

Inter-Network Neural Connectivity Predicts Differences in Intuitive Moral Decision-Making between Younger and Older Adults

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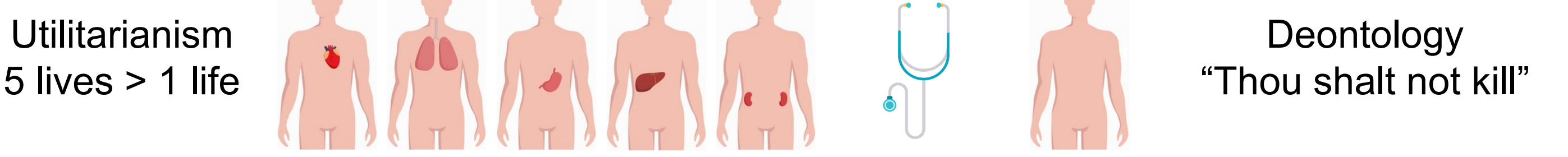
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Significance. Positions of power involving significant moral decisions are often held by older adults (OAs), yet little is known about how OAs differ from younger adults (YAs) in moral decision-making and how such differences relate to the brain’s intrinsic activity.

Hypothetical moral dilemmas are widely used to investigate people’s moral decision-making in relation to *utilitarianism* and *deontology*. As an example: “You are a doctor. You have five patients, each of whom is about to die due to a failing organ of some kind. You have another patient who is healthy. The only way that you can save the lives of the first five patients is to transplant five of this young man’s organs (against his will) into the bodies of the other five patients. If you do this, the young man will die, but the other five patients will live. Should you perform this transplant in order to save five of your patients?”



Limited extant research on age-related differences in moral decision-making using moral dilemmas found that OAs are more deontological than YAs.^[1-3]

The **intuitiveness of moral decisions**, however, is often neglected in studies using these moral dilemmas, in some of which one option is much more *intuitive*—eliciting an automatic and unreflective response among most people.^[4-6] Hence, those studies fail to disambiguate between an apparent ‘deontological’ tendency and a potential ‘intuitive’ tendency.^[7] As such, our first goal is to disambiguate the sources of age-related differences in moral decision-making.

Neural activity in the default network (DN) and between DN and executive control networks (frontoparietal control network, FPCN; dorsal attention network, DAN; salience network, SN) purportedly underpin moral processing: DN activity facilitates perceptions of the moral self, social norms, and the simulation of possible outcomes of different decisions^[8-9], while top-down executive control networks regulate self-generated thoughts and emotional response.^[10]

Aging leads to decreased intra-DN connectivity and enhanced DN connectivity with FPCN^[11] and DAN^[12]. This enhanced coupling of DN with executive control and attention networks might help explain a shift in utilitarian/deontological tendency in YAs and OAs. Thus, our second goal is to determine the extent to which resting-state DN connectivity is associated with age-related differences in moral decision-making.

Methods

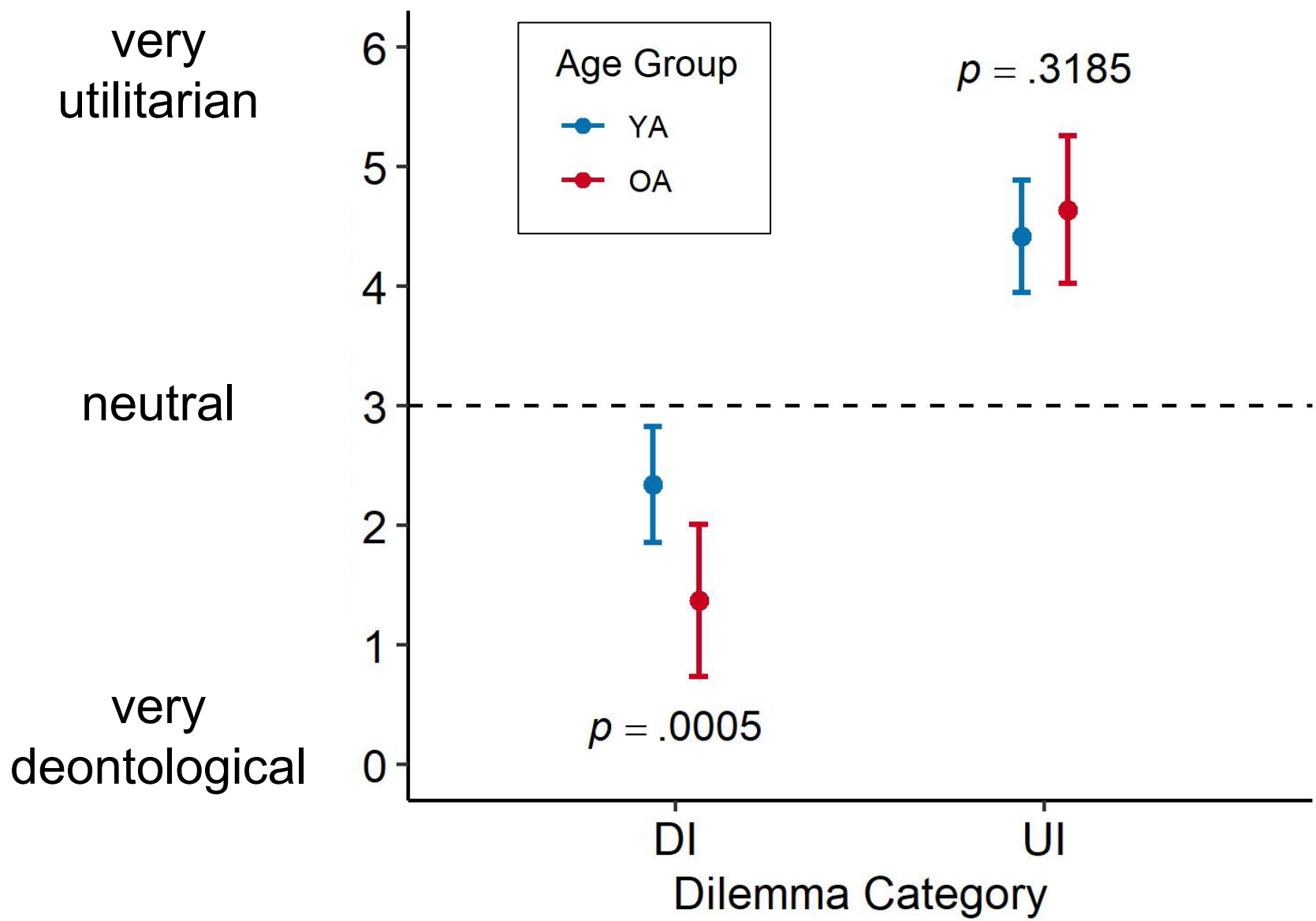
- 117 YAs (22.11±3.06 yrs, 68 female) + 82 OAs (67.54±5.74 yrs, 45 female), all right-handed with normal or corrected-to-normal vision
- Participants made moral decisions in 16 moral dilemmas, which consisted of 8 deontological intuitive (DI; where the deontological decision is more intuitive) and 8 utilitarian intuitive (UI; where the utilitarian decision is more intuitive) (see Kahane et al., 2012)
- Two 10 min 6 s resting-state fMRI scans were acquired on a 3T GE Discovery MR750 scanner at the Cornell Magnetic Resonance Imaging Facility in Ithaca, NY, using a multi-echo echo planar imaging sequence with online reconstruction (TR = 3000 ms; TEs = 13.7, 30, 47 ms; FA = 83°; matrix size = 72 × 72; FOV = 210 mm; 46 axial slices; 3.0 mm isotropic voxels; slice order = inferior-superior interleaved; 2.5 × acceleration with sensitivity encoding).

1. Difference in moral decision-making between YAs and OAs

Moral decisions ~ Dilemma category * Age group + [random effects]

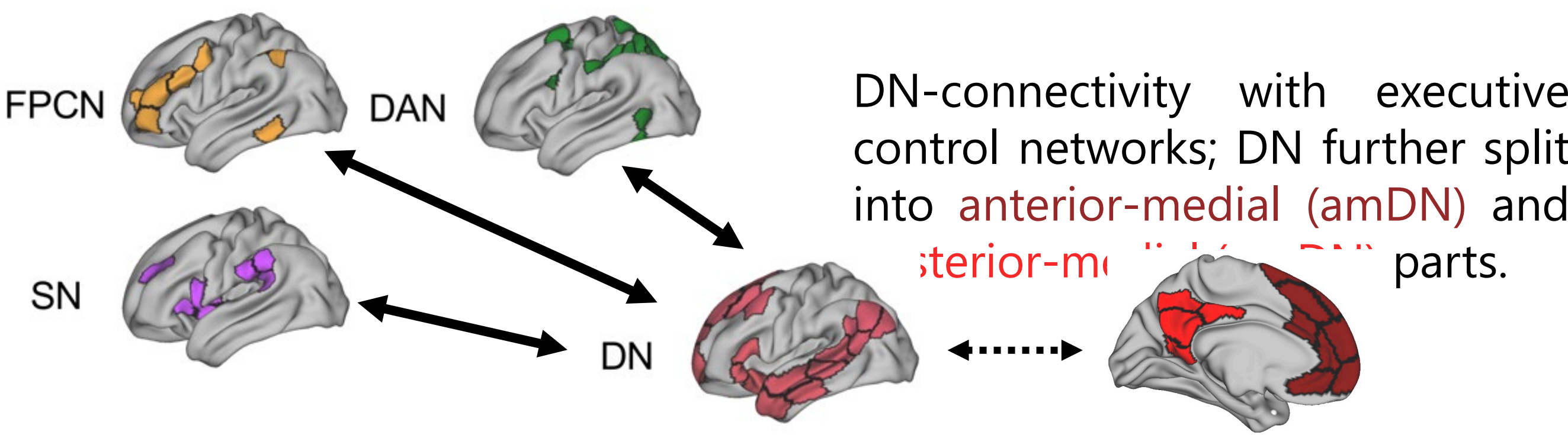
Predictor	b	p-value	95% CI
Dilemma category	2.67	< .0001	[1.95, 3.43]
Age group	-0.37	.0345	[-0.72, -0.04]
Category × Age	1.19	.0015	[0.56, 1.82]

The significant interaction **Dilemma category × Age group** resulted from OAs making more deontological moral decisions relative to YAs ($EMM_{DI, OA-YA} = -0.97, p = .0005, 95\% CI = [-1.46, -0.47]$) in DI dilemmas, while they did not differ in their decisions in UI dilemmas ($EMM_{UI, OA-YA} = 0.22, p = .3185, 95\% CI = [-0.24, 0.68]$).→

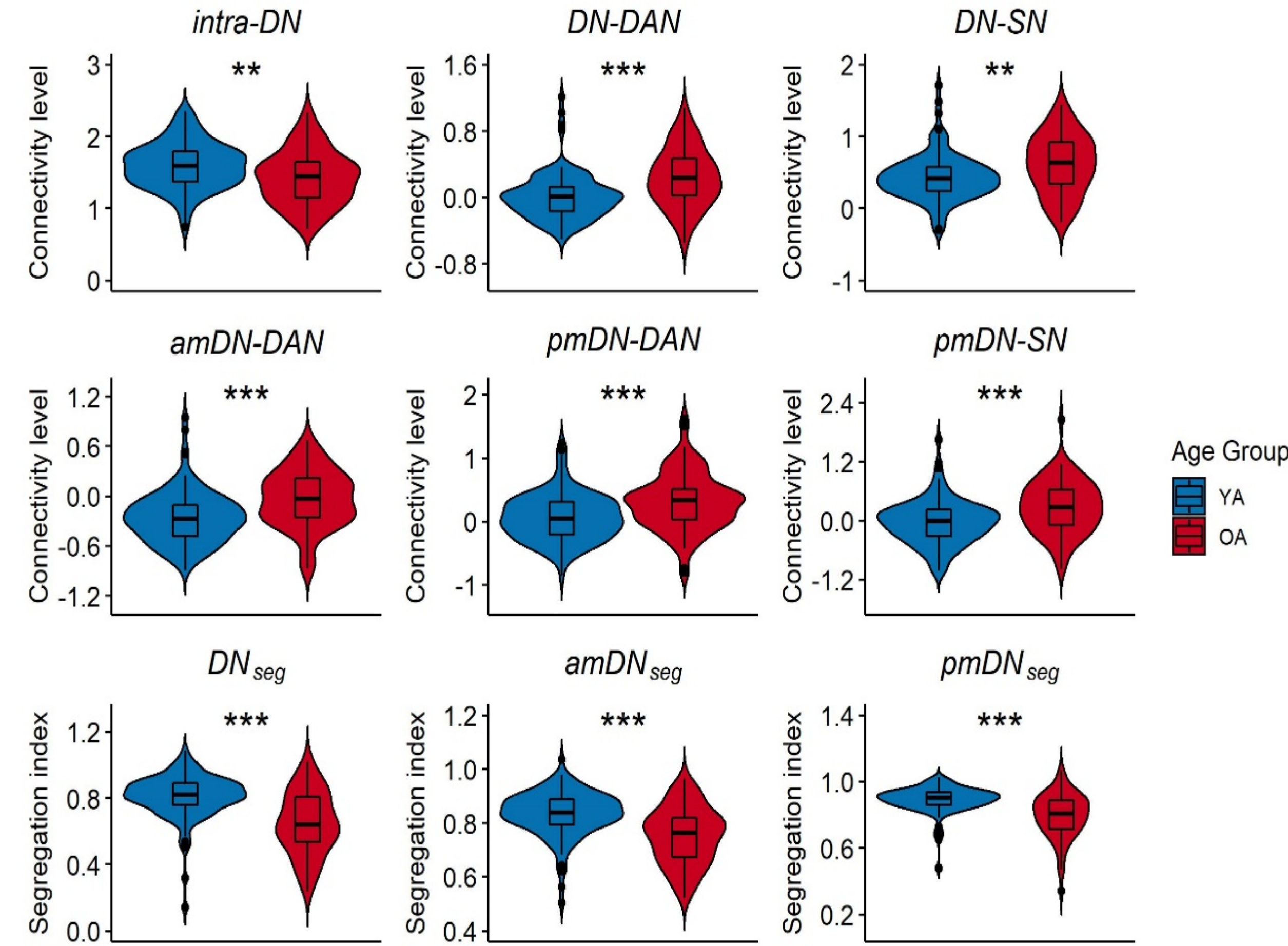


2. Differential network connectivity between YAs and OAs

Connectivity ~ Age group + [covariate].

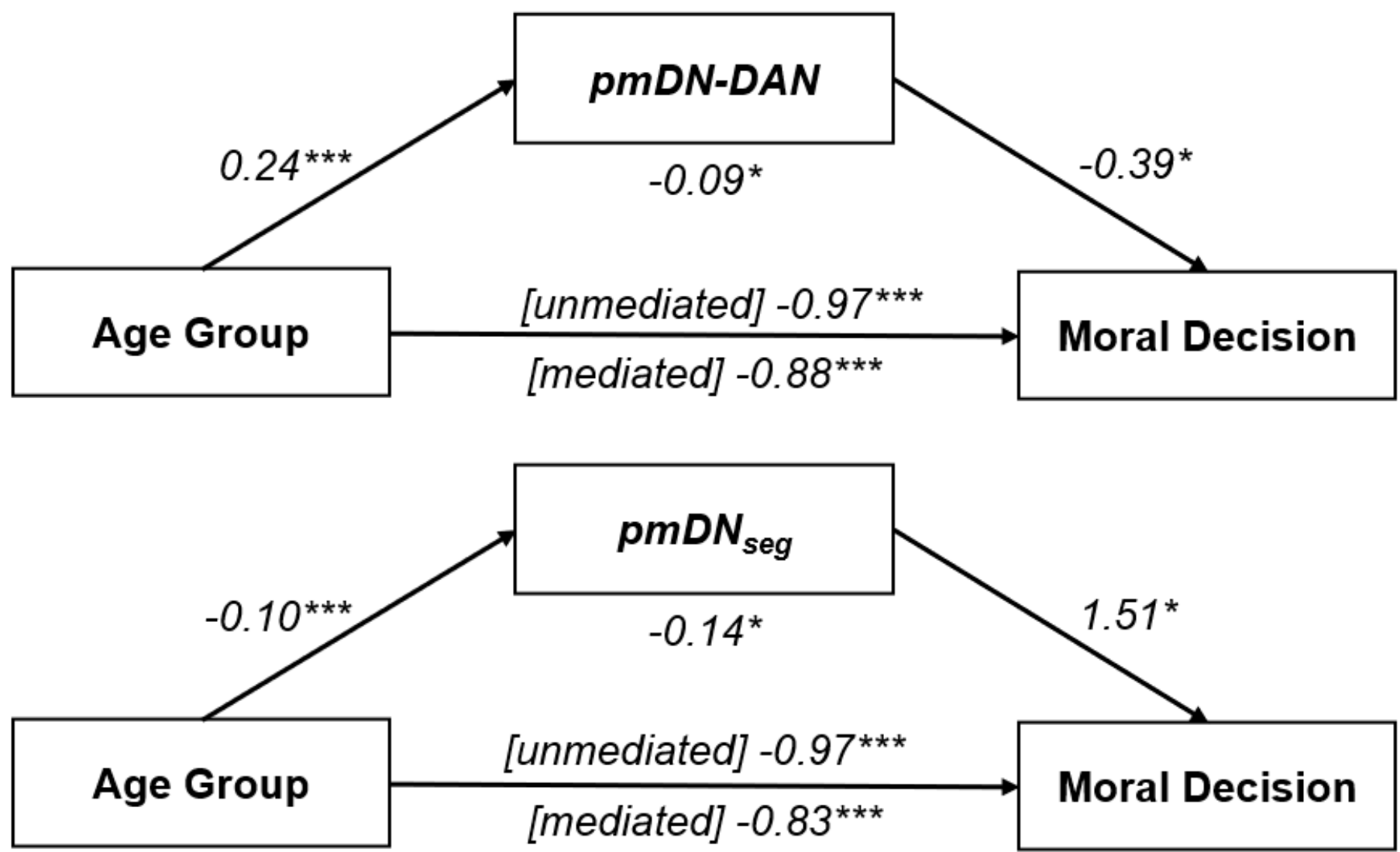


Segregation index computed as $(\overline{Z_{intra}} - \overline{Z_{inter}}) / \overline{Z_{intra}}$ (Chan et al., 2014); ** $p < 0.01$, *** $p < .001$, Bonferroni-corrected. ↓



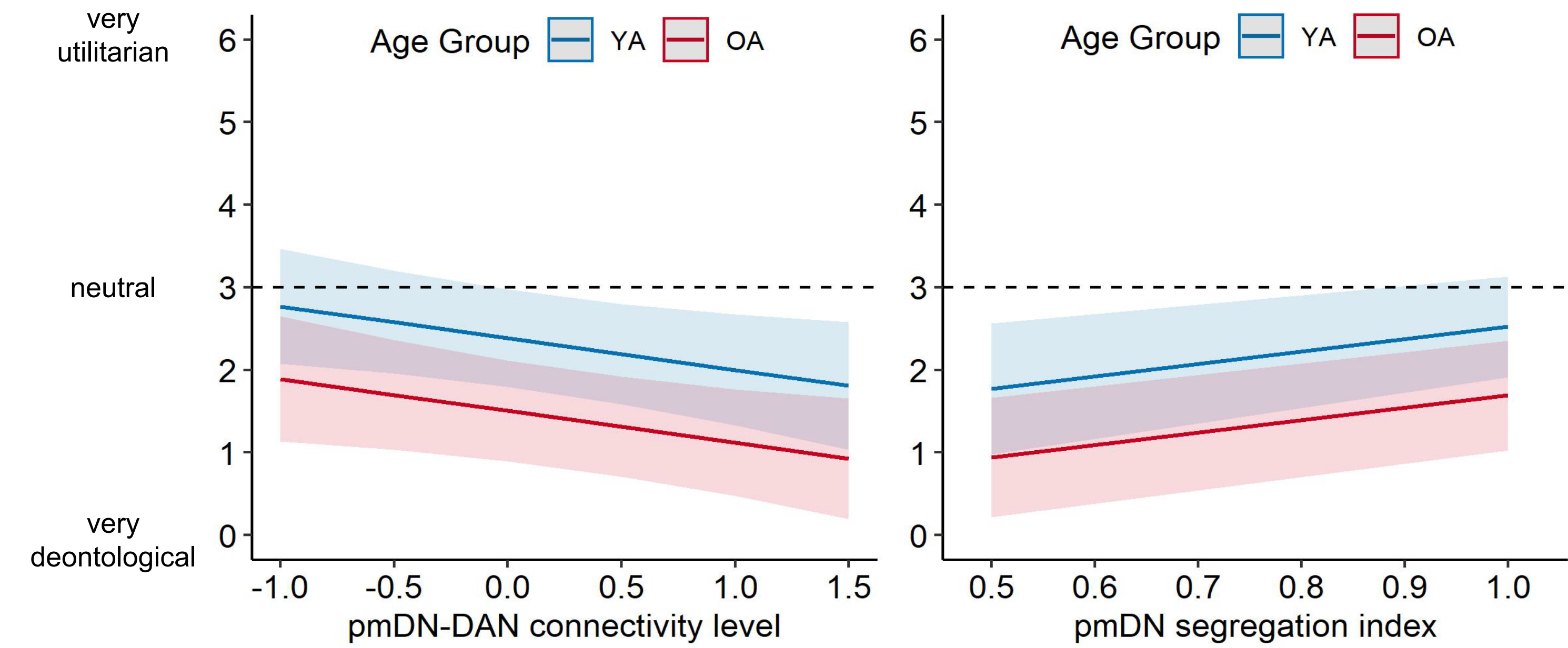
4. Exploratory mediation analysis

Enhanced pmDN-DAN connections, as well as reduced segregation of pmDN, partially mediated the more deontological-intuitive moral decision-making style in OAs.



3. Linking moral decisions, age group, and connectivity measures

Moral decision in DI dilemmas ~ Age group + Connectivity + [covariate] + [random effects]. In separate models, we found that more deontological-intuitive moral decisions were associated with higher **pmDN-DAN** ($b = -0.39, p = .0321, 95\% CI = [-0.73, -0.01]$) and lower **pmDN_seg** ($b = 1.51, p = .0306, 95\% CI = [0.15, 2.88]$). ↓



Moral decision in UI dilemmas ~ Age group + Connectivity + [random effects]. We found no evidence for any connectivity measure reliably predicting participant’s moral decisions in UI dilemmas.

Discussion

- OAs made more deontological moral decisions than YAs in DI dilemmas (where deontological decisions are intuitive) but did not differ from YAs in UI dilemmas (where utilitarian decisions are intuitive).
- OAs showed increased DN-connectivity with the executive control networks and increased DN integration with the rest of the brain.
- In both age groups, increased pmDN-DAN connectivity and reduced pmDN segregation predicted more deontological moral decision-making.
- To our knowledge, this study provides the first evaluation of differential network connectivity associated with age-related differences in moral decision-making.

Acknowledgements
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