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Research Report

Dedifferentiated face processing in older adults is linked to lower resting state metabolic activity in fusiform face area

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ABSTRACT

We used multimodal brain imaging to examine possible mediators of age-related neural dedifferentiation (less specific neural activation) to different categories of stimuli that had been shown in previous research. Specifically, we examined resting blood flow and brain activation in areas involved in object, place and face perception. We observed lower activation, specificity, and resting blood flow for older adults (OA) than younger adults (YA) in the fusiform face area (FFA) but not in the other regions of interest. Mediation analyses further revealed that FFA resting state blood flow mediated age differences in FFA specificity, whereas age differences in visual and cognitive function and cortical thickness did not. Whole brain analyses also revealed more activated voxels for all categories in OA, as well as more frontal activation for faces but not for the other categories in OA than YA. Less FFA specificity coupled with more frontal activation when passively viewing faces suggest that OA have more difficulty recruiting specialized face processing mechanisms, and the lower FFA metabolic activity even when faces are not being processed suggests an OA deficiency in the neural substrate underlying face processing. Our data point to a detuning of face-selective mechanisms in older adults.

1. Introduction

Theories of life span cognition propose that development is marked by the differentiation of abilities from childhood through adulthood with dedifferentiation in older adulthood when cognitive abilities become less distinctive and more homogeneous (Balinsky, 1941; Baltes, 1987; Ghisletta and de Ribaupierre, 2005). Age-related changes in differentiation have been evidenced at both the behavioral and neural levels. The present study extended previous research examining older adults (OA) neural dedifferentiation in visual processing by investigating whether it can be explained by age-related declines in visual acuity, cognitive function, cortical thickness, and/or cerebral blood flow.

Neural dedifferentiation can be conceptualized as an increasingly shared neural substrate for particular stimuli or tasks that yield less specificity in the activation pattern. Age related increases have been observed in various paradigms, and two non-mutually exclusive explanations for these age-related changes in specificity have been suggested: (1) functional compensation for neural decline that may yield age-related changes in recruitment of additional regions of activation and (2) difficulty recruiting specialized neural mechanisms that may yield age-related decreases in the 'tuning' of activation.

Evidence for neural dedifferentiation in OA has been empirically demonstrated in more brain activation in OA than younger adults (YA) during various cognitive tasks (Burianova et al., 2013; Grady, 2002; Zarahn et al., 2007). Greater activation in OA has been noted most frequently in frontal regions, consistent with the idea that this is a compensatory mechanism reflecting increased effort or increased demands on executive functions (Cabeza et al., 1997; Grady et al., 1994). Other research has provided evidence for dedifferentiation within the visual system. OA show within category dedifferentiation of faces, as evidenced by greater OA than YA adaptation in the FFA to faces that are moderately similar (Goh et al., 2010). This effect parallels behavioral research demonstrating that OA make fewer distinctions among faces when forming trait impressions (Ng et al., 2014), and show reduced accuracy in both face recognition (Bartlett and Leslie, 1986; Bartlett et al., 1989; Goh et al., 2010) and emotion recognition (Orgeta and Phillips, 2008; Ruffman et al., 2008, 2009a; Slessor et al., 2010), although the latter age effect may depend on the methods used (Hahn et al., 2006; Mather

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and Knight, 2006; Murphy et al., 2010; Ruffman et al., 2009b). OA also show between category neural dedifferentiation when attempting to remember a series of visual stimuli (Park et al., 2004), or when passively viewing them (Park et al., 2012), with a smaller difference in activation to faces than to other stimulus categories in voxels specialized for faces, and a parallel age difference for activation to buildings or chairs vs. other stimulus categories in voxels specialized for places or objects, respectively. These effects are consistent with the idea that OA dedifferentiation reflects difficulty recruiting specialized neural mechanisms.

In the present study, we examined age-related neural dedifferentiation during passive viewing of different categories of stimuli that included faces, buildings, objects and cars. We examined activation in whole brain as well as in ROIs located in the areas that should respond maximally to faces, buildings, or objects: the FFA (Kanwisher et al., 1997), the parahippocampal place area (PPA; (Epstein et al., 1999)), and the medial fusiform object area (FOA; (Hadjikhani et al., 2004; Ishai et al., 1999)), respectively. We also included a category of front views of car stimuli, because some research indicates that the face-like appearance of car grills can elicit activation in the FFA (Kuhn et al., 2014). Neural dedifferentiation in OA was conceptualized as: 1) a less specific, broader activation pattern to stimuli from each of the categories in the whole brain 2) a less specific, more uniform pattern of activation in each ROI, as evidenced by weaker differences between the preferred stimulus category and the other categories. Finally, in addition to the aim of replicating previous research evidence for OA neural dedifferentiation, we investigated possible mediators of these effects, including visual acuity, cognitive function, cortical thickness, and blood flow at rest.

Since OA show reduced visual acuity and contrast sensitivity, these peripheral mechanisms may mediate OA neural dedifferentiation to visual stimuli. OA deficits in executive function or speed also could mediate, as Grady (2002) found greater dedifferentiation with increased cognitive load, and Park et al. (2010) found that greater fluid processing ability predicted greater neural specificity of the BOLD response to faces and houses. Gray matter cortical thinning also has been shown in healthy OA (Fjell et al., 2009; Liu et al., 2010; Salat et al., 2004). Here we examined whether age-related cortical thinning mediated age-related BOLD dedifferentiation. Recent research has shown that weaker BOLD activation in OA than YA at rest is due not to age-related differences in cerebral vasculature alone but also to cognitive and structural factors (Marstaller et al., 2015). In order to examine whether lower cerebral blood flow (CBF) was at the origin of differences in BOLD signal, we also measured CBF at rest using asymmetric spin labeling, and determined whether any age differences in CBF mediated age differences in BOLD dedifferentiation within the ROIs we examined.

2. Results

2.1. Vision and cognition measures

As shown in Table 1, OA performed significantly worse than YA on visual acuity and contrast sensitivity, but not on the Benton face recognition test. OA also showed significantly slower performance on a speeded pattern comparison task, consistent with decreases in processing speed in older adulthood (Salthouse, 1993). On the card sorting task assessing executive control, OA showed marginally more perseverative errors, and significantly more non-perseverative errors. In contrast to poorer performance by OA on preceding measures, they performed better on a vocabulary task, consistent with the maintenance of crystallized intelligence in older adulthood and previous research with community dwelling OA who volunteer as research participants in our lab (Horn and Cattell, 1967; Zebrowitz et al., 2013). There were no differences between groups in task performance (pressing a key every time a red crossed appeared) during the scanning.

2.2. Cortical thickness

Using QDEC and a whole brain analysis approach, we observed regional thinning of the cortex in OA compared with YA, replicating results reported by many other studies (e.g. (Fjell et al., 2009; Liu et al., 2010; Salat et al., 2004)). Thinning was bilateral and most prominent in motor and premotor cortex, superior and inferior frontal gyri, angular gyri, superior and middle temporal lobes and pole, and posterior cingulate, as well as in the calcarine sulcus, the lingual gyri and the ventro-lateral prefrontal cortex (see Fig. 1).

In addition, a 2 (age group) × 3 (ROIs: FFA, FOA, PPA) ANOVA on measures of cortical thickness revealed a significant main effect for age group, $F(1,36)=24.14$, $p<.001$, $\eta_P^2=.401$, reflecting lower thickness for OA than YA that was not qualified by an interaction with ROI, $F(2,72)=1.26$, $p=.291$, $\eta_P^2=.034$.

2.3. Blood flow patterns

Whole brain analysis revealed regional cortical decrease of CBF bilaterally in the posterior and lateral occipital cortex, the fusiform gyrus, the inferior temporal gyrus, the dorsolateral prefrontal cortex, and the medial prefrontal cortex replicating results reported by others (e.g. (Chen et al., 2011)). Reduced CBF was also observed in subcortical structures including the thalamus, the

Table 1
Older and younger adults' scores on control measures.

Measure	Older adults		Younger adults		F-value	p-value
	M	SD	M	SD		
Snellen Visual Acuity (denominator)	27.50	9.89	14.68	5.32	24.46	<.001
Mars Letter Contrast Sensitivity (Mars Perceptrix, Chappaqua, NY)	1.60	.12	1.74	.03	20.90	<.001
Benton Facial Recognition Test (Benton et al., 1983)	45.67	5.75	47.68	2.91	1.84	.18
Timed Pattern Comparison Test (Salthouse, 1993)	29.56	7.59	43.26	8.97	25.04	<.001
Wisconsin Card Sorting Test (the Berg Card Sort Task (BCST validated by Piper et al., 2012)) http://pebl.sourceforge.net/battery.html	7.33	4.26	5.42	1.30	3.49	.07
Perseverative errors						
Non-Perseverative errors	10.44	9.20	4.21	1.75	8.42	.006
Shipley Vocabulary Test (Shipley, 1946)	36.11	2.87	34.16	2.79	4.99	<.001
Education	4.50	1.46	4.50	1.24	0	

Level of Education was coded for highest level attained: 1 – no high school diploma, 2 – high school diploma, 3 – some college, 4 – Bachelor's degree, 5 – some graduate work, 6 – Masters degree, 7 – Doctorate degree. Medians and range are reported.