Neural differentiation is moderated by age in scene-selective but not face-selective cortical regions.

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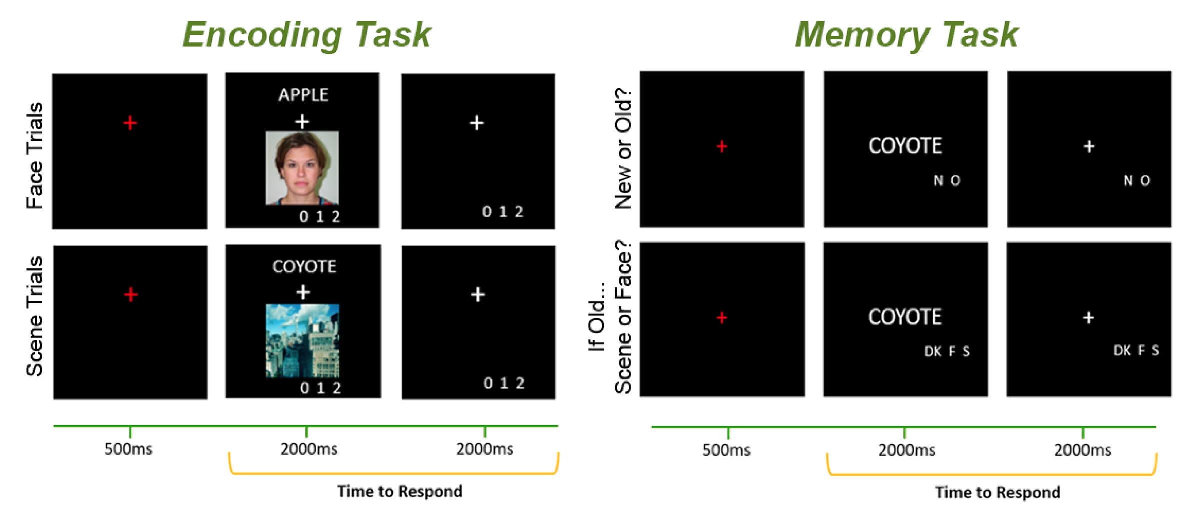
Introduction

- Category-selectivity of neural responses becomes less specific with increasing age. This is a phenomenon known as age-related neural dedifferentiation[1,2].
- Age-related neural dedifferentiation has been studied as a potential factor contributing to cognitive decline in older age[3]. However, recent research suggests that the relationship between neural differentiation and cognitive performance is not moderated by age (i.e. the relationship between neural differentiation and cognitive performance appears to be *age-invariant)*[2,4].
- Most consistently, studies of neural differentiation have identified reduced neural selectivity with older age in scene-selective[4-5] and face-selective[6,7] cortical regions. However, null effects of age have often been reported in object-[4,8] and word-selective regions[9], and null age differences have also been reported for scenes[10] and faces[11].
- In present study, participants underwent fMRI as they studied words paired with images of scenes and faces prior to a memory task. The study aimed to elucidate whether neural dedifferentiation is ubiquitous to both face- and scene-selective regions, and to examine the relationship between neural differentiation and memory performance.

Methods



Participants

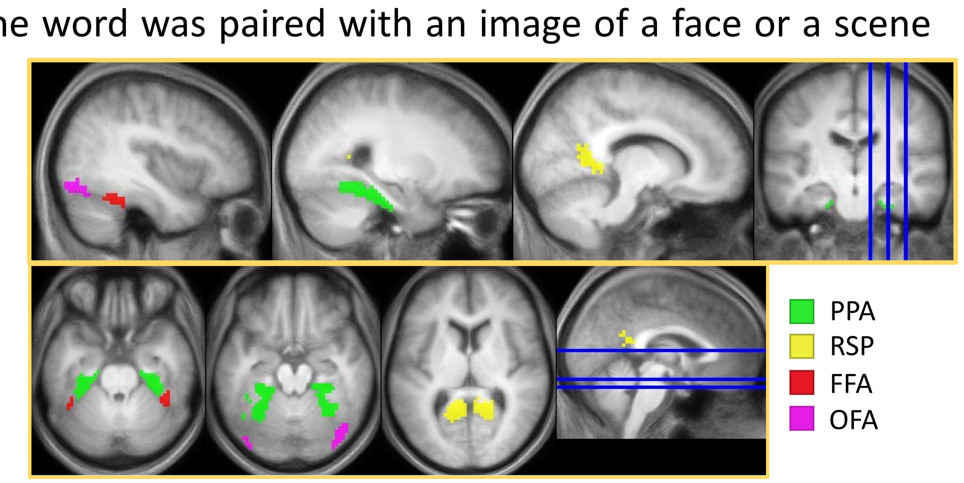
24 younger adults (18 – 28 years, Mean = 22, SD = 3.24)
24 older adults (65 – 75 years, Mean = 70, SD = 3.46)
Two study-test cycles inside scanner, additional data and findings from test phase reported elsewhere.

Encoding and Retrieval Tasks:

Active Encoding Task: 288 words paired with an image of a scene or a face. Participants were asked to imagine a scenario where the person in the image interacts with the object denoted by the word, or to imagine the object interacting with the scene. Participants were instructed to rate the vividness of this imagined scenario (0 – 2; not vivid – very vivid).

Memory task: 288 old (from study) and 96 new words. First, participants indicated whether they remembered seeing the word at study ("New / Old"). For items endorsed old, participants indicated whether the word was paired with an image of a face or a scene ("Face / Scene / Don't Know").

MRI Methods



T2*-weighted EPI (776 Study volumes, 992 Test volumes), 34 axial images/volume, 3mm thick, 1mm inter-slice gap, 3x3 mm in-plane, 80x80 matrix, TR = 2s, TE = 30ms. fMRI data for the four study sessions were concatenated and subjected to a least-squares-all GLM to estimate the BOLD response for each individual trial. Events of interest were modeled as a 2s boxcar function convolved with a canonical HRF.

Regions of Interest

Scene-selective regions: Parahippocampal Place area (PPA), Retrosplenial Cortex (RSP)
Face-selective regions: Fusiform Face area (FFA), Occipital Face area (OFA)
Empirically defined via scene>faces, faces>scenes group-level contrasts (PPA, FFA, OFA), and with the use of Neurosynth (RSP)

Operationalization of Neural Differentiation

Differentiation Index[8]: Differentiation index for a given ROI reflects the difference in across-trial average hemodynamic response for the ROI's preferred versus non-preferred image class, divided by pooled standard deviation.

$$Differentiation\ Index = \frac{\mu_{pref} - \mu_{non\ pref}}{\sqrt{\frac{\sigma^2_{pref} + \sigma^2_{non\ pref}}{2}}}$$

Pattern Similarity Analysis: Within – Between Similarity index computed for each ROI as the difference between the within-between-category similarity measures. Within-category similarity reflects the average Fisher z-transformed Pearson's correlation between a given trial of the ROI's preferred image category and all the trials of the same image category. Between-category similarity corresponds with the average correlation between a given preferred-category trial and all trials of the other image category. Greater Within – Between Similarity index assumes high neural selectivity to the ROI's preferred image category, as reflected by greater within-category and lower between-category similarity.

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Neural Differentiation Index

Differentiation Index across all encoding trials (figure A)

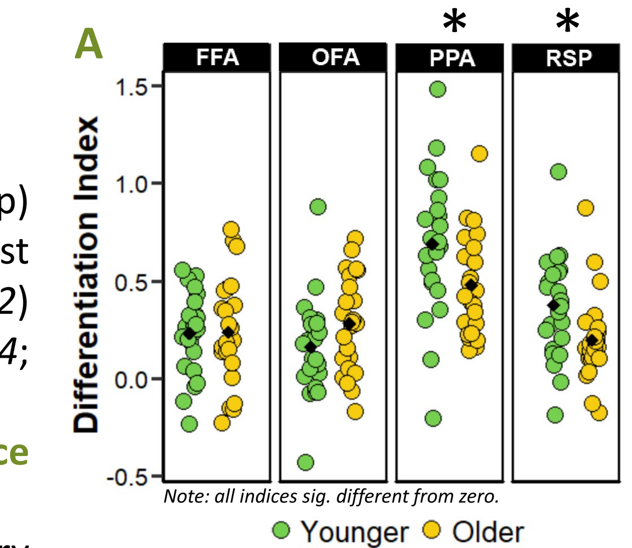
Differentiation index (collapsing across subsequent memory status) was subjected to a 2 (Age group) x 4 (ROI) ANOVA, which identified a significant Age group x ROI interaction ($p = .007$). Welch t-test demonstrated greater differentiation indices for younger adults in the scene-selective PPA ($p = .02$) and RSP ($p = .01$). However, no age differences were observed in the face-selective ROIs (FFA, $p = .94$; OFA, $p = .10$).

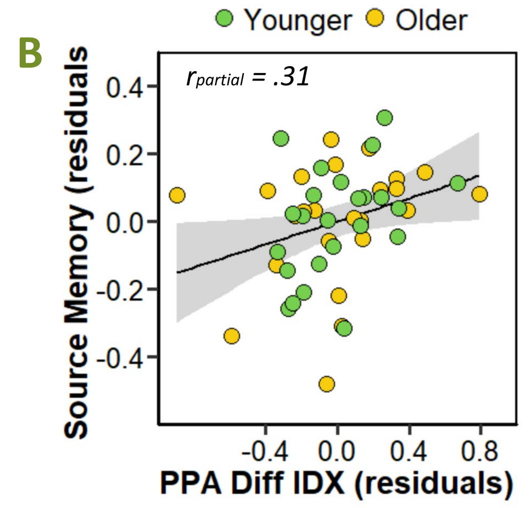
Age-invariant relationship between neural differentiation and source memory performance (figure B)

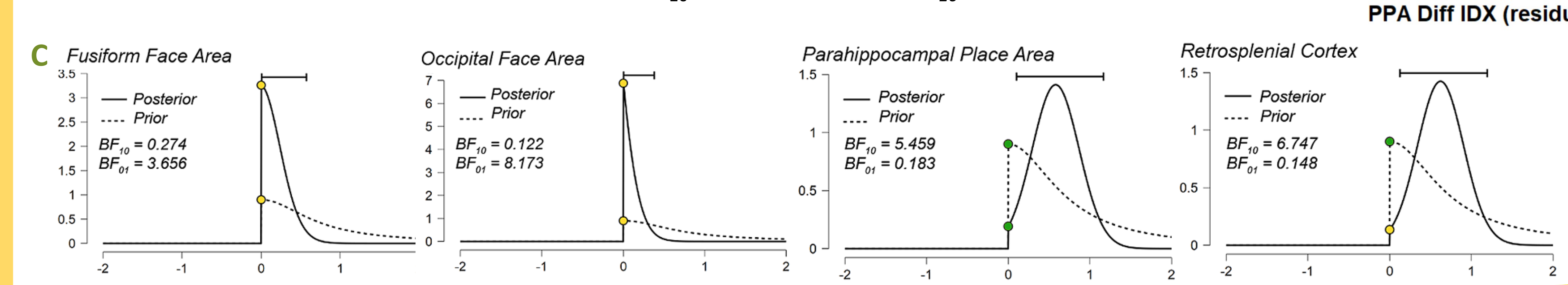
We identified a positive relationship between PPA neural differentiation index and source memory performance when controlling for age group, $r_{partial} = .31$, $p = .034$. This finding suggests that higher neural differentiation is associated with better source memory, and this relationship is not moderated by age (i.e. it is *age-invariant*).

Differentiation Index – Bayes Factor (figure C)

Bayesian independent samples t-test weighing the null hypothesis (younger = older) against the alternative hypothesis (younger > older) demonstrated substantial evidence favoring the null in the face-selective FFA ($BF_{10} = 0.274$) and OFA ($BF_{10} = 0.122$). In contrast, the model favored the alternative hypothesis in the scene-selective PPA ($BF_{10} = 5.459$) and RSP ($BF_{10} = 6.747$).



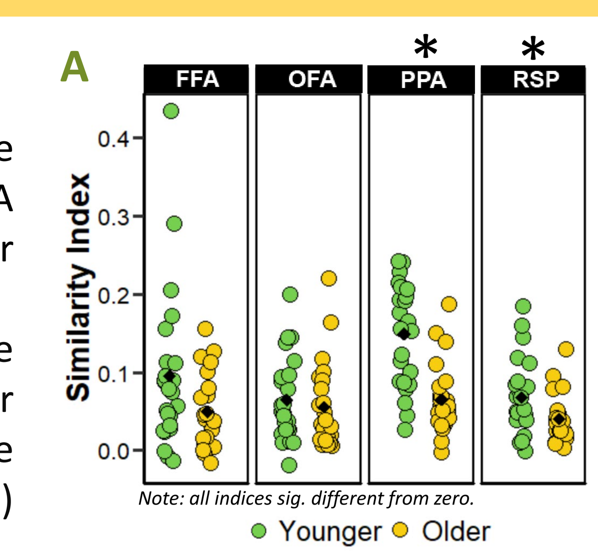


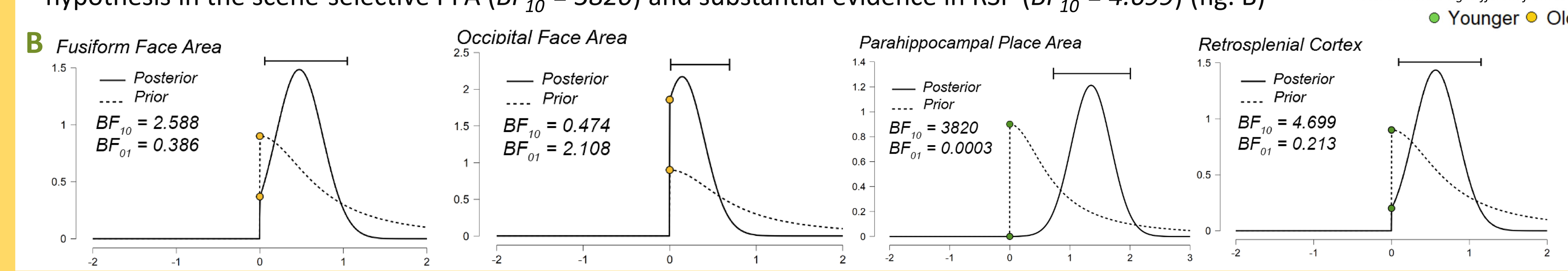


Pattern Similarity Analysis

Pattern Similarity Analysis was conducted complementary to the differentiation index analysis. The similarity indices derived from all encoding trials were subjected to a 2 (Age group) x 4 (ROI) ANOVA which identified a significant 2-way interaction ($p = .006$) driven by reduced similarity indices in older age within the scene-selective PPA ($p < .001$) and RSP ($p = 0.02$), (fig. A).

Bayesian independent samples t-test weighing the null hypothesis (younger = older) against the alternative (younger > older) showed ambiguous evidence in FFA ($BF_{10} = 2.588$) and weak evidence for null in the OFA ($BF_{10} = 0.474$). However, there was very strong evidence favoring the alternative hypothesis in the scene-selective PPA ($BF_{10} = 3820$) and substantial evidence in RSP ($BF_{10} = 4.699$) (fig. B)





Discussion

- The current study demonstrates that age-related neural dedifferentiation may not be ubiquitous for all types of stimuli. Although the overall finding is consistent with prior studies[4,8,9], null effects of age in face-selective regions are less typical.
- Various factors have been proposed to contribute to the findings of null age differences for certain types of visual stimuli[2]. For example, an image of a scene may elicit less specific neural responses in older age as a result of schematic processing enabled by accruing lifetime experience. In contrast, neural dedifferentiation for scene stimuli may reflect reduced efficiency of detailed perceptual processing of highly complex stimuli. Regarding the inconsistencies in face-selective regions, these may be reflected by different task demands at encoding: numerous studies which report age-related neural differentiation when employing passive viewing tasks[1,8], whereas studies report null effects of age often employ active judgement tasks[4,10].
- Additionally, findings are consistent with recent studies demonstrating age-invariant relationship between neural differentiation and memory performance[2,4]. Therefore, the variance associated with neural differentiation appears to come from two sources: age and cognition irrespective of age. Crucially, this age-invariant relationship was observed only in the scene-selective PPA.

This research was funded by NSF Grant 1633873