Neural Signatures of Dual-Task Response Conflicts and Their Modulation by Age

Lya K. Paas Oliveros [1,2], Aleks Pieczykolan [3,4], Rachel N. Pläschke [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** usually increase in **advanced age** with costs on performance speed and accuracy, compared to single-task performance [1,2].
- Dual-tasking has been associated with increased fronto-parietal activity [3], but studies mostly ignore interference arising from output-related features, e.g., **opposing response codes**.

➢ **Aim:** Study the neural mechanisms of **output-specific dual-task crosstalk** and their age-related differences by implementing a **spatial auditory-manual single-onset paradigm** with one vs. two simultaneous speeded choice responses [4-6].

Methods

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

➢ **Behavioral Analysis:**

- **Dual-task costs [DTC]** on reaction time **[RT]**, error rate **[ER]**, and **bin-score** (combined measure of speed and accuracy, [7])
- 2 × 2 × 2 mixed ANOVA with age group as between-subject and S-R compatibility and R-R congruency as within-subject factors.

➢ **tb-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: Removal of 4 first volumes, FM correction, realignment, slice time correction, normalization to MNI space, smoothing (FWHM 8 mm).
- Event-related model of experimental effects with random-effects contrasts
- **Single-subject analysis:** 3 regressors with **dual-task effects** (and in association with PM of mean RT) for each level of conflict
- **Group-level GLM:** Dual-task effects (and in association with PM of mean RT) were entered, separately for each **age group**. Conjunction analyses.

Paradigm

Single-onset dual-task paradigm

- Fig. 1: Respond to high- or low-pitched tones by pressing upper or lower response buttons with one (single-task) or both hands simultaneously (dual-task).

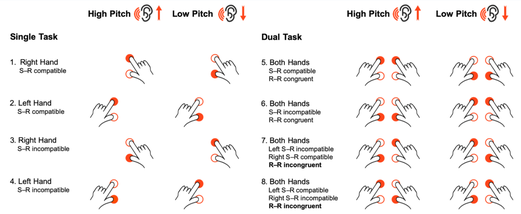
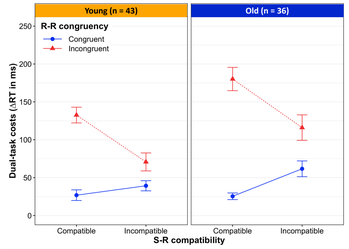


Figure 1. Single-onset dual-task paradigm.

- **Stimulus–response [S-R] compatibility:** Respond either in the compatible or incompatible direction implied by the pitch
- → Response selection difficulty
- **Response–response [R-R] congruency:** Motor codes for each response in dual-task blocks either mutually congruent or incongruent
- → Response initiation difficulty

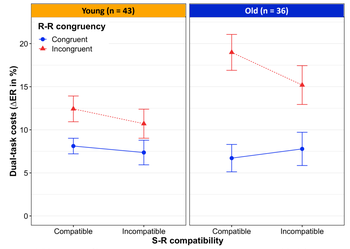
Results

(A) Dual-task speed costs



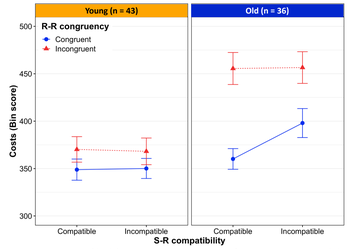
- Sig. main effects (age, S-R comp. and R-R congr.)
- **Age × R-R congr.** interaction (p = .040)
- **S-R comp. × R-R congr.** interaction (p < .001)

(B) Dual-task accuracy costs



- Sig. main effect (R-R congruency)
- **Age × R-R congr.** interaction (p = .028)
- **S-R comp. × R-R congr.** interaction (p = .013)

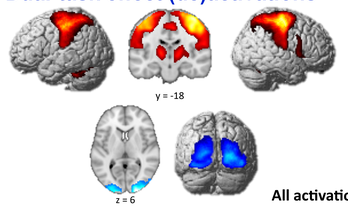
(C) Bin-score (speed costs and accuracy)



- Sig. main effect (age and R-R congruency)
- **Age × R-R congr.** interaction (p = .007)
- **S-R comp. × R-R congr.** interaction (p = .035)

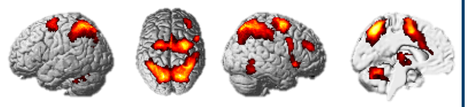
Figure 2. Mean dual-task costs on reaction time **(A)**, error rate **(B)**, and bin-score **(C)** according to age, stimulus–response (S-R) compatibility and response–response (R-R) congruency. Error bars represent SEM.

(A) Dual-task effect (de)activations



(B) DTE_{Old} > DTE_{Young}

(C) DTE_{RRI} > DTE_{RRC}



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

Figure 3. Brain activity associated to output-specific dual-task effects. **(A)** Brain activations (left) and deactivations (right) associated with main dual-task effect. **(B)** Brain activations associated with the dual-task effects of older (vs. young) healthy adults. **(C)** Brain activations associated with the dual-task effects of response–response incongruence (vs. congruence). **Abbreviations.** DTE: Dual-task effects, RRC: Response–response congruent, RRI: Response–response incongruent.

Results

➢ **Dual-task effects in association with mean RT**

Figure 4. Brain activity associated to output-specific dual-task effects in correlation with mean reaction time, modeled as parametric modulator.

Discussion

- **R-R congruency** sig. increased DTC in all performance scores (RT, ER and bin-score) → Further enhanced with age
- S-R comp. and R-R congr. sig. interacted (DTC on RT and ER) → **Reversed S-R comp. effect in R-R incongr. trials**
- Dual-task-specific brain activations fit the action-focused nature of this paradigm → Motor and parietal areas involved in **sensory-to-motor coordinate transformations** [8].
- Although S-R incompatibility elicited larger behavioral DTC, it did not recruit additional neural resources → In line with notion of structural bottleneck at response selection stage [3].
- No dual-task specific associations between brain activity and performance, as measured through mean reaction time.

Conclusions

➢ Dual-tasking is impeded by **opposing response codes → Multiple demand network, associated with top-down executive control [9,10], as well as multitasking [3].**

➢ Particular age-related deficits in the cognitive control of response-conflict in dual-tasking, but absence of age-related brain activity differences in this effect → **Output-related conflict resolution in advanced age suffers from a less efficient brain network subserving top-down control.**

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Acknowledgments

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