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

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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.

➢ **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).
- Event-related model of experimental effects with random-effects contrasts.
- **Single-subject GLM:** 16 regressors (plus mean RT as parametric modulator, PM) for each experimental condition and direction of the response.
- **Group-level GLM:** 6 regressors = **dual-task contrasts** separately for each **age group**. Analogous model for PM effects.

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).

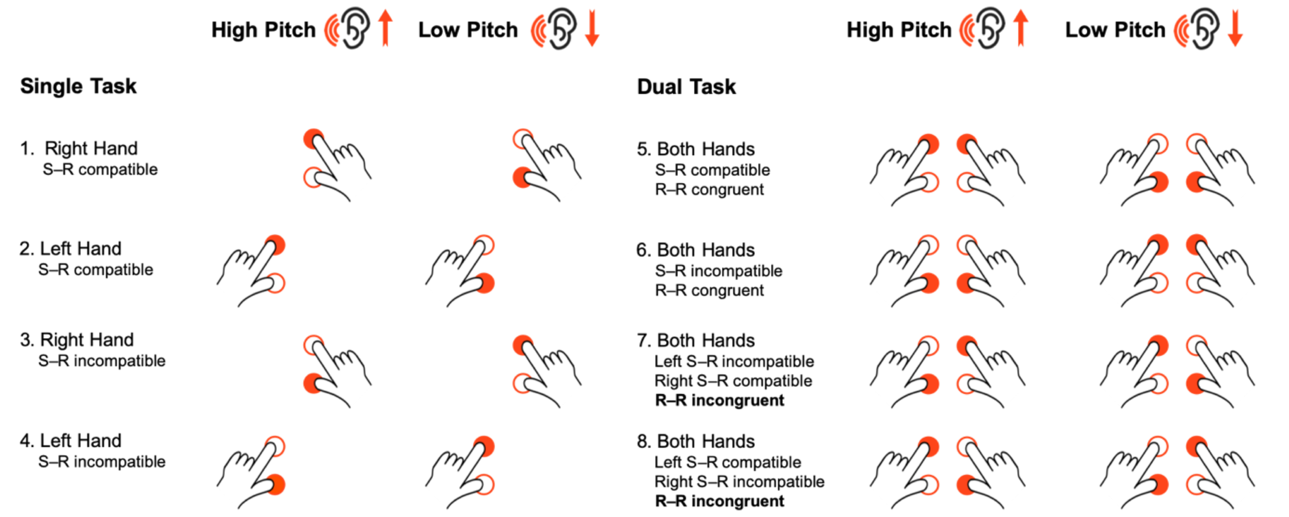
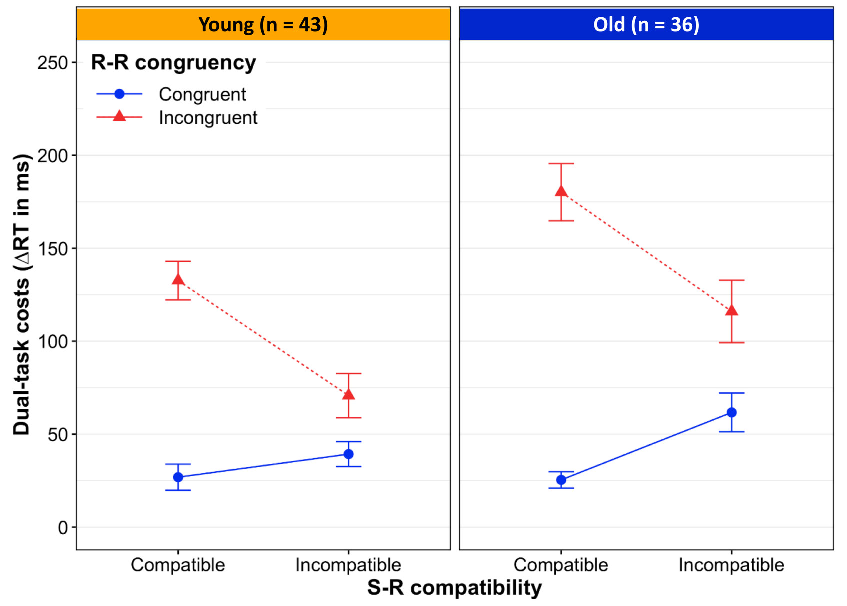


Figure 1. Single-onset dual-task paradigm.

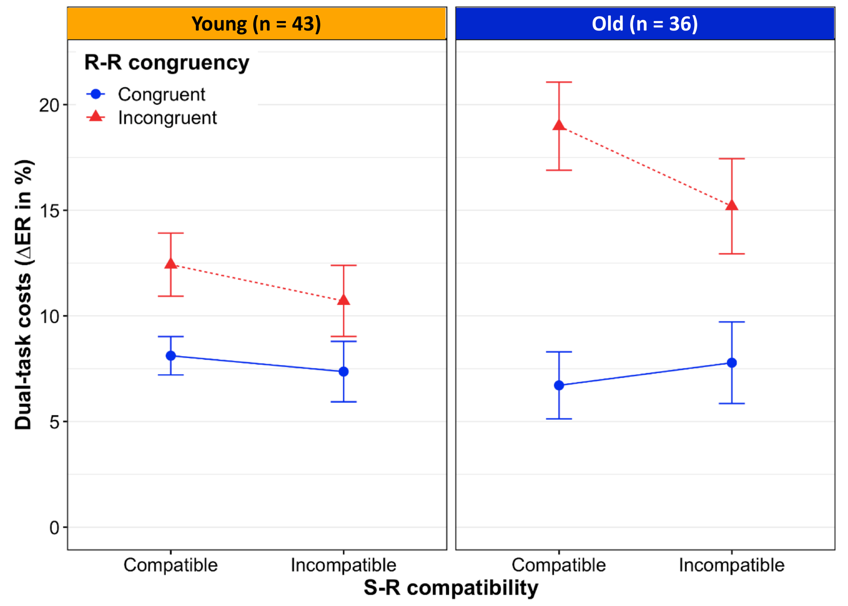
- **Stimulus–response [S-R] compatibility:** Respond either in the compatible or incompatible direction implied by the pitch.
- → Response selection difficulty
- **Response–response [R-R] congruency:** Motor codes for each response in dual-task blocks either mutually congruent or incongruent
- → Response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

Results

(A) Dual-task speed costs



(B) Dual-task accuracy costs



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

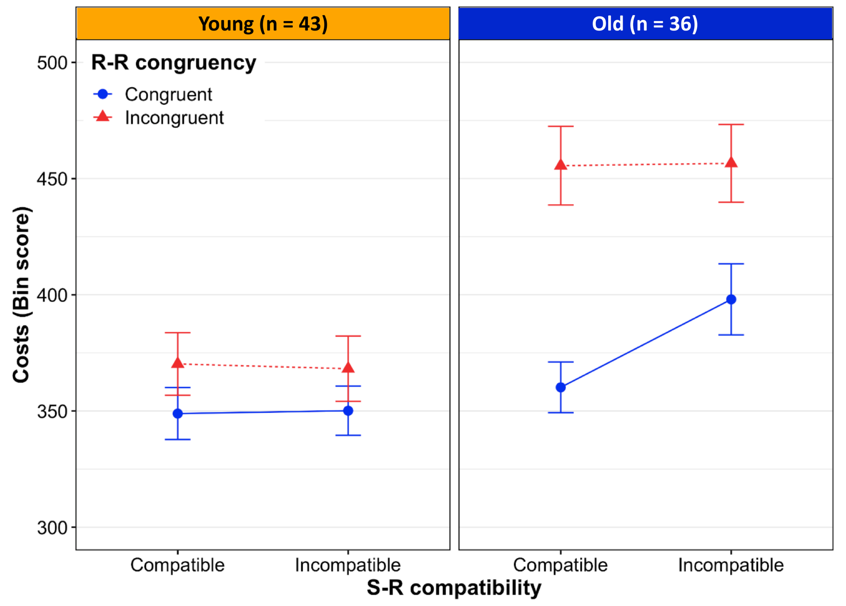


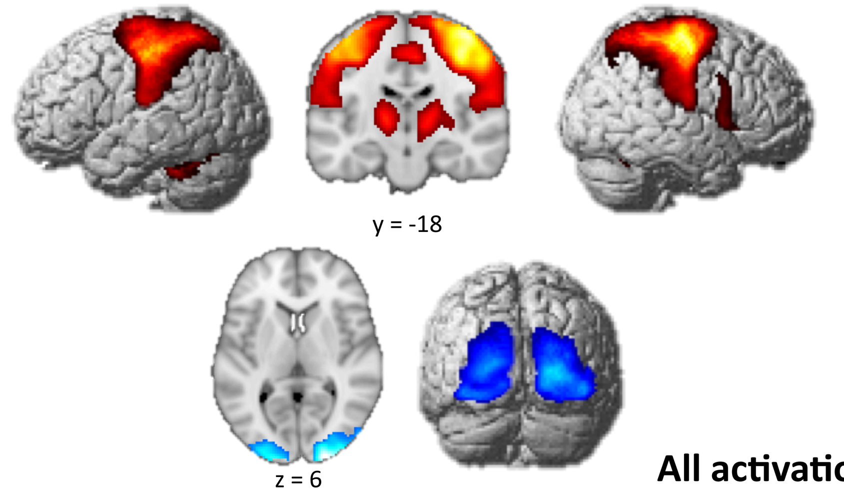
Figure 2. Mean dual-task costs on reaction time **(A)**, error rate **(B)**, and bin-score **(C)** according to age, stimulus–response (S-R) compatibility and response–response (R-R) congruency. Error bars represent SEM.

(A)
- 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)

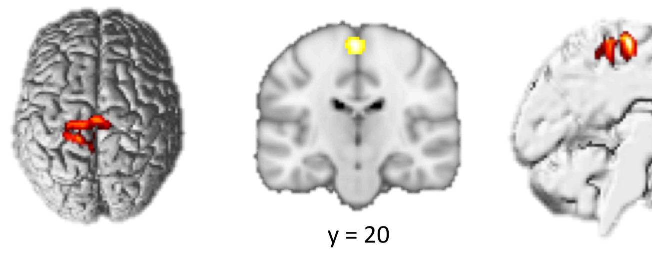
(B)
- Sig. main effect (R-R congruency)
- **Age × R-R congr.** interaction (p = .028)
- **S-R comp. × R-R congr.** interaction (p = .013)

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

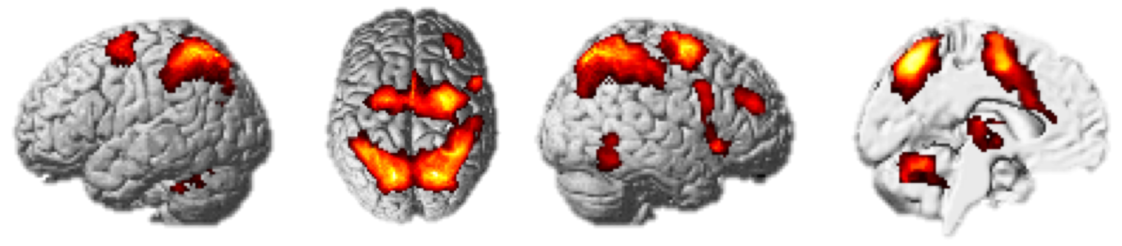
(A) Dual-task effect (de)activations



(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 activation (upper panel) and deactivations (lower panel) associated with dual-tasking. **(B)** Greater brain activation associated with dual-tasking in older (vs. young) healthy adults. **(C)** Dual-task-related brain activation during response–response incongruency (vs. congruency). **Abbreviations.** DTE: Dual-task effects, RRI/RRC: Response–response incongruent/congruent.

Results

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

Figure 4. No dual-task-specific linear associations between brain activity and intraindividual RT fluctuation over time, modeled as parametric modulator.

Discussion

- **R-R congruency** sig. increased DTC in all performance scores (RT, ER, bin-score) → Further **enhanced with age**
- S-R comp. and R-R congr. interacted (RT and ER) → **Reversed S-R comp. effect with R-R incongruency**
- 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].
- S-R incompatibility elicited larger behavioral DTC but 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 fluctuation over trials.

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 may suffer from less efficient brain network subserving top-down control.**

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Acknowledgments

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