Does eccentric fixation alter head movement strategy for smooth pursuit?

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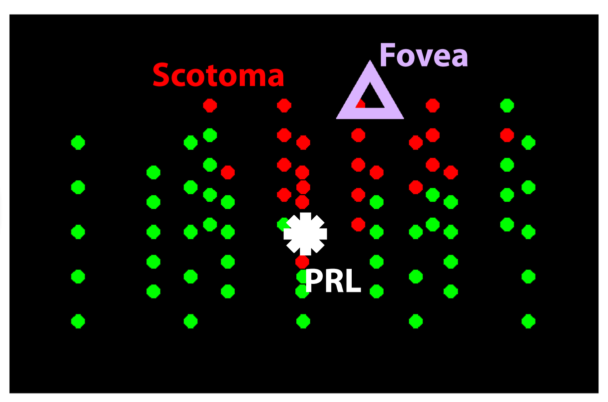
Introduction

Age-related macular degeneration (AMD) can often lead to the loss of foveal vision and the surrounding central visual field. This type of visual loss is extremely common (affecting nearly 7% of individuals over 40 in the United States alone) and can present particular challenges for oculomotor tasks that rely on the high-acuity foveal retina. For certain tasks, individuals develop a new, eccentric fixational area – the preferred retinal locus (PRL).

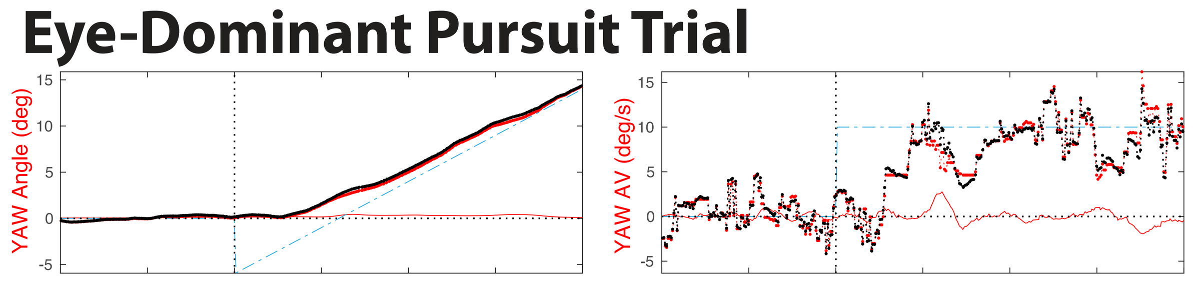


Methods

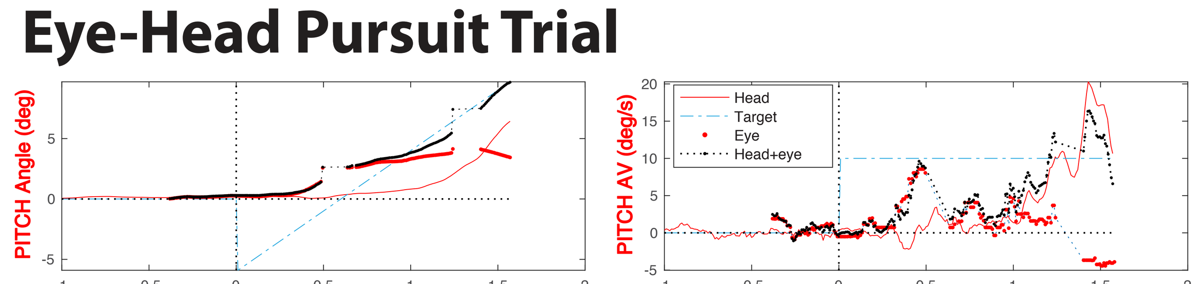
- **Participants:** 8 AMD participants (75-95, 5M, 4 binocular scotomas); 4 age-matched controls (72-76, 1M)
- **Eye Tracking:** PupilLabs head mounted, binocular tracker (120 Hz)
- **Head Tracking:** Head-mounted IMU (LPMS)
- **Task:** pursuit of a 1° spot, modified step ramp paradigm, 6 directions (0°, 90°, 135°, 180°, 270°, 315°) at 10°/s

1 Different Eye & Head Movement Strategies

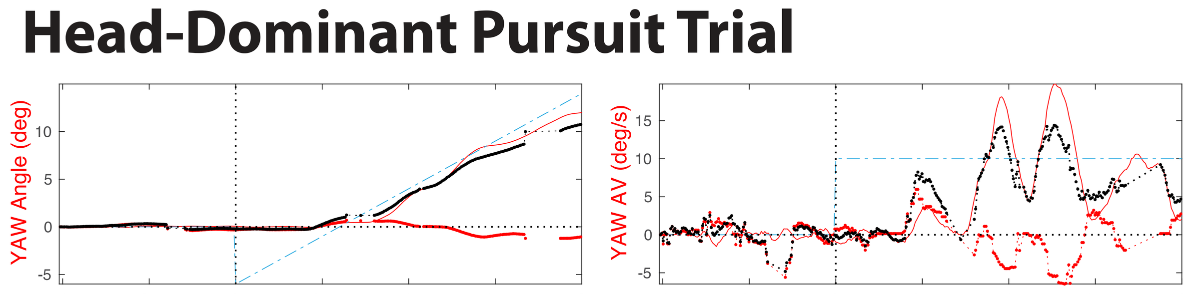
Eye-Dominant Pursuit Trial



Eye-Head Pursuit Trial

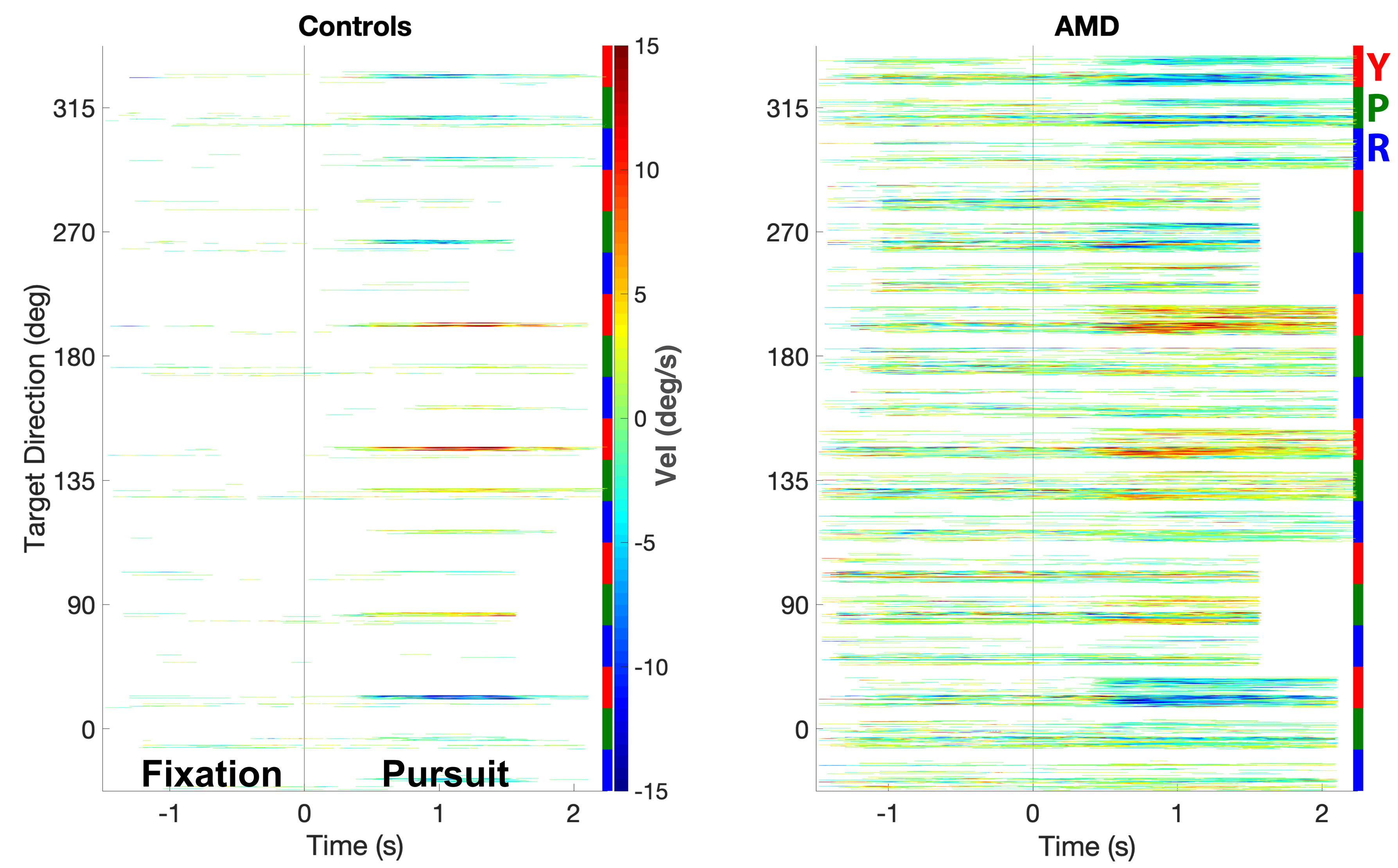


Head-Dominant Pursuit Trial



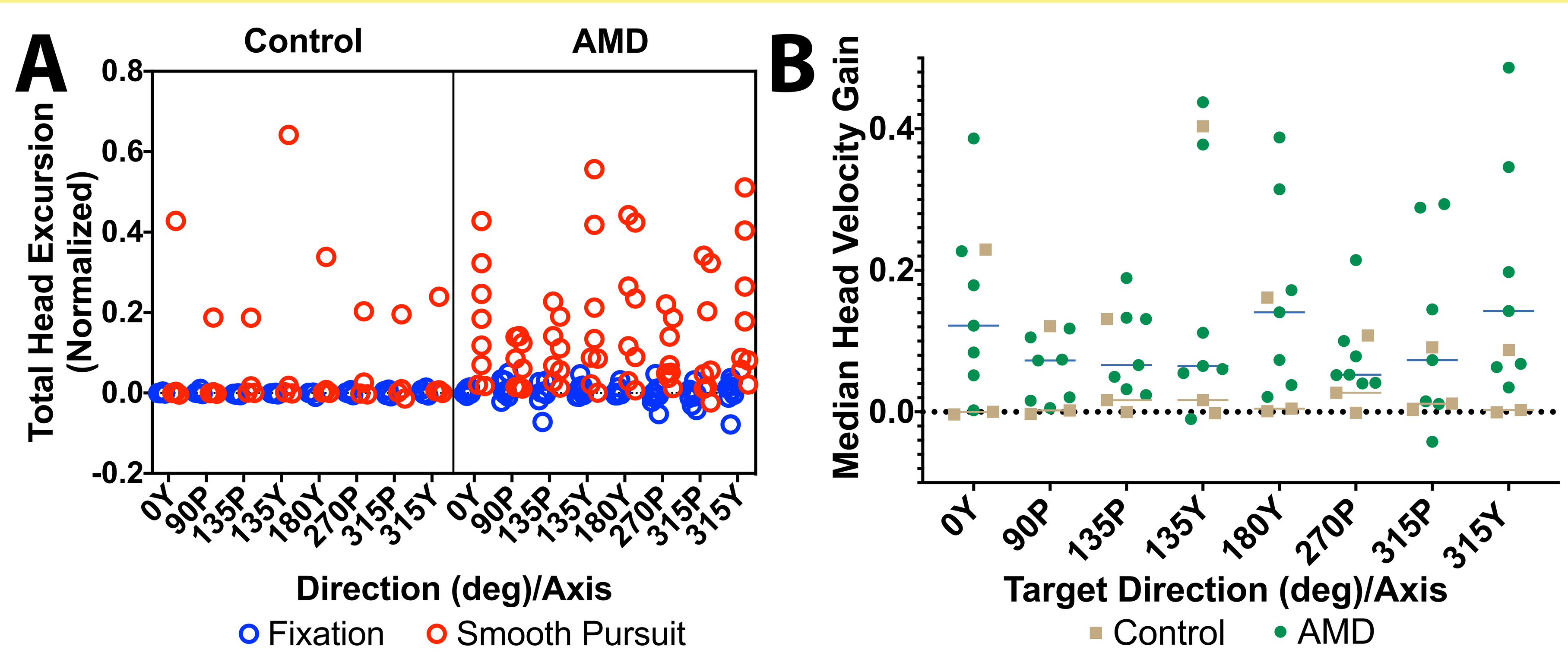
Examples of 3 head-free smooth pursuit trials from one control participant. Each example has different level of eye/head involvement.

2 AMD & Control Participants Use Head Movements in Pursuit



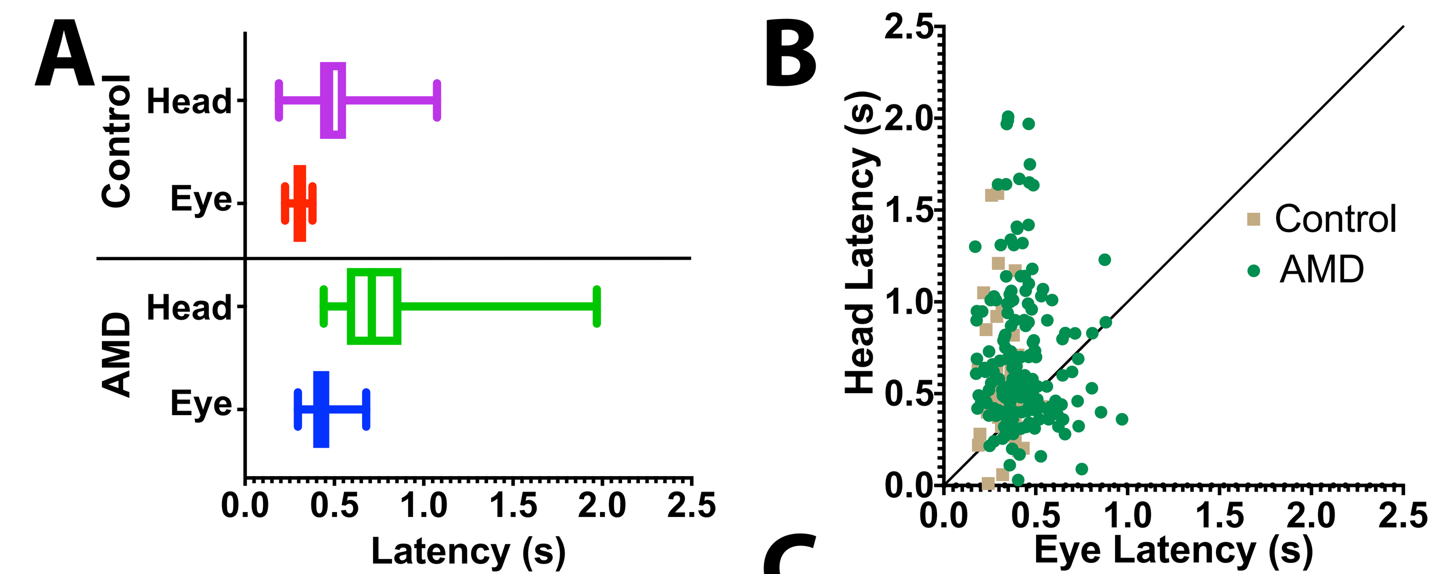
Head movements along each movement axis (yaw, pitch, roll) with velocity peaks greater than 2 deg/s are plotted for each trial and participant. Black vertical line indicates target onset. Trace color indicates magnitude & direction (bluer: rightward/up, redder: leftward, down). Controls have overall greater head stability, but both groups have significant movement in target direction during pursuit.

3 Same Head Movement Range in Control & AMD Participants

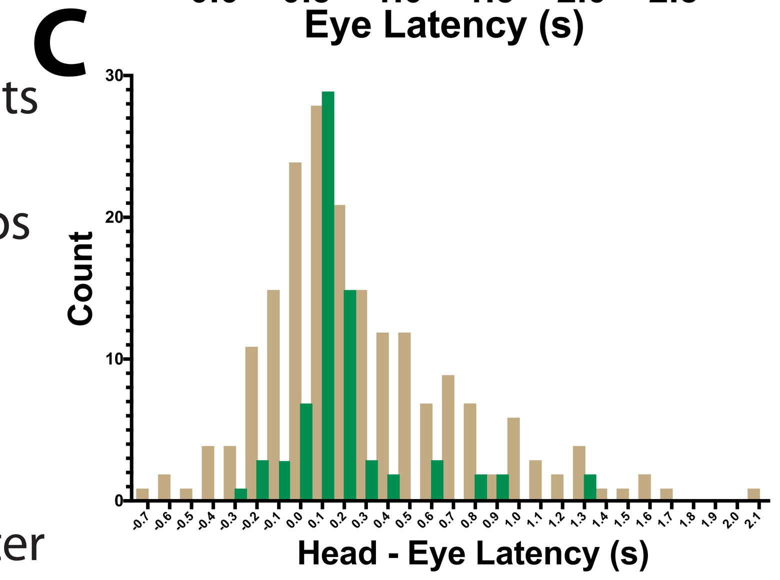


A. Average total head displacement during the fixation and smooth pursuit phases of each trial, plotted for each participant. Data is normalized by target excursion for each trial's direction, taking direction into account. Positive values indicate displacement in the target direction. AMD participants had significantly greater head displacement than controls ($p = 0.02$).
B. Median head velocities were averaged for each participant, for each target direction. Head velocity gain is calculated as the ratio of head and target velocities. Both AMD and Control groups have similar gain range, although higher proportion of individuals with AMD used head movements during pursuit. Gains were not significantly different across groups.

4 AMD Participants Have Longer Eye & Head Latencies

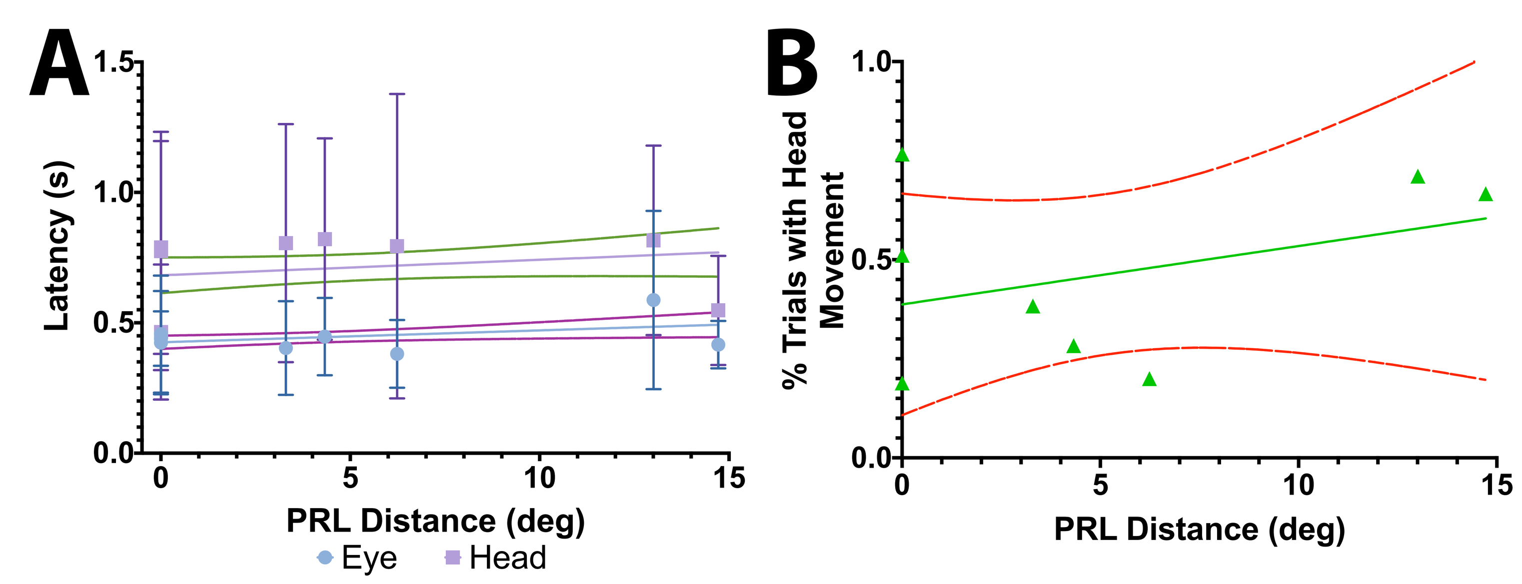


A. On average, head movements started significantly later than eye movements for both groups ($p < 0.0001$). Participants with macular degeneration had longer eye and head latencies than controls ($p < 0.0001$).



B. Head movements started after eye movements on a majority of trials for both groups.
C. Lag between eye and head onset did not differ between groups ($\text{median}_{AMD} = 0.189$ s, $\text{median}_{Cont} = 0.132$ s).

5 Eye, Not Head Movements Affected by Disease Severity



Fovea-PRL distance of each AMD participant's better eye was measured and regressed with (**A**) latency of eye & head movement and (**B**) proportion of trials with task-relevant head movements. PRL distance had a small but significant effect on eye latency but not head.

Conclusions

- Both participants with AMD and age-matched controls use multiple eye and head control pursuit strategies.
- Usually head movement starts later than the eye to increase total gaze displacement.
- Overall, the AMD group starts tracking the target later and the head stability is reduced compared to controls.
- Disease severity does not affect head tracking but may affect eye movements.

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