Towards a combined behavioural and physiological measure of listening effort

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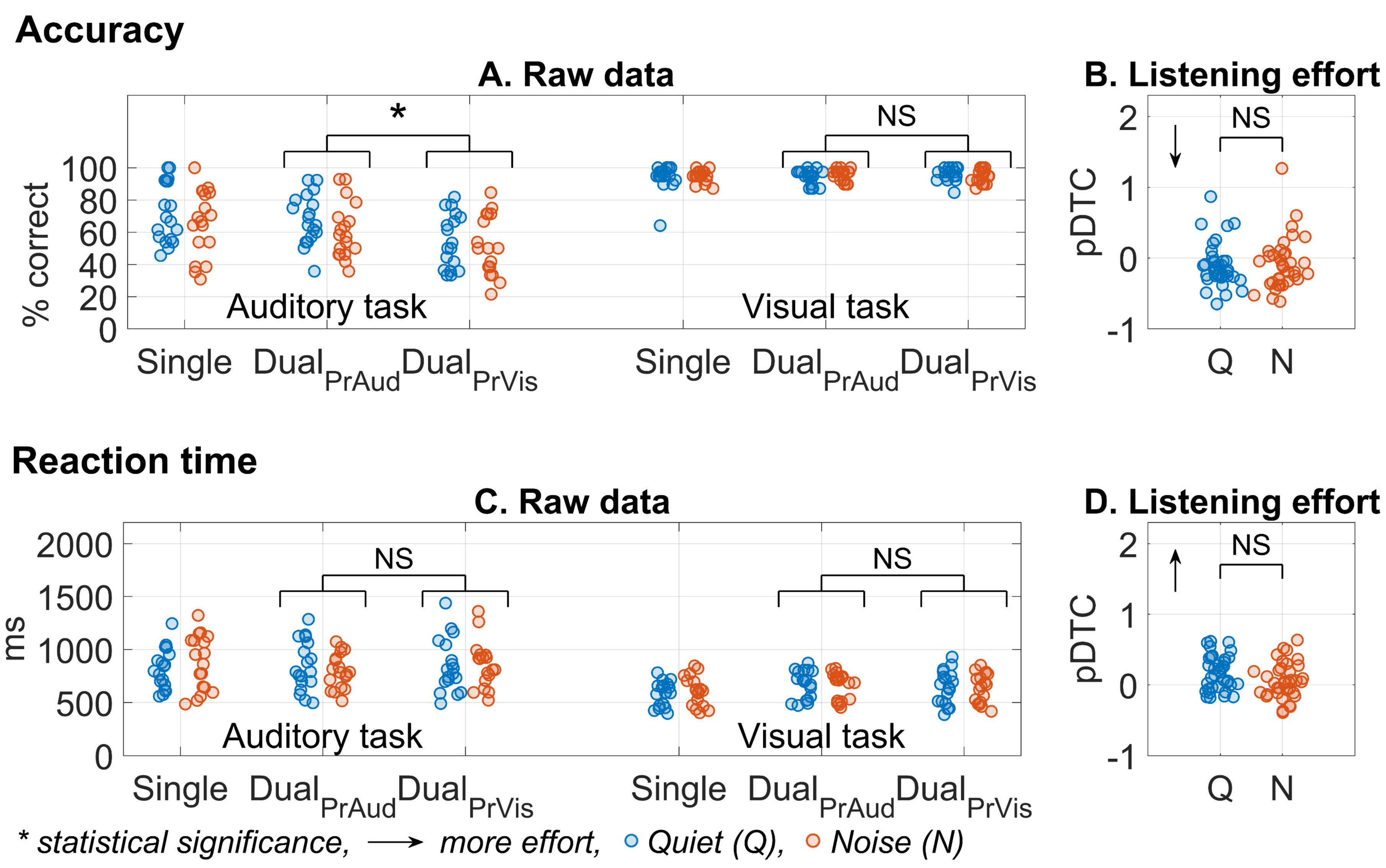
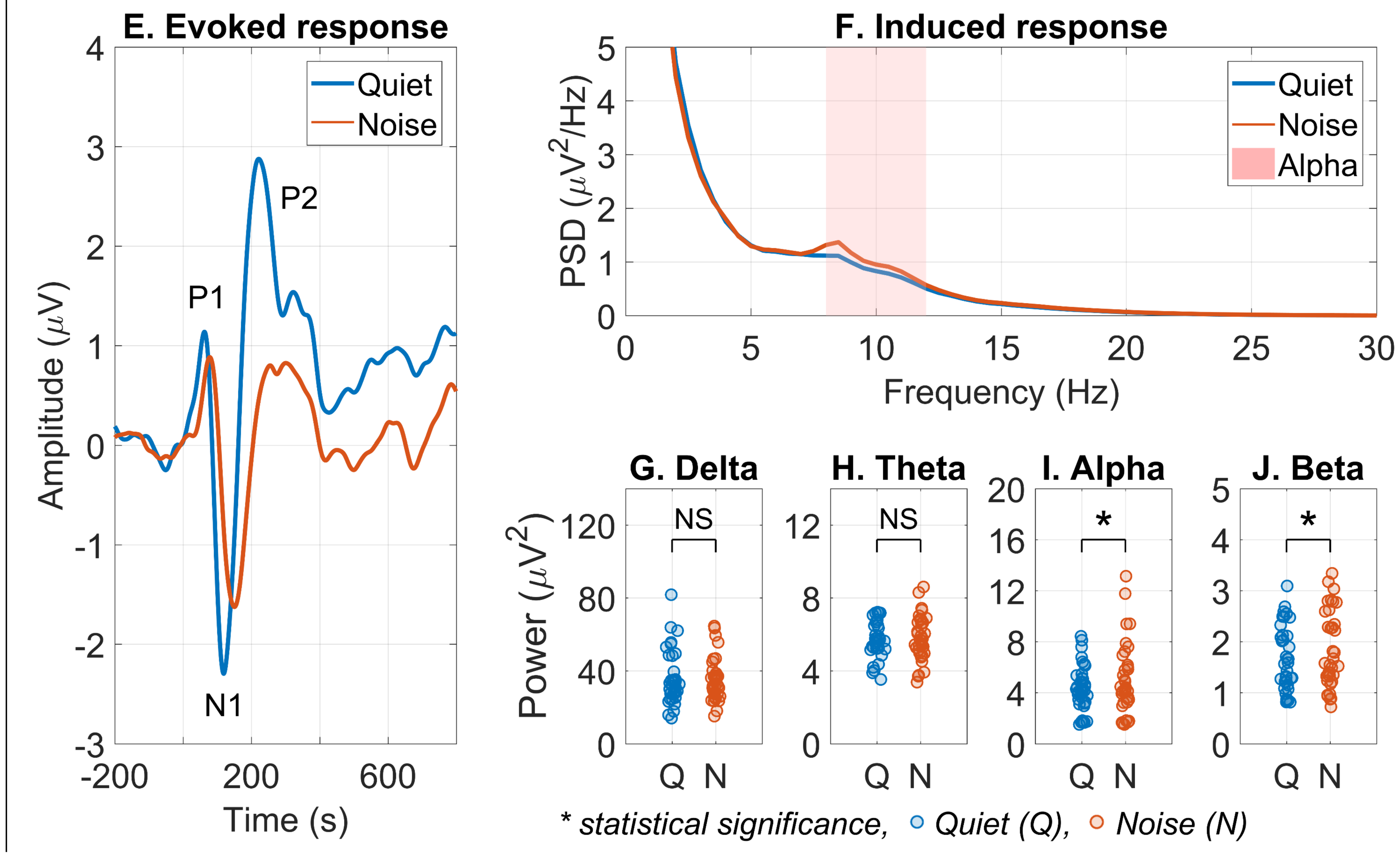
Behavioural results



Electrophysiology results



Aims

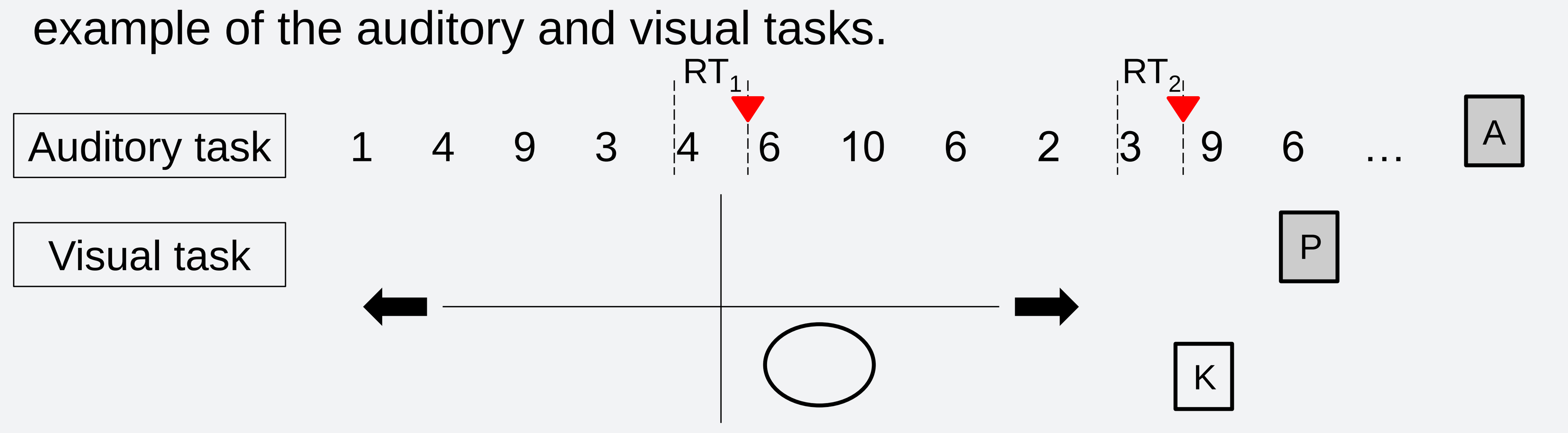
- ✓ Investigate the sensitivity of a dual-task paradigm to listening effort measured both behaviourally and electrophysiologically.
- ✓ Evaluate the validity of the assumption of participants being able to prioritize a particular task in a dual-task paradigm.

Conclusions

- ✓ The proposed dual-task paradigm is sensitive to listening effort.
- ✓ The SNRs used were not challenging enough, and the protocol could benefit from using lower SNRs in which intelligibility is compromised.
- ✓ Behavioural performance depends on participants' task priority.
- ✓ At group level, alpha power is a robust indicator of listening effort.

Methods

Six **subjects** (aged 25-35, mean = 29.5 years, SD = 4.28 years, 1 female) participated in the study. The **dual task** consisted of an auditory task and a complex visual task. In the *auditory task*, participants had to press the 'A' key as soon as they identified a consecutive digit in a series (e.g. '5' after '4') in the presence of a masking audiobook. The auditory task was delivered in quiet [+30 dB SNR] and in noise [+5 dB SNR]. The *visual task* consisted of a cued switching attention task proposed by Meiran (1996). In this task, a large cross was placed in the middle of the screen. Then, a pair of arrows appearing either in the horizontal or vertical axis would instruct the participant to identify whether a circle appearing in one of the four quadrants of the cross was on the [left/right] or [top/bottom], respectively. Participants were instructed to press as soon as the circle was presented the 'P' key for responses indicating 'right' or 'top'; or the 'K' key for responses indicating 'left' or 'bottom'. Accuracy and reaction time (RT) were evaluated in the two tasks. In each participant, four conditions (auditory only, visual only, dual-task [priority to auditory], dual-task [priority to visual]) were evaluated 3 times in the 2 SNRs, i.e. 24 tests per session. The diagram below shows an example of the auditory and visual tasks.



The **electroencephalogram (EEG)** was recorded from Cz referenced to the combined mastoid, i.e. $[Cz - \frac{M1+M2}{2}]$, using a sampling rate of 1 kHz. The evoked response was obtained by averaging the EEG segments around each digit, after digital filtering [0-30 Hz] and suppressing blink-artifacts with ITMS (Valderrama et al., 2018). Brain oscillation analysis was based on the power spectral density (PSD) of the induced-response.

Listening effort was quantified electrophysiologically through brain oscillations; and behaviourally through the proportional dual-task cost (pDTC), i.e. $pDTC = \frac{DualTask_{Aud} - SingleTask_{Aud}}{SingleTask_{Aud}} + \frac{DualTask_{Vis} - SingleTask_{Vis}}{SingleTask_{Vis}}$.

Statistical analysis consisted of a number of linear mixed effects model tests, considering the task mode (priority to the auditory or visual task) and the SNR (quiet or noise) as predictor variables.

Results & discussion

Figures A-D show the raw data and listening-effort estimates for the accuracy and reaction time **behavioural performance**. Figure A shows that accuracy in the auditory task was, on average, 12% higher when participants prioritized the auditory task (Dual$_{PrAud}$) compared to the condition in which they gave priority to the visual task (Dual$_{PrVis}$) [$p<0.001$]. This result validates the assumption typically made in dual-task paradigms in which **participants are able to prioritize** the allocation of different cognitive resources needed to perform two task simultaneously.

In contrast to our predicted outcomes, behavioural estimates of **listening effort** (figures B and D) showed no statistically significant differences between the two SNR conditions, both in accuracy and reaction time performance. This result possibly points out that the tested SNRs were not challenging enough to observe an effect on the behavioural estimate of listening effort, and that lower SNRs in which intelligibility is compromised could increase the sensitivity of the proposed dual-task paradigm.

Electrophysiology results are presented in figures E-J. Figure E presents the grand-average **evoked response** in quiet (blue) and in noise (brown). As expected, increasing background noise reduced the amplitude and increased the latency of the P1, N1, and P2 components. Figure F shows the grand-average PSD of the **induced response**. A detailed analysis of the total power in the main four frequency bands (figures G-J) shows that alpha and beta power were higher in the low SNR condition [Alpha: +0.68µV^2, $p=0.036$; Beta: +0.16µV^2, $p=0.039$]. This result is consistent with recent literature showing that higher alpha power is associated with increased listening effort.

Meiran N (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology* 22, 1423-1442.

Valderrama J, de la Torre A, Van Dun, B (2018). An automatic algorithm for blink-artifact suppression based on iterative template matching: Application to single channel recording of auditory evoked potentials. *Journal of Neural Engineering* 15, art. 016008, 15p.