Neural Variability of Crosstalk Effects in Dual-Tasking and Its Modulation by Age

Lya K. Paas Oliveros [1,2], Aleks Pieczykolan [3,4], Rachel N. Pläschke [2], Edna C. Cieslik [1,2], Simon B. Eickhoff [1,2], & Robert Langner [1,2]

[1]Institute of Neuroscience and Medicine (INM-7: Brain and Behaviour), Forschungszentrum Jülich, Jülich, Germany; [2]Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf, Düsseldorf, Germany; [3]Institute of Psychology, University of Würzburg, Würzburg, Germany; [4]Human Technology Center, RWTH Aachen University, Aachen, Germany; l.paas.oliveros@fz-juelich.de

Introduction

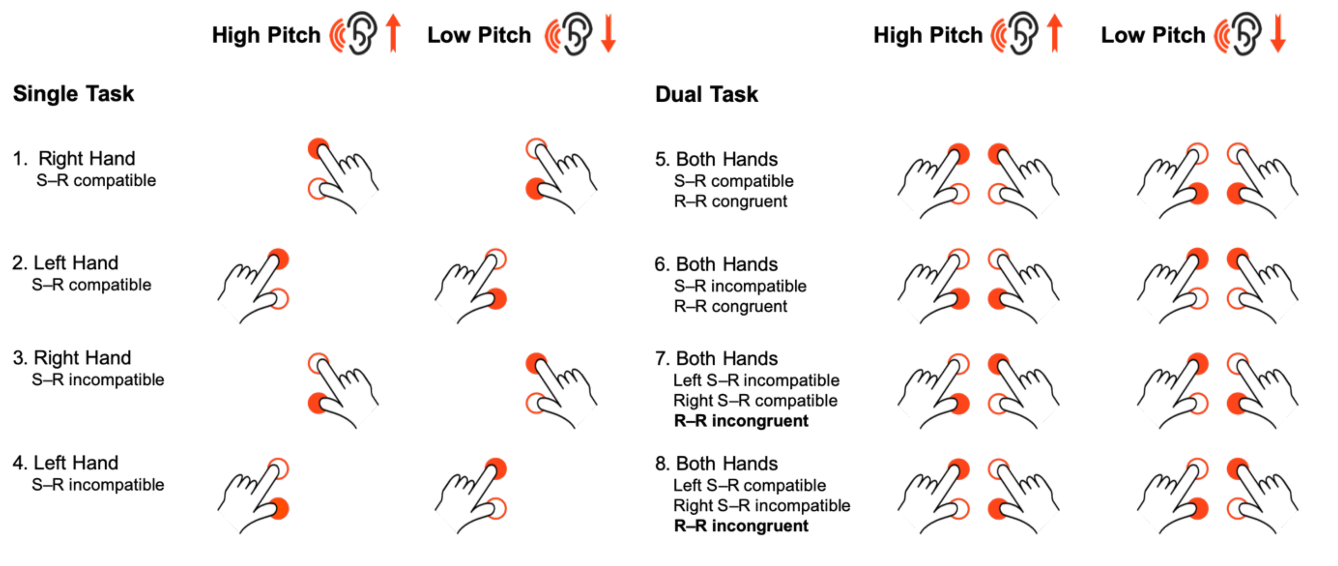
- Difficulties in **dual-tasking** arise from several sources and usually increase in **advanced age** [1,2].
- Dual-tasking has been associated with increased fronto-parietal activity [3], but output-related interference, e.g., **opposing response codes,** has remained understudied.

➢ **Aim 1:** To study the neural correlates of **response-code crosstalk** in dual-tasking and their age-related differences by implementing a **spatial auditory-manual, single-stimulus onset, dual-response paradigm** [4-6] (see Fig. 1).

➢ **Aim 2:** To investigate how we can explain crosstalk-related brain activity with **other facets of dual-task performance** in young and older adults.

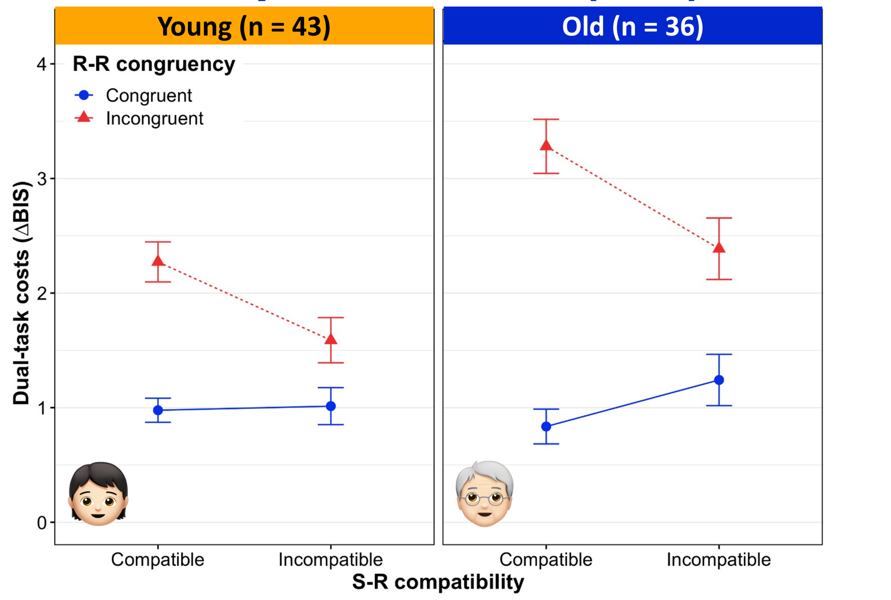
Paradigm, Behavioural and fMRI Results

Single-stimulus onset paradigm



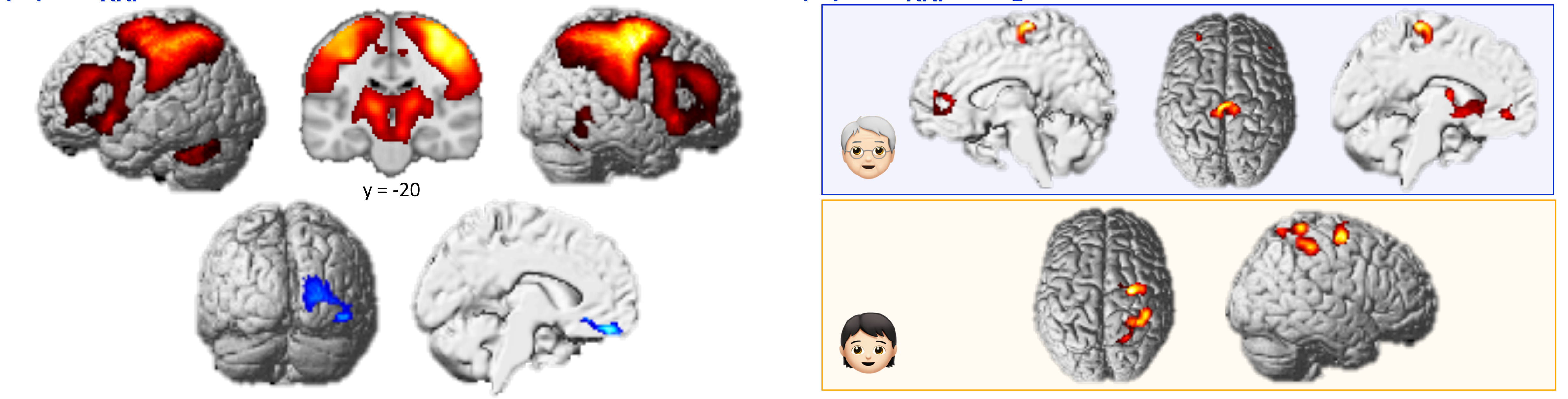
▲ **Figure 1.** Speeded choice responses to **high- or low-pitched tones** via pressing **upper or lower** response buttons with one hand (single-tasking) or both hands simultaneously (dual-tasking).

Dual-task performance (BIS) costs



▲ **Figure 2.** Mean **dual-task costs on BIS** according to age, stimulus–response (S-R) compatibility and response–response (R-R) congruency. Error bars represent SEM.

(A) $DT_{RRI} \gtrsim ST$ (B) $DT_{RRI} \times$ Age interaction



▲ **Figure 3.** Brain activity associated to response-code crosstalk. **(A) Brain activation** (hot colors) and **deactivations** (cool colors) associated with **response-code conflict in dual-tasking**. **(B)** Greater brain activation associated with **dual-task cross-talk in older** (upper panel) and **young** (lower panel) healthy adults.

Methods

➢ **Participants:** **43 young** adults (22 ♀, Ø 25.6 ± 3.4 years old)
36 older adults (15 ♀, Ø 61.9 ± 5.5 years old)

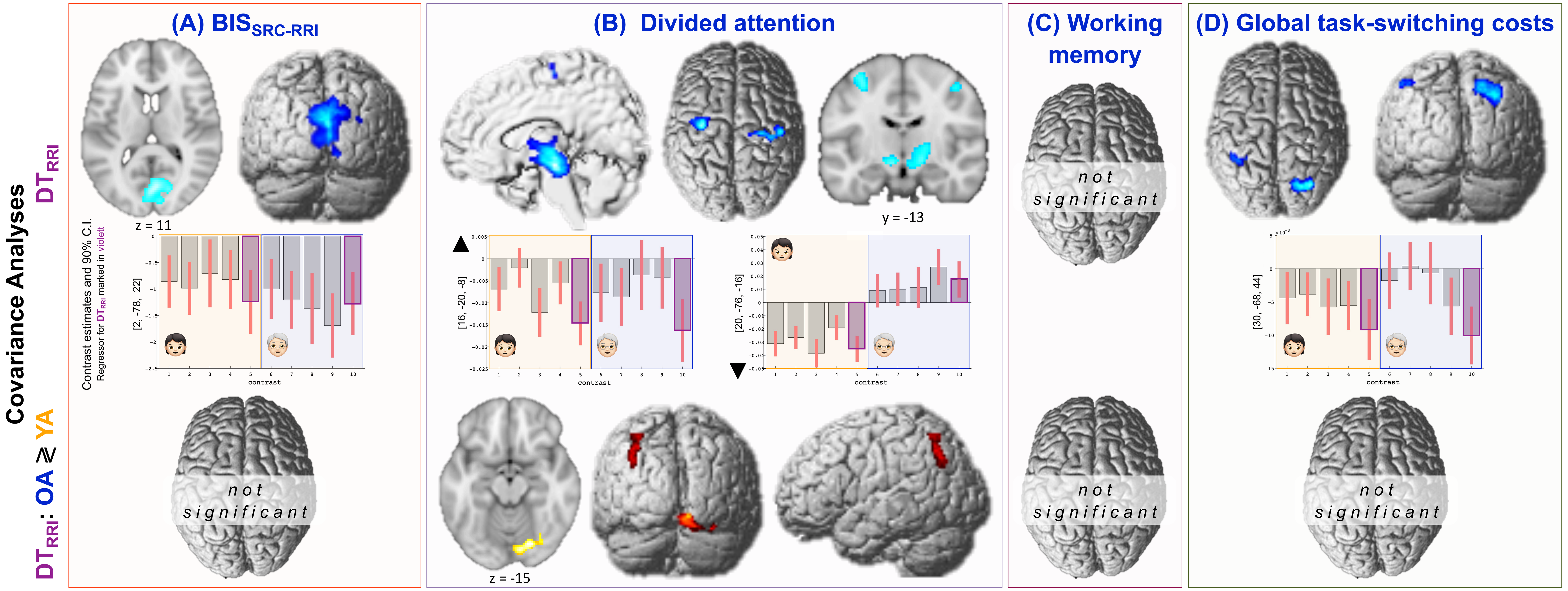
➢ **Behavioral Analysis:**

- **Dual-task costs [DTC]** on the **Balanced Integration Score [BIS]** (combined measure of standardized accuracy and speed with higher values indicating better performance, [7]).
- 2(Age) × 2(S-R compatibility) × 2(R-R congruency) mixed ANOVA.
- Tasks used as covariates: Audio-visual crossmodal **selective and focused attention tasks**, forward and backward **Corsi block-tapping test** (Vienna Test System), **task-switching paradigm**.

➢ **fMRI Data Analysis:**

- 3.0 T Siemens • Whole–brain EPI • 36 slices • TR = 2.2 s, TE = 30 ms, 3.1 mm^3 voxels ➜ Standard preprocessing with SPM12: Realignment & unwarping, slice time correction, normalization to MNI space, smoothing (FWHM 8 mm).
- **Single-subject GLM:** Event-related model with sum contrasts for **5 experimental conditions (ST_{SRC}, ST_{SRI}, DT_{SRC}, DT_{SRI}, DT_{RRI}).**
- **Group-level GLM:** **10 regressors** ➜ 5 experimental conditions for each age group (YA, OA).
- **Covariance analysis models:**
  (A) **BIS** for S-R compatible hand in R-R incongruent trials
  (B) **Divided attention** compound mean reaction time
  (C) **Working memory** compound number of achieved sequences
  (D) **Global task-switching** reaction time costs (repeat vs. single)

Results



All activations significant at cluster-level FWE-corrected $p \leq .05$ (voxel-level inclusion threshold: $p < .001$).

▲ **Figure 4.** Analyses of **covariance**: Effects of covariates of interest assessing other facets of dual-task performance on the brain activity associated to response-code crosstalk in dual-tasking and their modulation by age. Association with **(A) BIS** for the stimulus–response compatible hand in response–response incongruent trials, **(B)** mean reaction time of two tasks assessing **divided attention**, **(C) working memory** by the number of achieved sequences, and **(D) global task-switching costs**. **Abbreviations.** DT: Dual-task, OA: Older adults, RRI: Response–response incongruent, SRC: Stimulus–response compatible, ST: Single-task, YA: Young adults.

Discussion

- Dual-tasking is impeded by **opposing response codes**
  → Fits action focus of task with motor-parietal areas involved in **sensory-to-motor coordinate transformations** [8].
  → **Extensive multiple demand network (eMDN) [3,9,10]** activity is associated with solving **response-code crosstalk** and **flexibly allocating attention to response selection**.
- Increased **response-code confusability** in **older adults** is accompanied by hyperactivity in **medial precentral gyrus** and **frontal pole**.
- **Task-specific eMDN** is linked to **divided attention** and **global switch performance** in **"low-order" motor-parietal areas.**
- **Left IPS** and **right occipito-cerebellar** areas are involved differently in **age**, and this is associated with **divided attention**.

Conclusions

➢ **Age differences** point towards a **dedifferentiation** pattern or **inter-individual variability in attentional strategies**.

➢ **DT performance (BIS)** is only related to **task-irrelevant visual cortex** activity, but **some task-activated regions** are associated with **other facets of dual-tasking** ➜ Individual activity patterns linked to dual-task performance differences?

References
[1] Koch, I, et al. (2018) *Psychol Bull*, 144:557–83.
[2] Verhaeghen, P, et al. (2003) *Psychol Aging*, 18:443–60.
[3] Worringer, B, et al. (2019) *Brain Struct Funct*, 224:1845–69.
[4] Huestegge, L, et al. (2009) *JEPHPP*, 35:352–62.
[5] Huestegge, L, et al. (2010) *Mem Cognit*, 38:493–501.
[6] Pieczykolan, A, et al. (2014) *J Vis*, 14:1–17.
[7] Liesefeld, HR, et al. (2019) *Behav Res*, 51:40–60.
[8] Colby, CL, et al. (1999) *Annu Rev Neurosci*, 22:319–49.
[9] Camilleri, JA, et al. (2018) *NeuroImage*, 165:138–47.
[10] Duncan, J (2010) *Trends Cogn Sci*, 14:172–79.