Compression of Time during Smooth Pursuit Eye Movements

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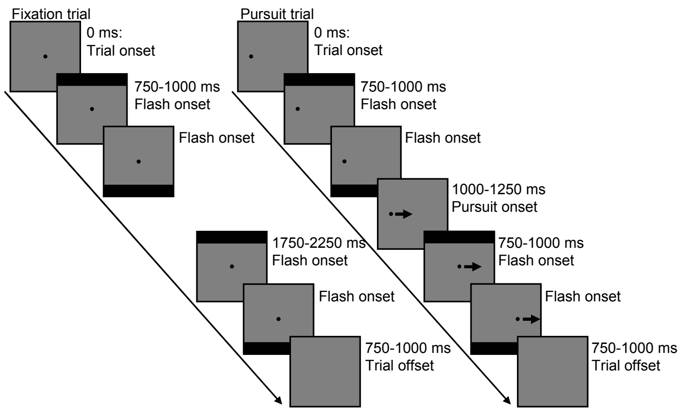
Introduction & Methods

Introduction:

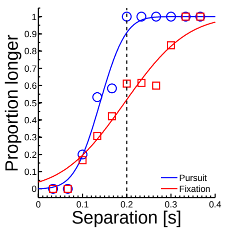
Saccadic and smooth pursuit eye movements have similar effects on perception: for instance contrast sensitivity as well as spatial localization is affected by saccades and smooth pursuit. Besides the compression of space[1], also time[2] is compressed during saccadic eye movements. Here we investigated if such a compression of apparent time also occurs during smooth pursuit eye movements.



Methods:

We presented two time intervals, each marked by the onset of two flashes. The flashes were horizontal bars of 45 deg width and 3 deg height. The second interval was the standard interval and the first interval was the test interval. The standard interval was set to one constant duration (100, 200 & 300 ms) in one experimental session. The length of the test interval was adjusted according an adaptive staircase procedure. At the end of each trial, subjects were asked to indicate which interval was shorter.

We fitted cumulative Gaussian functions to the data and analyzed the mean and the standard deviation of the Gaussian.



References:

[1] Ross J, Morrone MC, Burr DC (1997) Compression of visual space before saccades. Nature 386:598-601.

[2] Morrone, M. C., Ross, J., & Burr, D. (2005). Saccadic eye movements cause compression of time as well as space. Nature Neuroscience, 8(7), 950-954.

[3] Schütz, A. C., Braun, D. I., Kerzel, D., & Gegenfurtner, K. R. (2008). Improved visual sensitivity during smooth pursuit eye movements. Nature Neuroscience, 11(10), 1211-1216.

[4] Terao, M., Watanabe, J., Yagi, A., & Nishida, S. (2008). Reduction of stimulus visibility compresses apparent time intervals. Nat Neuroscience, 11(5), 541-542.

[5] Kerzel D, Souto D, Ziegler NE (2008) Effects of attention shifts to stationary objects during steady-state smooth pursuit eye movements. Vision Research 48:958-969.

[6] Cicchini, G. M., & Morrone, M. C. (2009). Shifts in spatial attention affect the perceived duration of events. Journal of Vision, 9(1), 9 1-13.

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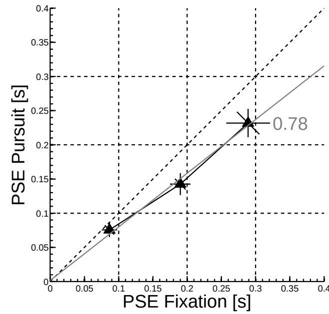
Main Experiment (n=11)

Perceived duration:

During pursuit the perceived separation was consistently smaller than during fixation for all standard intervals. The magnitude of the compression effect scaled with the duration of the standard interval. The slopes of linear regressions ranged between 0.60 and 0.94 with an average of 0.78.

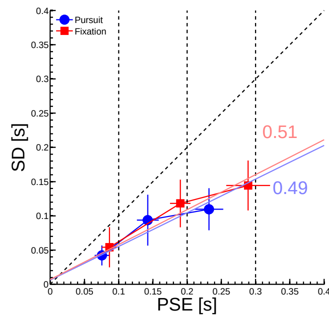
For equiluminant colored bars (n=4), we measured an average regression slope of 0.87, with individual values ranging from 0.75 to 0.95.



Precision:

The precision of interval judgments depends typically on the interval duration. During saccades, the compression of time also leads to an increase of precision. As a result, the Weber fraction is constant for the perceived but not for the physical duration.

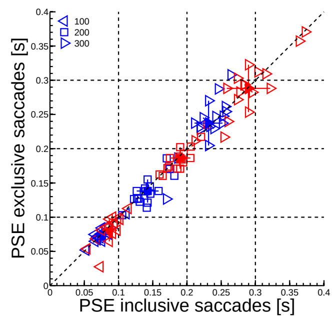
This is the same for pursuit. The precision of the interval judgments improved with the compression during pursuit. The Weber fractions were similar for fixation and pursuit, if they were expressed in dependence of the perceived duration.



Influence of catch-up saccades:

The time compression during pursuit might be caused by the effects of catch-up saccades on time perception. To investigate this possibility we identified trials in which a saccade occurred in a time interval of 100 ms before stimulus onset and 100 ms after stimulus offset.

Neither the PSEs during fixation nor during pursuit changed by excluding saccade trials. We found the same compression of time, if saccade trials were excluded. Hence it is unlikely that the compression during pursuit is caused by catch-up saccades.

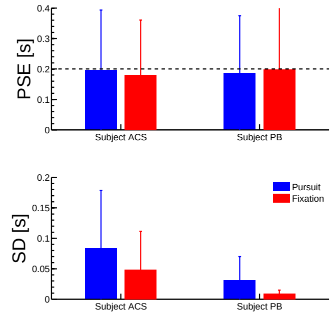


Control Experiments

Auditory Stimuli (n=2):

In this experiment subjects had to judge the perceived separation between two auditory noise bursts. The bursts were delivered binaurally by head phones and had a duration of 12 ms. We tested only a standard interval of 200 ms.

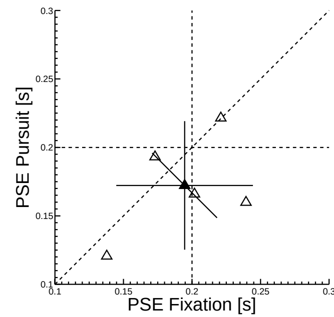
For two subjects there was no significant change in perceived duration during smooth pursuit. Hence the compression of time during pursuit seems to be limited to the visual domain. This rules out a general compression due to the increased attentional demand by the dual task.



Foveal Stimuli (n=5):

Here we used vertical bars as stimuli. The bars were horizontally aligned with the pursuit target and spanned half of the monitor height from bottom or top to the vertical center. We tested only a standard interval of 200 ms.

For five subjects there was only a trend for a reduction of perceived duration during smooth pursuit. Thus it might be that visuo-spatial attention plays a role in the compression of time during smooth pursuit.



Discussion

We found a compression of apparent time during pursuit which is accompanied by an increase of precision. This compression might be associated with two different mechanisms:

1. **Contrast sensitivity**: During smooth pursuit, contrast sensitivity is enhanced for color and high-spatial frequency luminance stimuli and suppressed for peripheral, low-spatial frequency luminance stimuli[3]. A reduction of stimulus visibility also leads to a compression of time[4]. However we found a compression for color as well as for luminance, which indicates that the compression is not caused by the changes of contrast sensitivity.
2. **Attention**: During pursuit spatial attention is bound to the pursuit target[5]. Spatial attention shifts also cause a reduction of perceived duration[6].