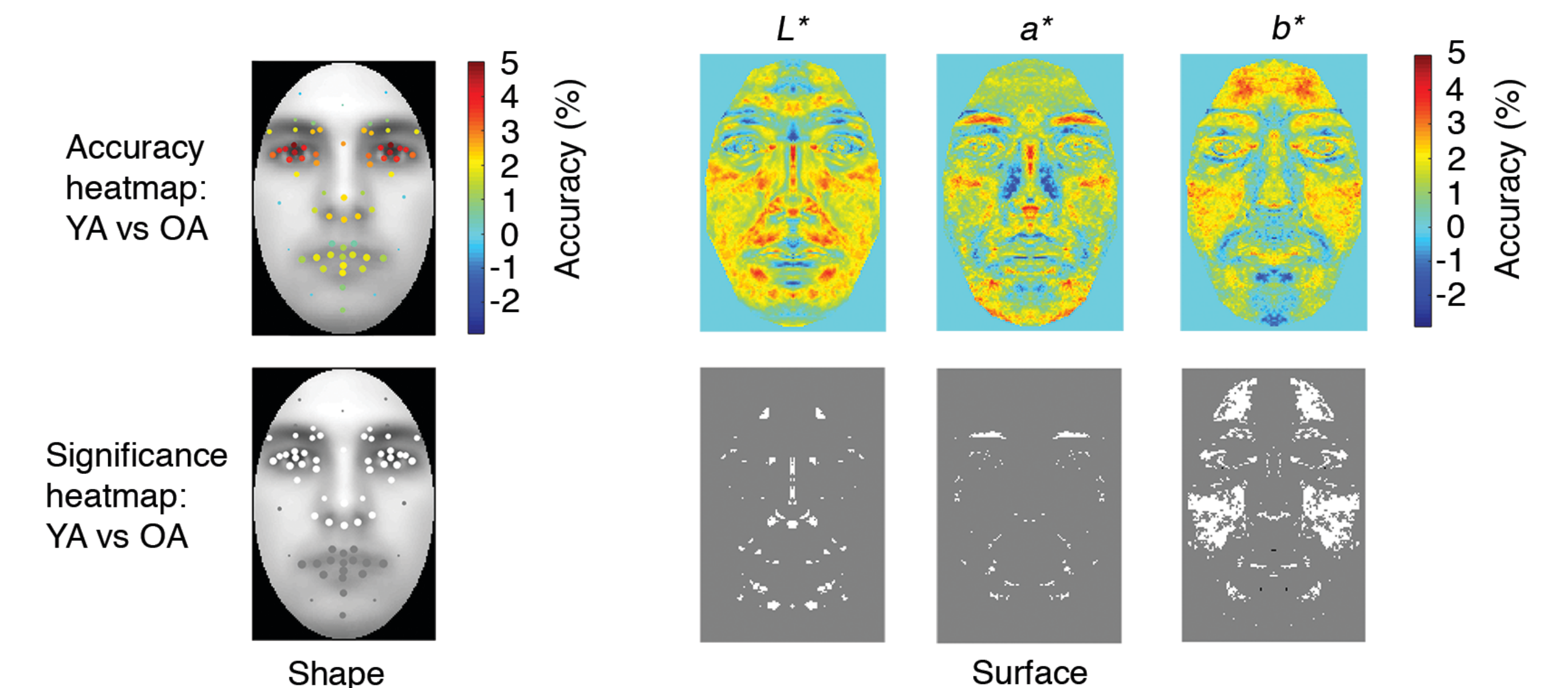
In significance heatmaps, colours mark the local difference (FDR, q < .05) across fiducial points (shape) and pixels (surface): white indicates information more accurately retrieved in YA and black in OA. The relative size of fiducial points corresponds to their location variability across faces (SD).

- Shape information was better reconstructed around eyes and nose areas for YA.
- Differences in surface reconstruction between YA and OA were found in all colour channels, with greater differences around forehead and cheeks areas.

Individual Variability
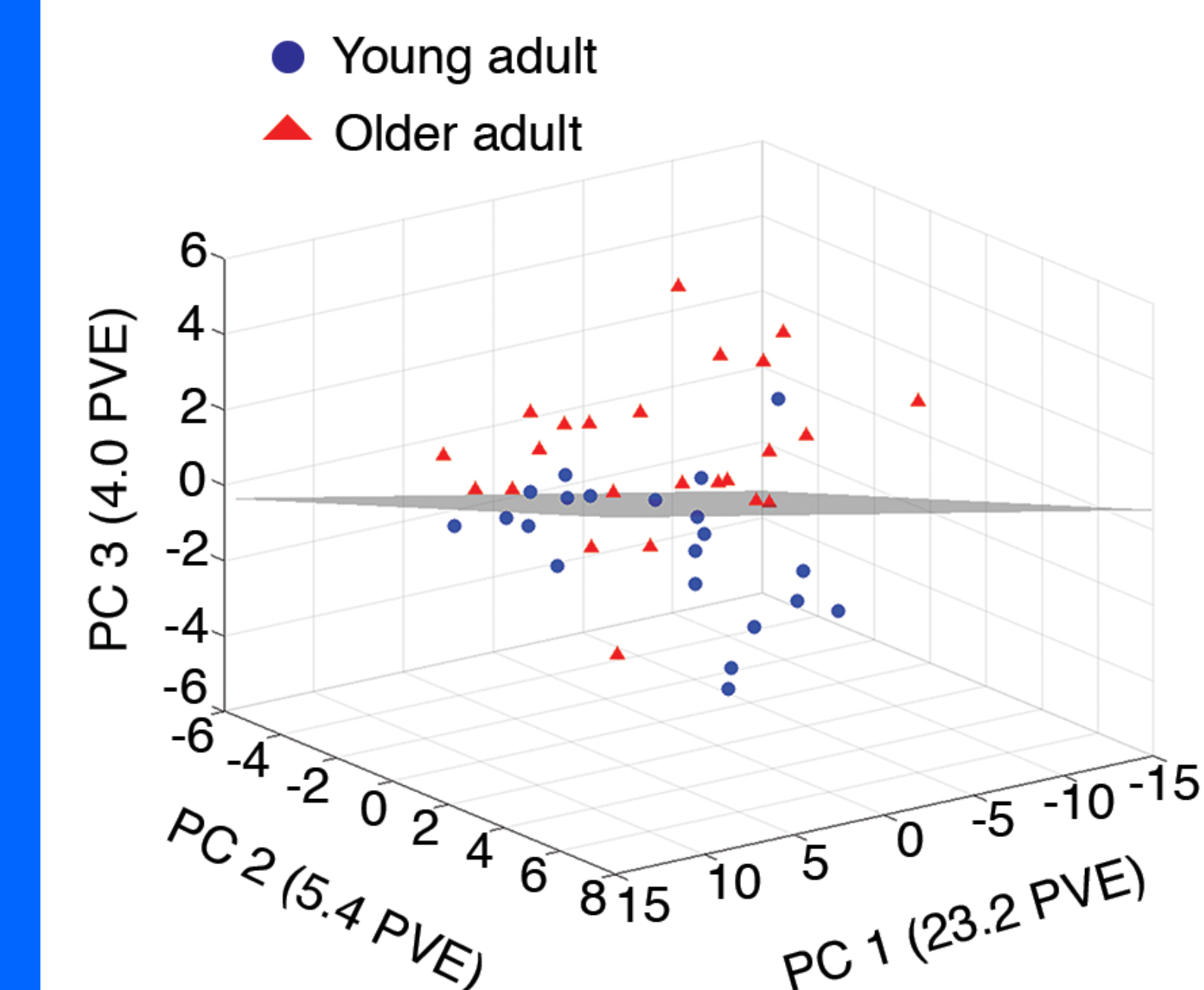
- Age was successfully classified (leave-one-out LDA accuracy: 85.55%) in a 10-dimensional participant space, constructed via the application of PCA to individual face similarity ratings.
- Age was significantly correlated with PC3 scores.
- PC1 and PC2 were significantly correlated with the the different-view FOFT accuracy.

Conclusions

- Shape and surface reconstructions were successful for both groups of participants, with information more accurately represented by young adults than older adults.
- Surface information was systematically better retrieved than shape information.
- While aging plays a crucial role in face perception, individual differences in visual representations impact face representation to a greater extent than aging.
- Visual information diagnostic about facial identity (e.g., eye shape and skin tone) is compromised in OA.

References (1) Boutlet et al. (2015) *Front. Psychol., 6*; (2) Grady et al. (2000). *Cogn. Neuropsychol., 17(1-3)* 165-186;(3) Bruce & Young (1998). In the Eye of the Beholder. The Science of Face Perception. Oxford University Press Inc.; New York.; (4) Andrews et al. (2016). *Cortex, 83* 280-291; (5) Nestor et al. (2016). *Proc. Natl. Acad. Sci. 113(2)*, 416-421; (6) Chang et al. (2017). *Sci. Rep.* 7:6499; (7) Kramer et al. (2016). *Behav. Res. Methods* 1-10; (8) Lee et al. (2005) *Hippocampus, 15*(6) 782-797