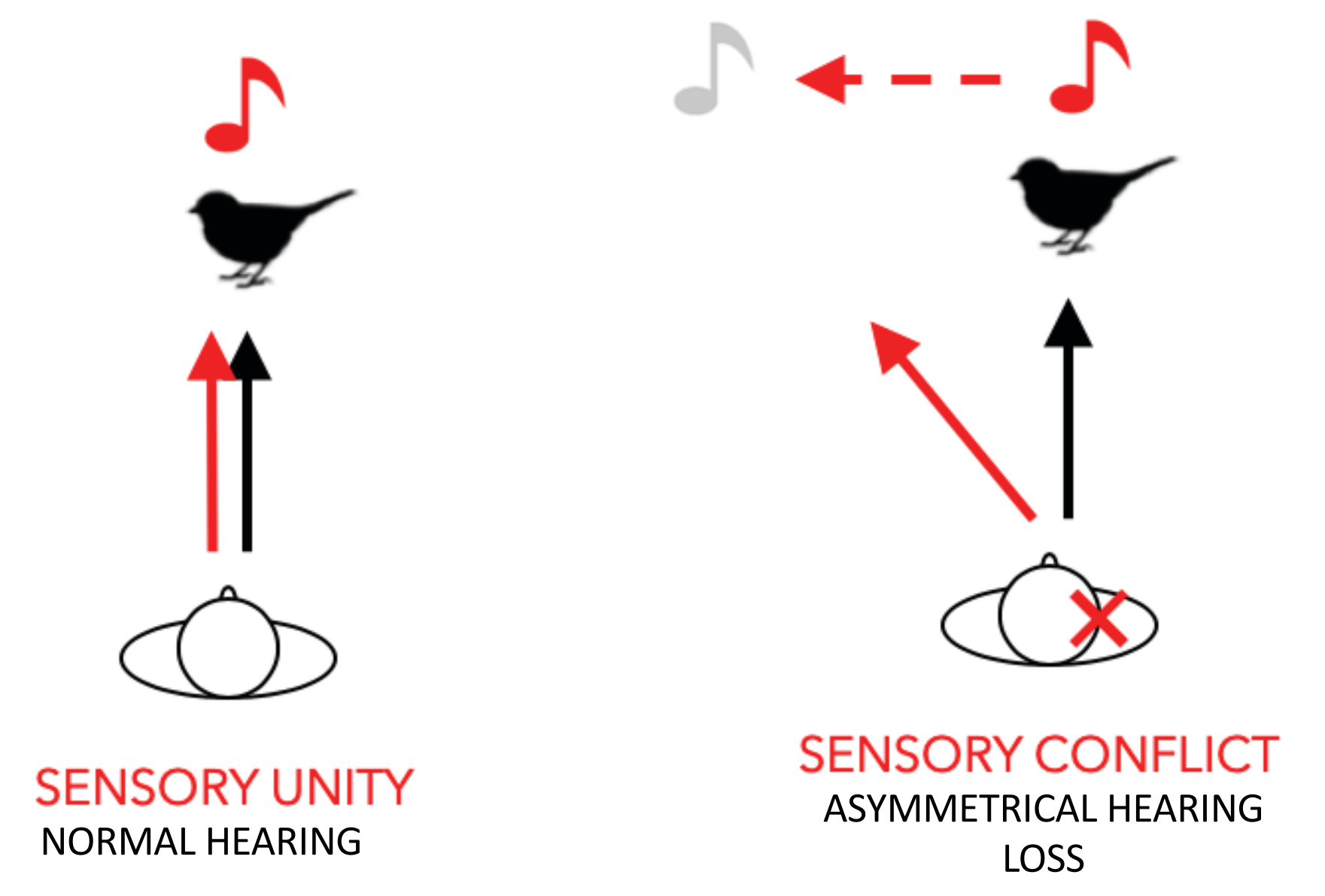
The impact of simulated asymmetrical hearing loss on multisensory integration of auditory and visual spatial information

Nathan Van der Stoep, Sanne Böing, S., & Stefan Van der Stigchel
Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands

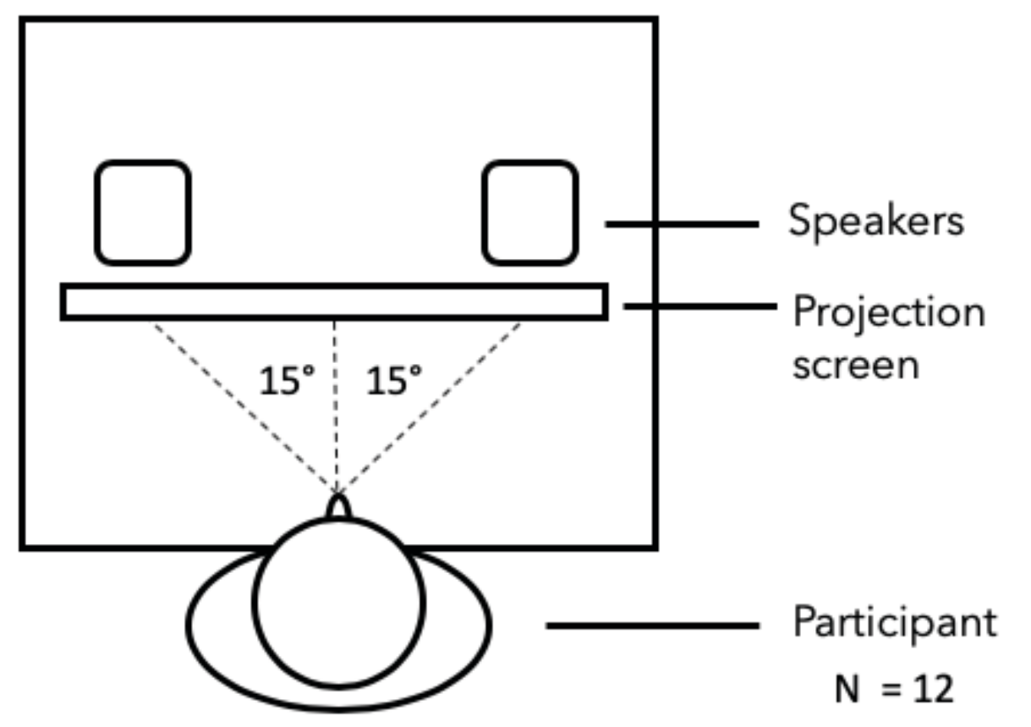
BACKGROUND

- Asymmetrical hearing loss (AHL) is a common type of hearing loss (14-20%)[1, 2] that heavily distorts sound localization[3].
- Multisensory integration (MSI) of auditory (A) and visual (V) input normally greatly enhances perception of AV input when A and V are spatially aligned [4, 5, 6].
- The impact of (simulated) AHL on MSI was investigated by measuring eye-movements.
- Hypothesis: AHL disrupts MSI because of the spatial conflict between hearing and vision and reduces multisensory benefits.



METHODS

Setup



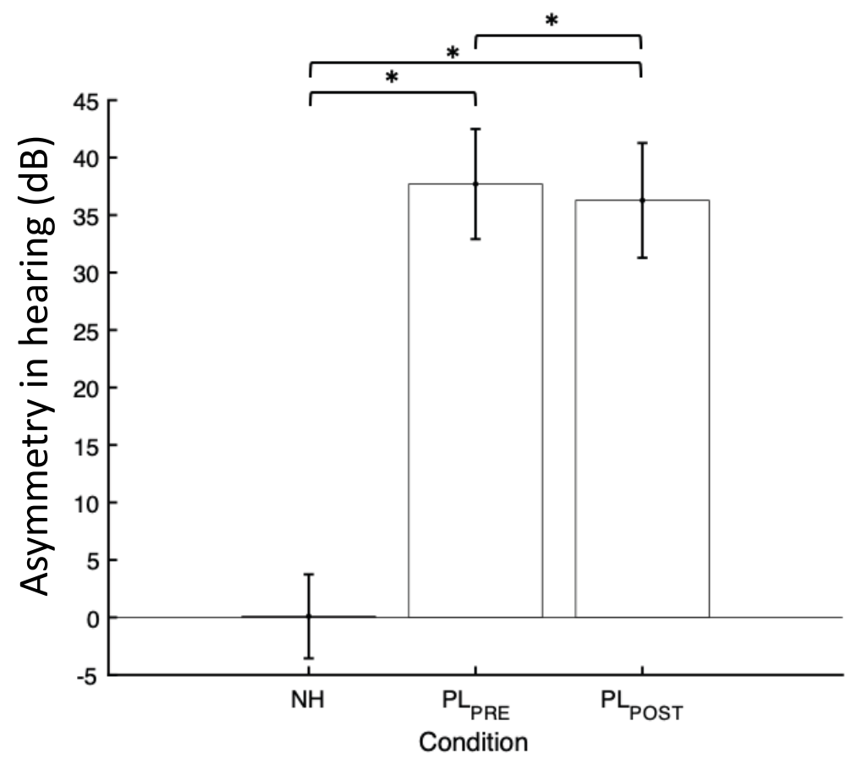
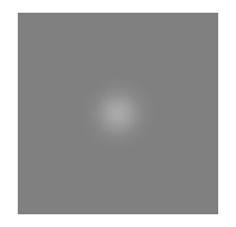


Fig. 1 The earplug caused a hearing loss of ~32 dB with a small reduction of the earplug effect throughout the experiment (pre vs post)

Targets:

- Auditory: 100ms 60/44 dB(A) high-pass noise (>3kHz).
- Visual target: Small or large Gaussian blob
- Audiovisual: Combination of A and V
- Catch trial: No target



Eye-tracker: Eyelink 1000
Sennheiser HD 201 headphone for the hearing test.
Ohropax Soft earplugs. Noise reduction: ~37 dB(A) (Fig. 1).

Tasks

- Equal loudness test
- Saccade task

RESULTS: WHERE DO WE LOOK?

Auditory localization

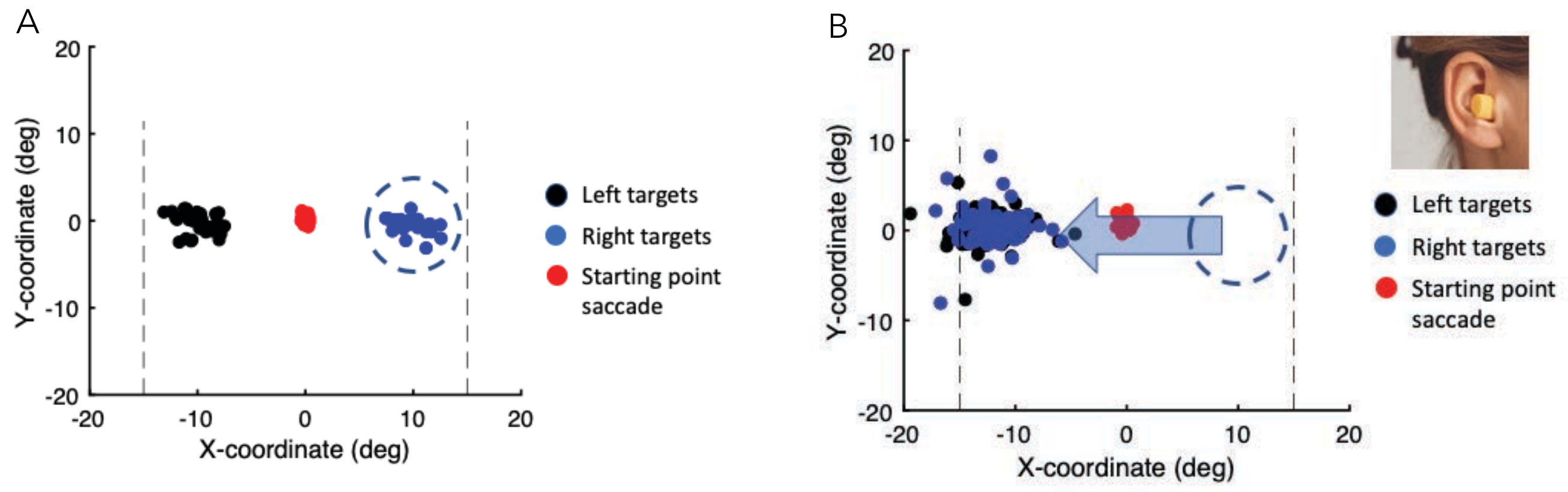


Fig. 2 Saccade start (red) and landing points (black, blue) for eye-movements to sounds on the left (black) and right (blue) side of the fixation cross. Normal hearing (A) and plugged hearing (B) of one participant.

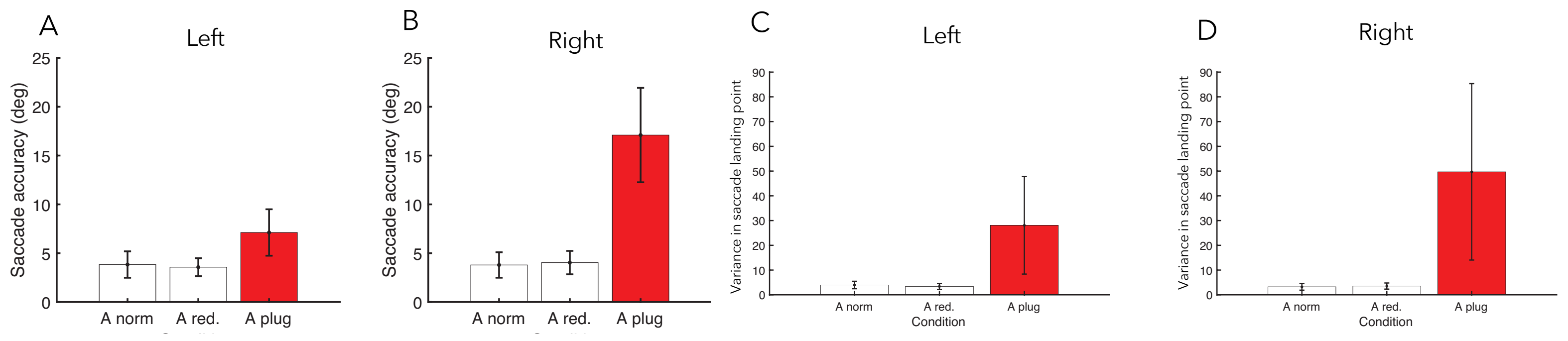


Fig. 3 Saccade endpoint accuracy (A, B) and variance (precision, C, D) for auditory targets on the left and right side of space. Reducing the sound intensity (A red.) with normal hearing did not result in the same change in saccade accuracy and precision (middle bar). Normal hearing: A norm = 60 dB, A red. = 44 dB, Plugged hearing : A plug = 60 dB

Visual localization

- Saccade accuracy for visual targets was unaffected by plugging the ear.
- Saccade precision was generally higher for visual targets.
- As expected, saccade precision was lower for the large relative to the small Gaussian blobs.

Audiovisual localization: accuracy

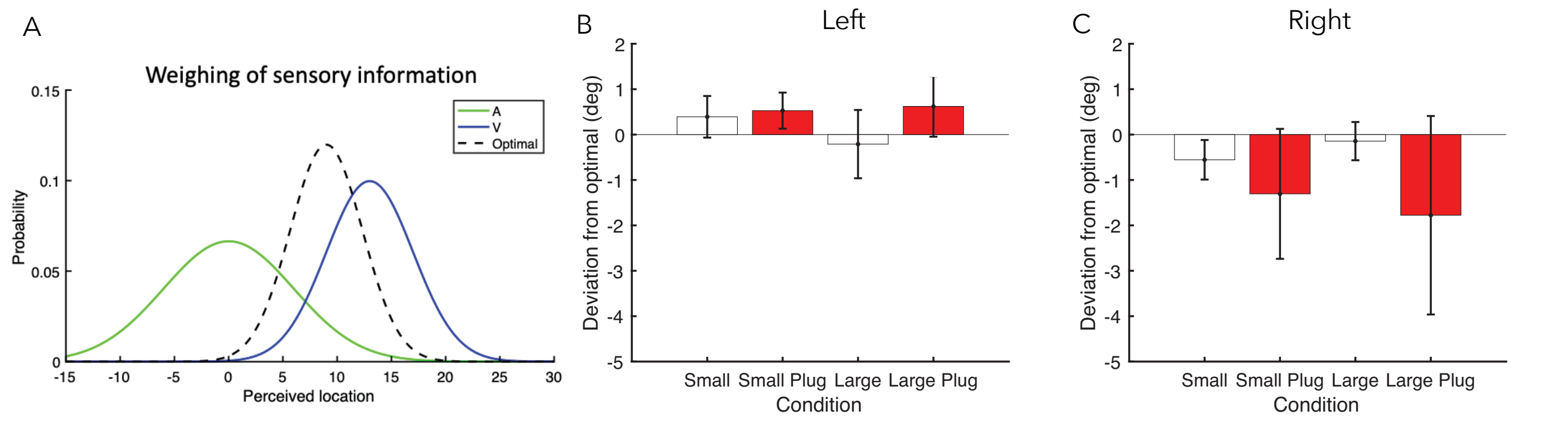


Fig. 4 (A) Example of optimal integration of auditory and visual location estimates. Each sensory estimate is weighted according to its reliability (here variance in saccade landing point). The dashed black line indicates the optimal location estimate and optimal variance of that estimate based on optimal cue integration[7]. The observed AV saccade endpoint was compared to the optimal endpoint. (B, C) The difference between the predicted saccade endpoint and the observed saccade landing point in the audiovisual conditions for small and large Gaussian blobs with normal hearing and plugged hearing (red bars) for targets in the left (B) and right visual hemifield (C).

Audiovisual localization: precision

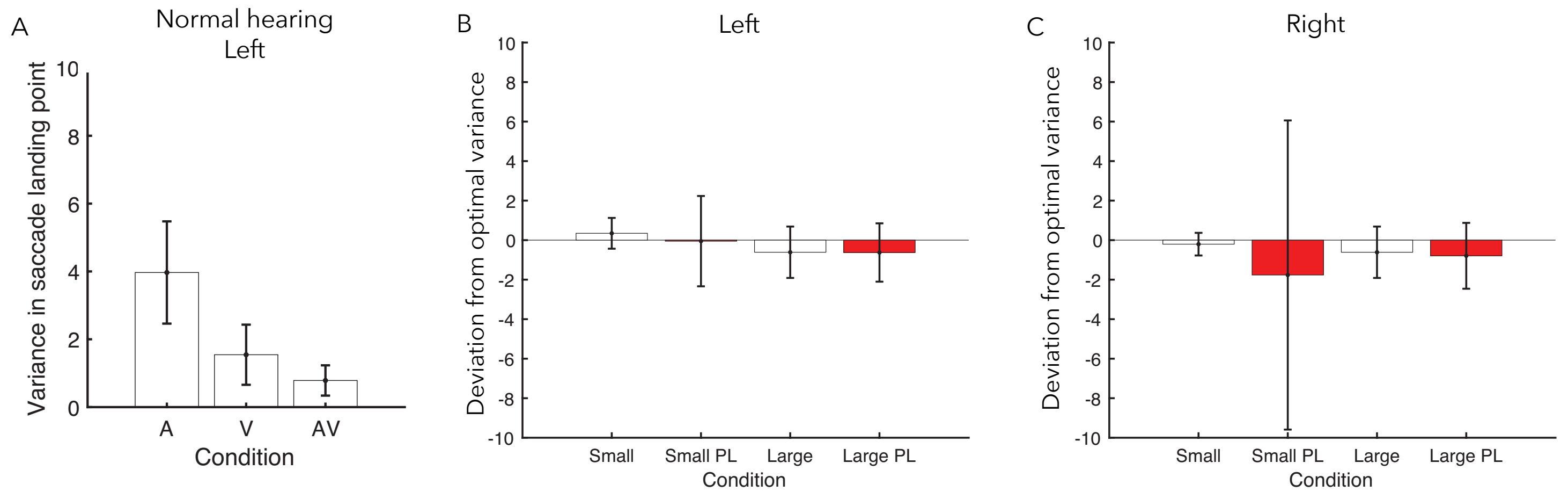
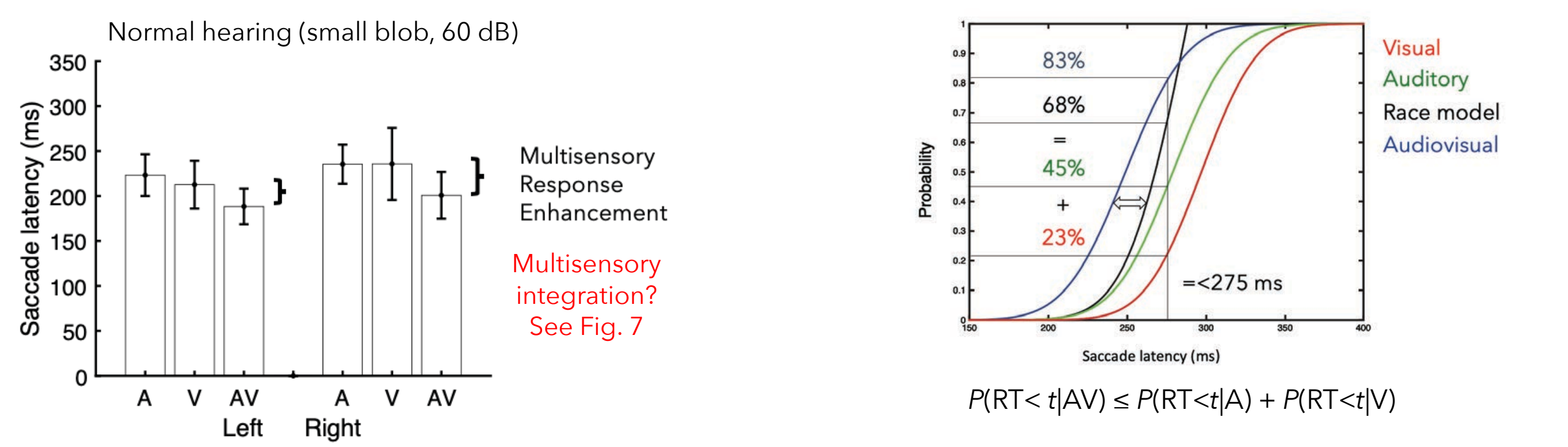


Fig. 5 A: As example: the average precision in the A, V (small), and AV (V small) condition in normal hearing for targets on the left side of space. B: The difference between the observed AV saccade endpoint variance and the predicted optimal variance in the AV condition. Small = Small visual blob, Large = Large visual blob, PL = Plugged hearing.

RESULTS: WHEN DO WE LOOK?

Saccade latency



$P(RT< t|AV) \leq P(RT<t|A) + P(RT<t|V)$

Fig. 6 Saccade latencies in the unisensory and multisensory conditions in normal hearing with visual small targets. As expected, saccade latencies for multisensory targets were shorter than the fastest unisensory saccade latencies. To check whether the speed up in saccade latency in the AV condition was due to integration or independent processing, race model inequality violations were calculated (see Fig. 7).

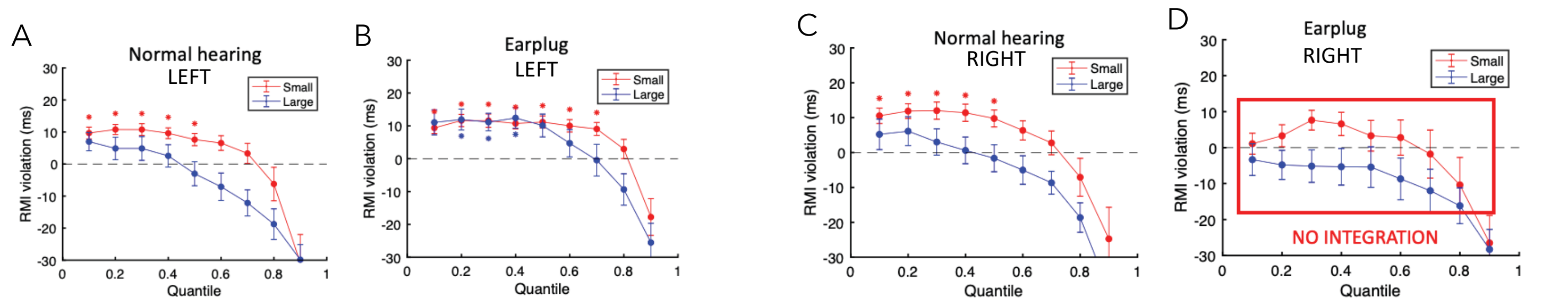


Fig. 7 The amount of race model inequality (RMI) violation in normal hearing and plugged hearing for targets on the left (A, B) and right side of space (C, D). The results show multisensory integration in normal hearing (small blob) but not in plugged hearing for targets on the earplug side.

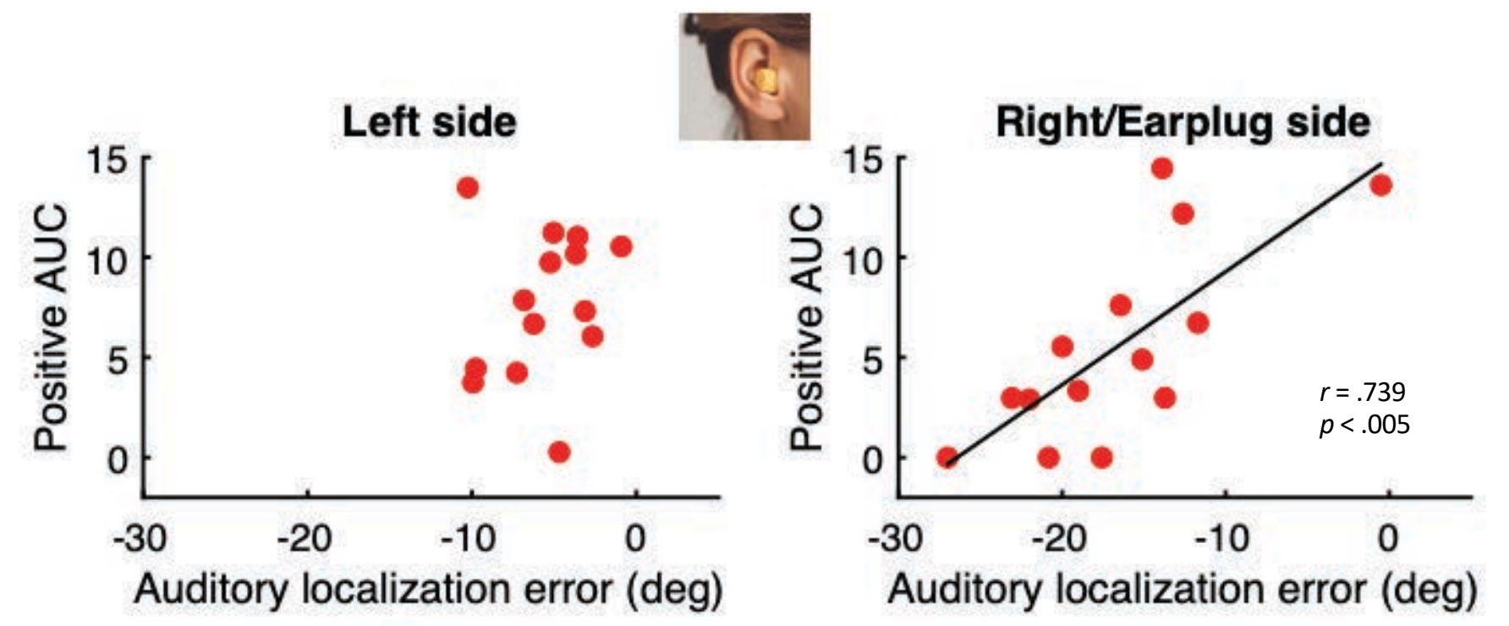


Fig. 8 The relation between auditory localization error and the amount of race model inequality violation (positive Area Under the Curve, pAUC). The amount of integration decreased with an increase in sound localization error for multisensory targets presented on the side of the earplug.

CONCLUSIONS

Simulated conductive asymmetrical hearing loss:

- Impairs auditory localization
- Creates sensory conflict between hearing and vision
- Impairs multisensory integration on the affected side
- Causes immediate non-optimal reweighting of sensory input to improve external accuracy
- The larger the auditory localization error, the smaller the benefit of multisensory integration

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www.multisensoryspacelab.com

Contact: N.VanderStoep@uu.nl