

The Multiple-Demand Network in Language Processing: Its Role in the Aging Brain

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Introduction

Normal **aging** leads to **changes in neural networks** of speech and language perception and production, i.e. older adults commonly display less activation of domain-specific areas but a **stronger involvement of the domain-general "multiple-demand" network** in different tasks [1].

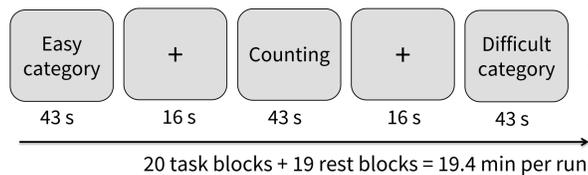
This **change** in activation patterns appears to be especially robust when **task demands increase** and older adults show **poorer behavioural performances** in comparison to young adults [2].

Research questions:

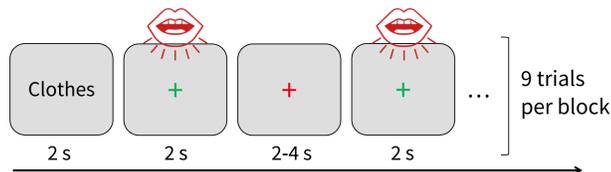
- Which brain regions are engaged in a semantic word generation task in older adults?
- To what extent does this language production task rely on domain-general vs domain-specific networks?
- How do these networks interact?

Methods

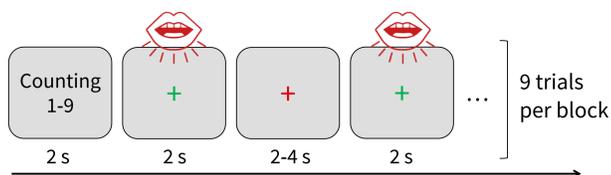
A Experimental Paradigm



B Overt Semantic Word Generation Task



C Control Task: Overt Counting



Participants

- 31 native German older adults, mean age: 65.18 years, age range: 60-69 years
- MMSE $M = 28.36$ (1.19)

Materials

- 20 semantic categories: 10 easy categories (e.g. animals) and 10 difficult categories (e.g. metals) based on pilot study

Design

- 2 runs in 1 session of continuous-sampling block design fMRI
- Whole brain, T2*-weighted multiband dual GE EPI sequence

Data analysis

- Preprocessing with fMRIPrep 1.2.6 [3, 4]
- 3 participants excluded due to heavy motion (≥ 2.5 mm)
- Second-level in SPM12: One-sample t-tests with contrast images from direct comparisons at the first level
- PPI with generalized PPI toolbox [5]: seeded from 5 mm sphere around individual peak activation within radius of 10 mm

Results

1 Behavioural Results

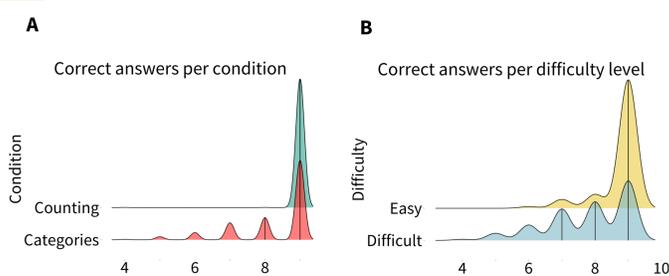


Fig. 1: Density plots with quantile lines illustrating the number of correct answers (A) for all categories and the control task, (B) for difficult and easy categories in semantic word generation task.

2 fMRI Results

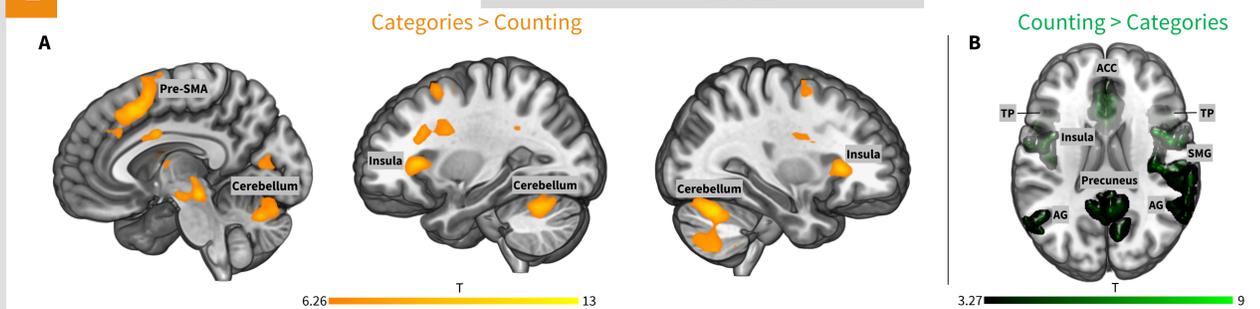


Fig. 2: Significant activation for the contrast (A) categories > counting and (B) counting > categories. Activation map (A) is thresholded at $p < 0.05$ FWE-corrected at peak level. Activation map (B) is thresholded $q < 0.05$ FDR-corrected at peak level and FWE-corrected ($p < 0.05$) at cluster level. ACC = anterior cingulate cortex, AG = angular gyrus, pre-SMA = pre-supplementary motor area, SMG = supramarginal gyrus, TP = temporal pole.

3 Functional Connectivity Results: Functional Coupling for Semantic Word Generation in the Aging Brain

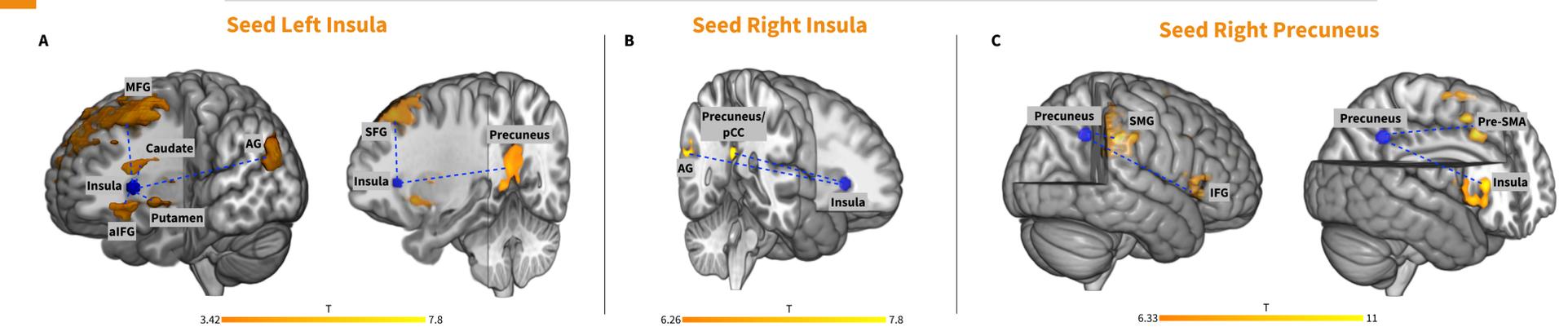


Fig. 3: PPI results with (A) left insula, (B) right insula, and (C) right precuneus as seed regions for the contrast categories > counting. Activation map (A) is thresholded at $p < 0.001$ at peak level and FWE-corrected ($p < 0.05$) at cluster level. Activation map (B) and (C) are thresholded at $p < 0.05$ FWE-corrected at peak level. AG = angular gyrus, aIFG = anterior inferior frontal gyrus, MFG = middle frontal gyrus, pCC = posterior cingulate cortex, pre-SMA = pre-supplementary motor area, SFG = superior frontal gyrus, SMG = supramarginal gyrus.

Discussion

- Behavioural effects of:
 - Condition: less verbal output for categories than for counting trials
 - Difficulty: less words produced for difficult than for easy categories
- Semantic word generation** engages widespread brain network of frontal areas (pre-SMA, SFG, MFG, dACC), bilateral insulae, and bilateral cerebellum
- Counting** engages bilateral network of TP, SMG, AG, precuneus, posterior insulae, and ACC

- PPI analyses reveal **interaction of multiple-demand network and default-mode network** during semantic word generation:
 - Multiple-demand hubs of bilateral insulae interact with other domain-general nodes as well as default-mode network regions (AG, precuneus, pCC)
 - Default-mode hub of right precuneus interacts with multiple-demand regions (pre-SMA, Insula/IFG)

References

- Grady et al. (2010), *Cerebral Cortex*, 20, 1432-1447.
- Hoffman & Morcom (2018), *Neuroscience and Biobehavioral Reviews*, 84, 134-150.
- Esteban et al. (2018), *Nature Methods*, 16, 111-116.
- Gorgolewski et al. (2011), *Frontiers in Neuroinformatics*, 5, 1-15.
- McLaren et al. (2012), *Neuroimage*, 61, 1277-1286.