Human Oculomotor Response to Virtual Auditory Motion

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I. Introduction

It is widely believed that a moving visual target is required to drive smooth pursuit eye movements (SPEM). However, some studies have provided evidence of low-gain SPEM in response to real, moving auditory targets (Paige et al., 2000; Hashiba et al., 1996), while others have failed to find an auditory pursuit response (e.g. Fiebig et al., 1981). We reexamined this phenomenon using virtual moving auditory stimuli. We also explored the possibility that any observed auditory pursuit might simply be a response to the motion of an imagined target, rather than to the actual auditory motion stimulus.

II. General Methods

- A virtual 3D auditory sound source generated the illusory motion of a sampled real sound source (ringing of a small bell) delivered through stereo headphones.
- Stimulus motion consisted of horizontal sinusoidal oscillation (± 30 deg, at either 0.1, 0.2, 0.3, or 0.4Hz).
- Individualized head-related transfer functions (HRTFs) were measured and used for each observer.
- HRTFs combine interaural timing and intensity differences (ITDs & IIDs) as well as binaural spectral cues.
- Three human observers (one naïve) participated in the two experiments.
- Pupil position of the left eye was monitored using an ISCAN 726 infra-red video-based eye-tracker sampling at 240Hz.
- Visual stimulus was a laser point source back projected onto a screen, manipulated with mirror galvanometers.
- Pursuit amplitude and phase was computed by Fourier analysis of the de-saccaded velocity traces.
- Means and standard deviations calculated for each observer over 4 blocks in Exp. 1 and 3 blocks in Exp. 2.

References

Fiebig, E., Schaefer, K.-P., and Suss, K.-J. (1981) J Neurol 226:77-84.
Hashiba, M., Yasui, K., Watabe, H., Matsuoka, T., and Baba, S. (1996) Acta Otolaryngol (Stockh); Suppl 525: 151-154.
Paige, G.D., Avissar, M., Macuga, K.L., and Giffi, J.T. (2000) Soc. Neuro. Abs. 26: 1713.

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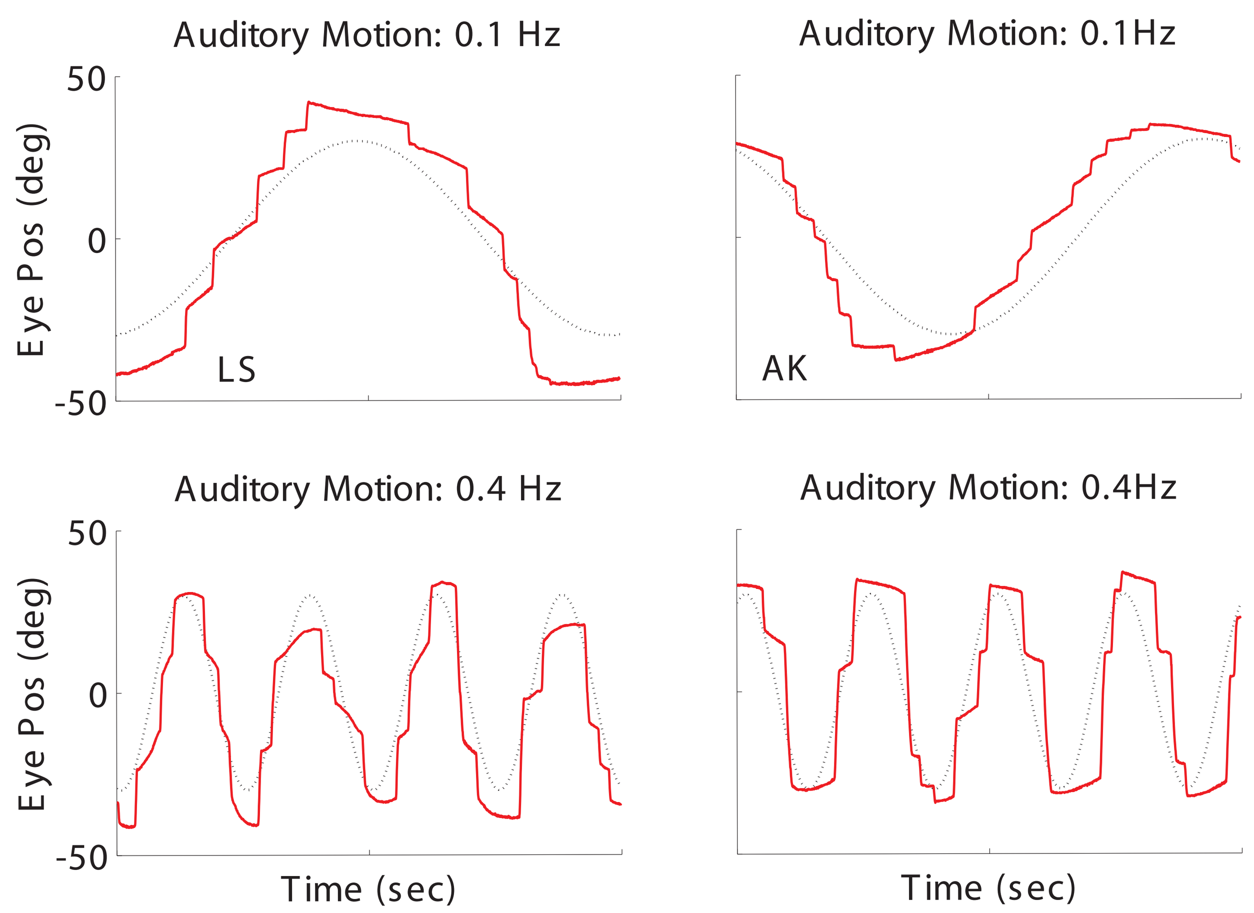
III. Results

Experiment #1: Basic Phenomenon

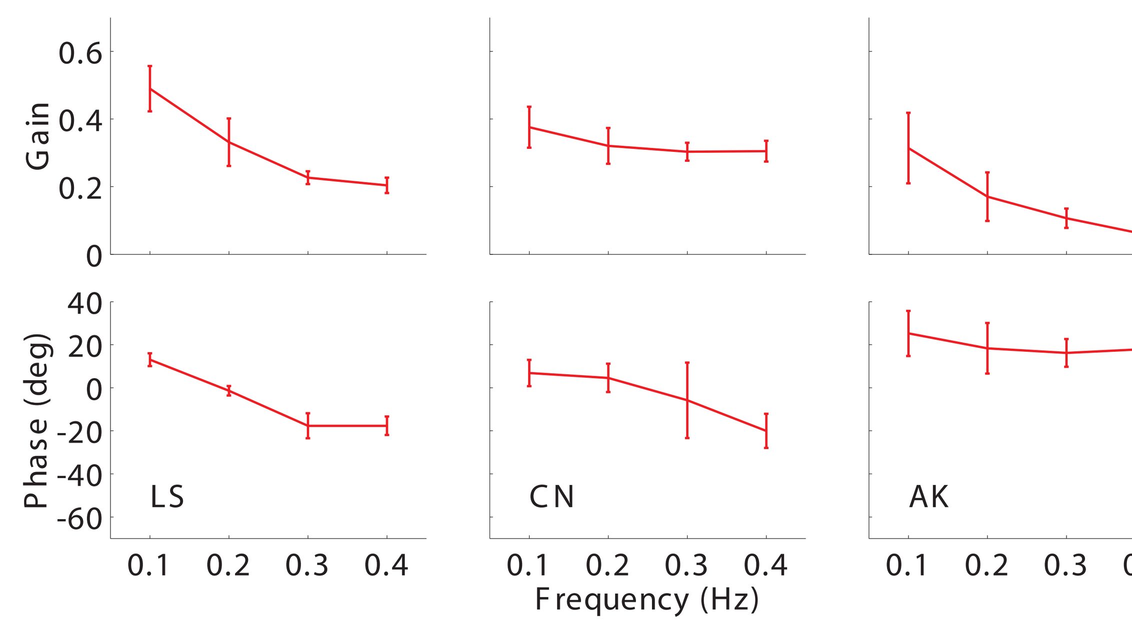
- Oculomotor responses to purely auditory motion (A) and to combined auditory and visual motion (A+V).
- Each block of 16 trials consisted of randomly interleaved trials of A and A+V (2 repetitions x 4 frequencies x 2 stimulus types).

Raw Data



- Note the periods of smooth eye movement between saccades.

Auditory Pursuit Response

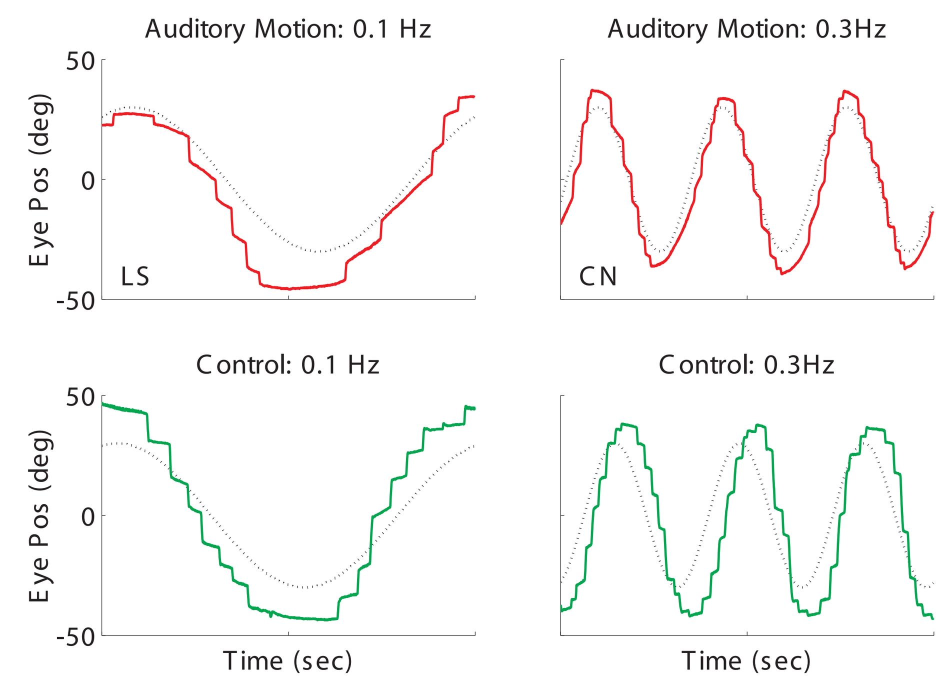


- The pursuit component of the auditory tracking response is well behaved.
- Gains as high as 50% at 0.1 Hz.
- Gains decrease and phase lags increase with increasing temporal frequency (as with visual pursuit).

Experiment #2: "Metronome" Control

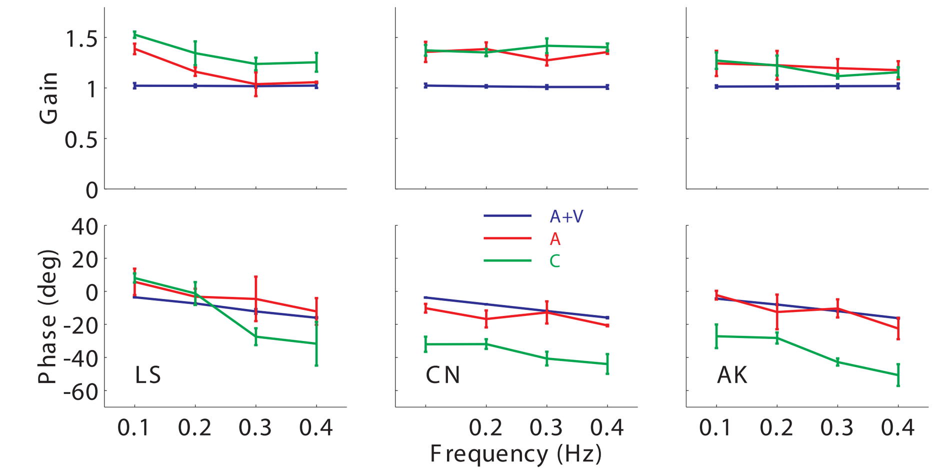
- Comparison of oculomotor tracking responses to a purely auditory "metronome" control (C) with the same A and A+V stimuli as in Exp. 1.
- The metronome control consisted of 150ms stationary presentations of the same bell sound, jumping between the 2 extrema (±30 deg) at one of the same frequencies, thereby providing the same spatial and temporal information as A albeit without any auditory motion.
- The task for the metronome control was to move the eyes as smoothly as possible between the two end points, phase locked with sound presentations.
- Each block of 24 trials consisted of a sequence of A+V, A and C trials, with the same 4 stimulus frequencies randomly interleaved (2 repetitions x 4 frequencies x 3 stimulus types).

Raw Data



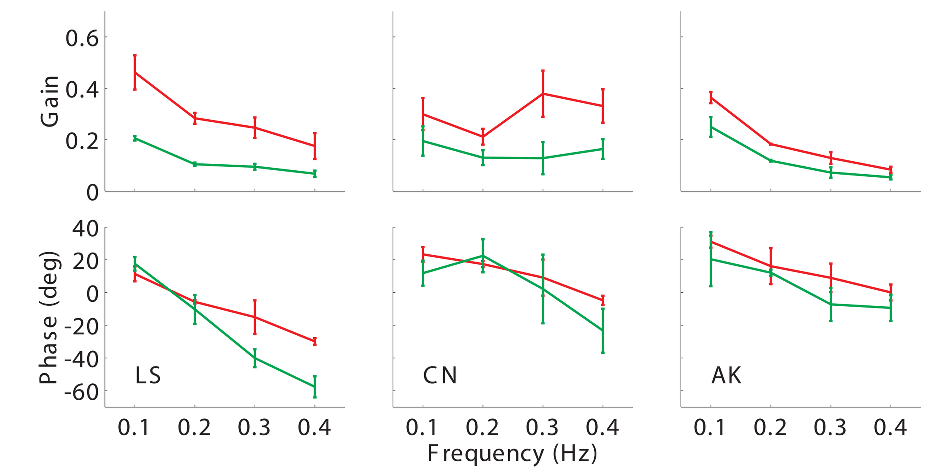
- Note that periods of pursuit are briefer and less steep for imagined motion control (green) than for auditory motion (red).

Overall Tracking Response



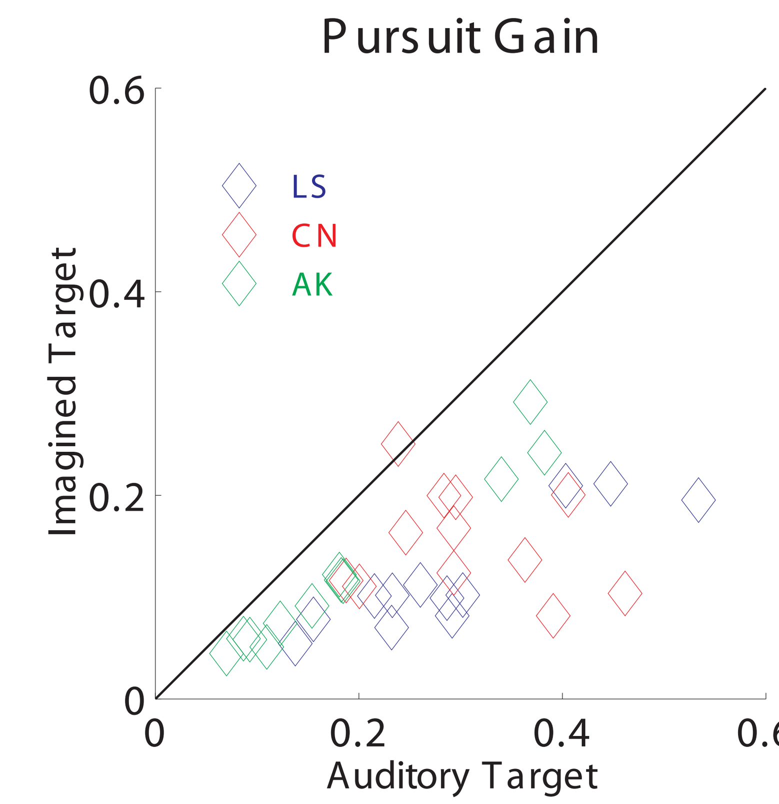
- Overall tracking response has gain>1 for both auditory and imagined motion, indicating an overshooting of the target.
- Phase of auditory tracking response is remarkably similar to visual tracking, while tracking of imagined motion exhibits some phase.

Auditory versus Imaginary Pursuit

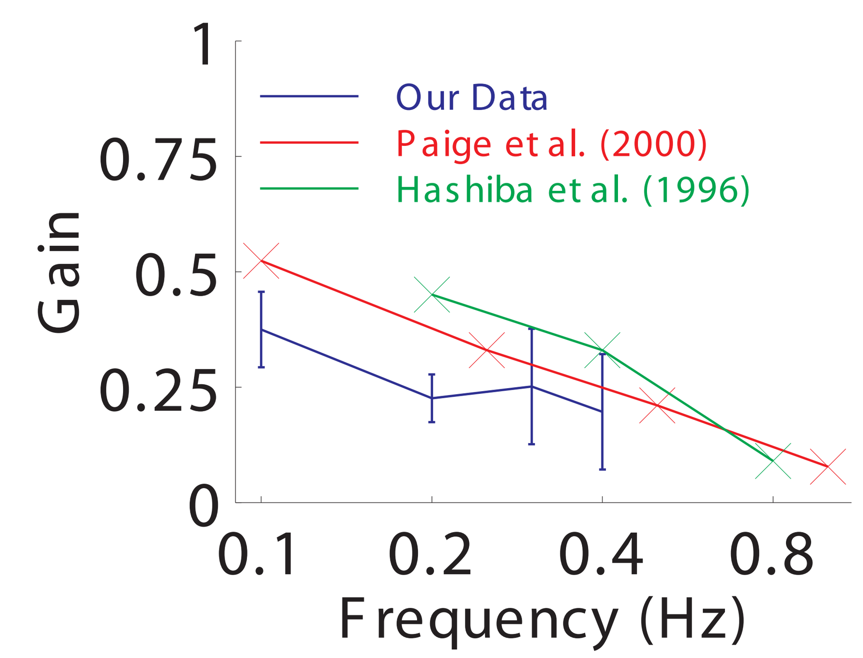


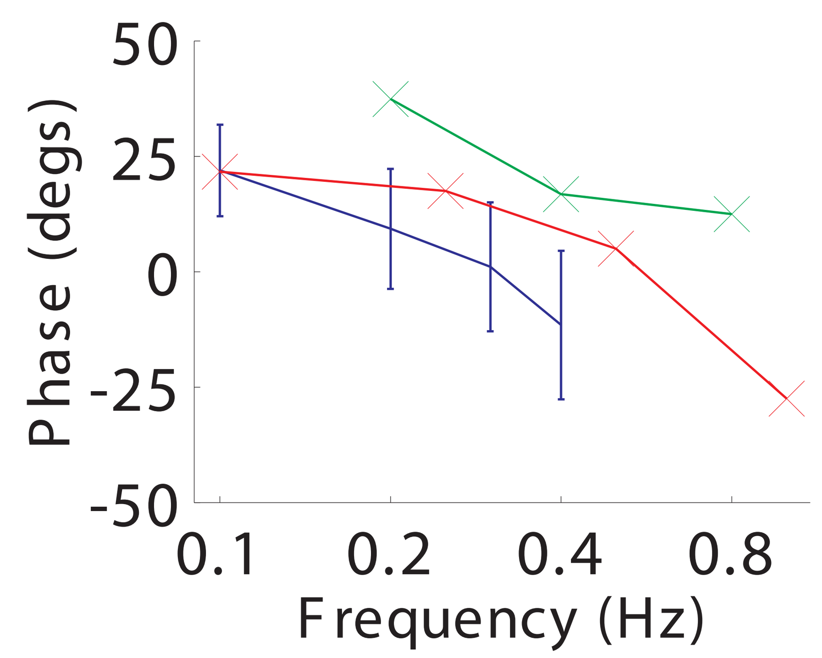
- Although pursuit to imagined target motion appears remarkably robust and well behaved, it has significantly lower gain than that for auditory motion.
- The mean gains (±SD across observers) for auditory motion were 0.37±.08, 0.23±.05, 0.25±.13, and 0.20±.13 at 0.1, 0.2, 0.3, and 0.4 respectively, while those for imagined motion were 0.22±.03, 0.12±.01, 0.10±.03, and 0.10±.06.

IV. Summary



- Note that pursuit gains to imagined target are lower that to the auditory target for all 3 subjects.





- Auditory pursuit gains and phases for our virtual auditory sound source are similar to previous studies that used real auditory sources.

V. Conclusions

- Our data demonstrate that human pursuit of auditory motion is robust and cannot be accounted for by pursuit of imagined motion.
- A previous attempt to control for imagined motion (Hashiba et al. 1996) used temporal cueing and no spatial information, making gain and phase comparisons with auditory pursuit difficult.
- Within the range of frequencies tested, pursuit of our virtual auditory sound source is similar to the pursuit of real sound sources observed by others. The use of virtual auditory sources, however, will allow future studies to probe which cues (ITD, IID and spectral cues) are critical for supporting pursuit.
- Our data also show that pursuit of an imagined moving target, cued by sparse temporal and spatial information, can be reliable, although with significantly lower gain than pursuit of auditory motion.