Statistical Identification of Fixations in Noisy Eye-Movement Data

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What is a fixation?

Ilya Repin, An Unexpected Visitor, 1884

What is a fixation?

Painting with overlaid scan path (Yarbus, 1956, 1965, 1967)

Why do people fixate certain things?

Instructions: estimate the ages of the subjects

Why do people fixate certain things?

Instructions: estimate the material circumstances of the subjects

Why do people fixate certain things?

from www.worldairroutes.com/AF747.html

Making non-invasive and unobtrusive measurements

SmartEye multi-camera system installed in helicopter simulator
from www.noldus.com/labs/boeing-ah-64-de-apache-simulator-systems-integration

Two approaches to parsing scan-paths

- Saccade-finding

  looks for velocity/acceleration above a threshold

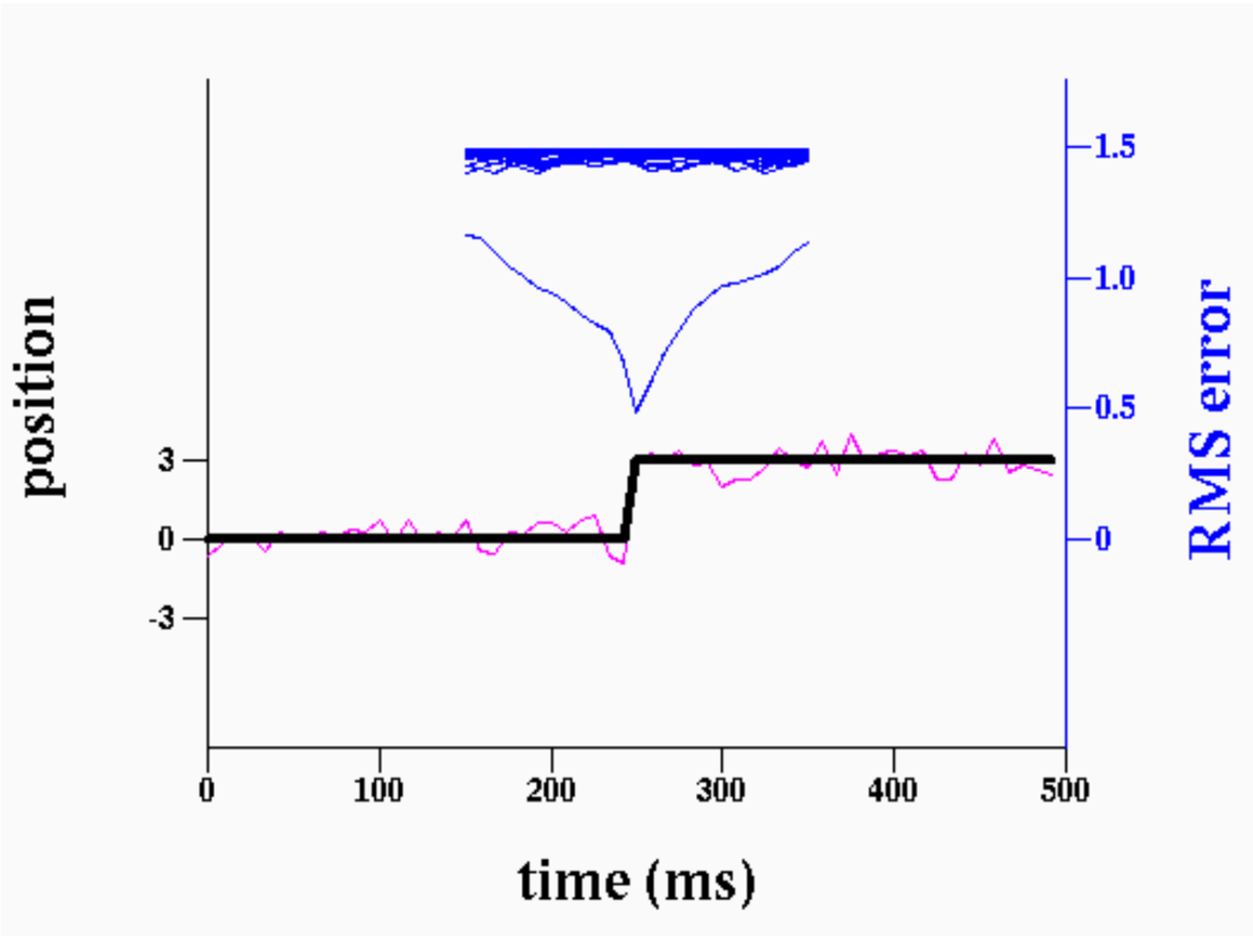
  performs poorly when SNR is low

- Fixation-finding

  looks for groups of samples with similar values

  may depend on arbitrary threshold ("dispersion" algorithm)

Fitting a noisy step



Exhaustive search for best split point

Should we accept the best split?

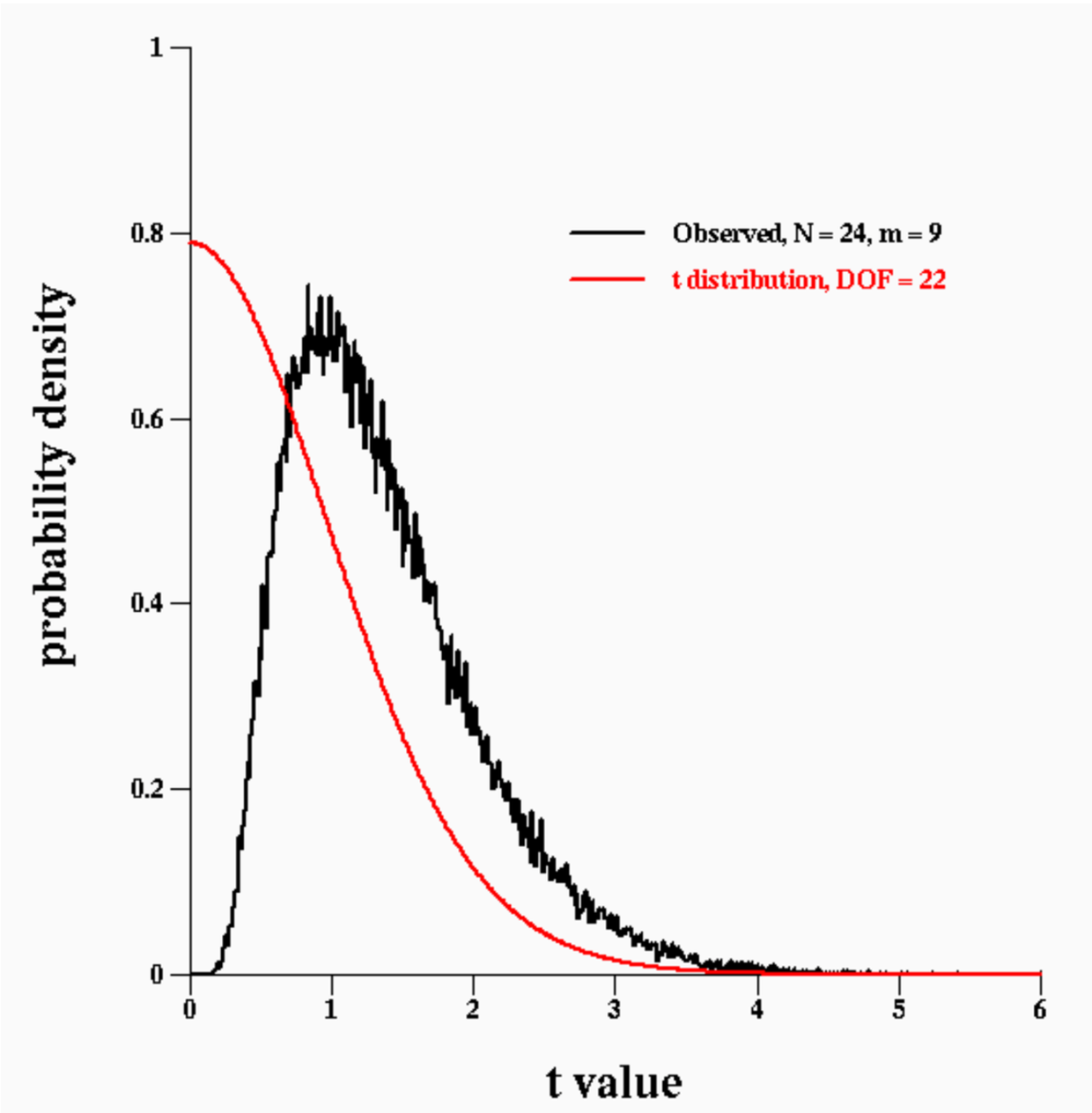
$$t = \frac{\mu_1 - \mu_2}{\sigma_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

t statistic for t test

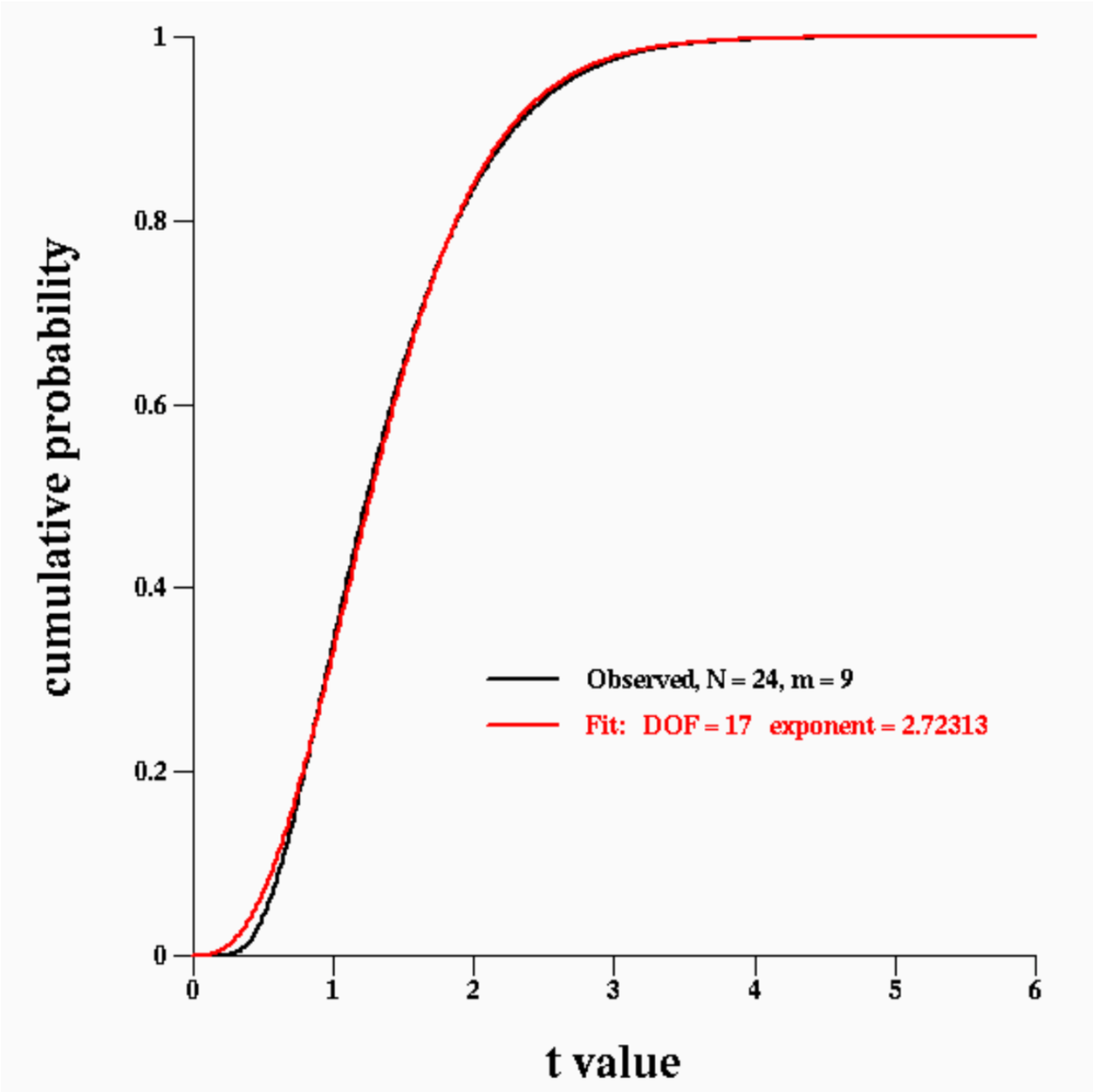
$$\sigma_p = \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}}$$

pooled variance

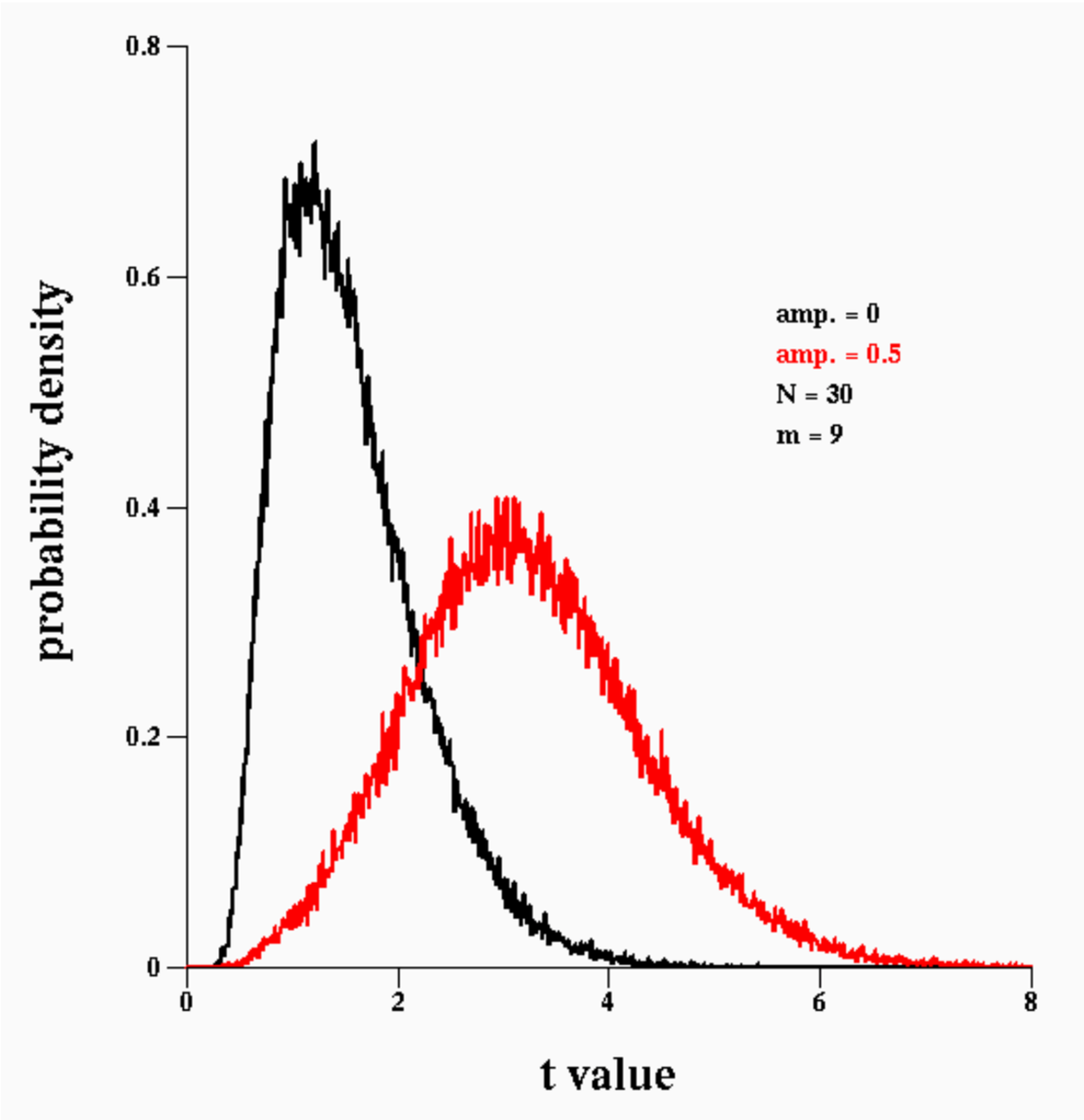
The standard t distribution is wrong!



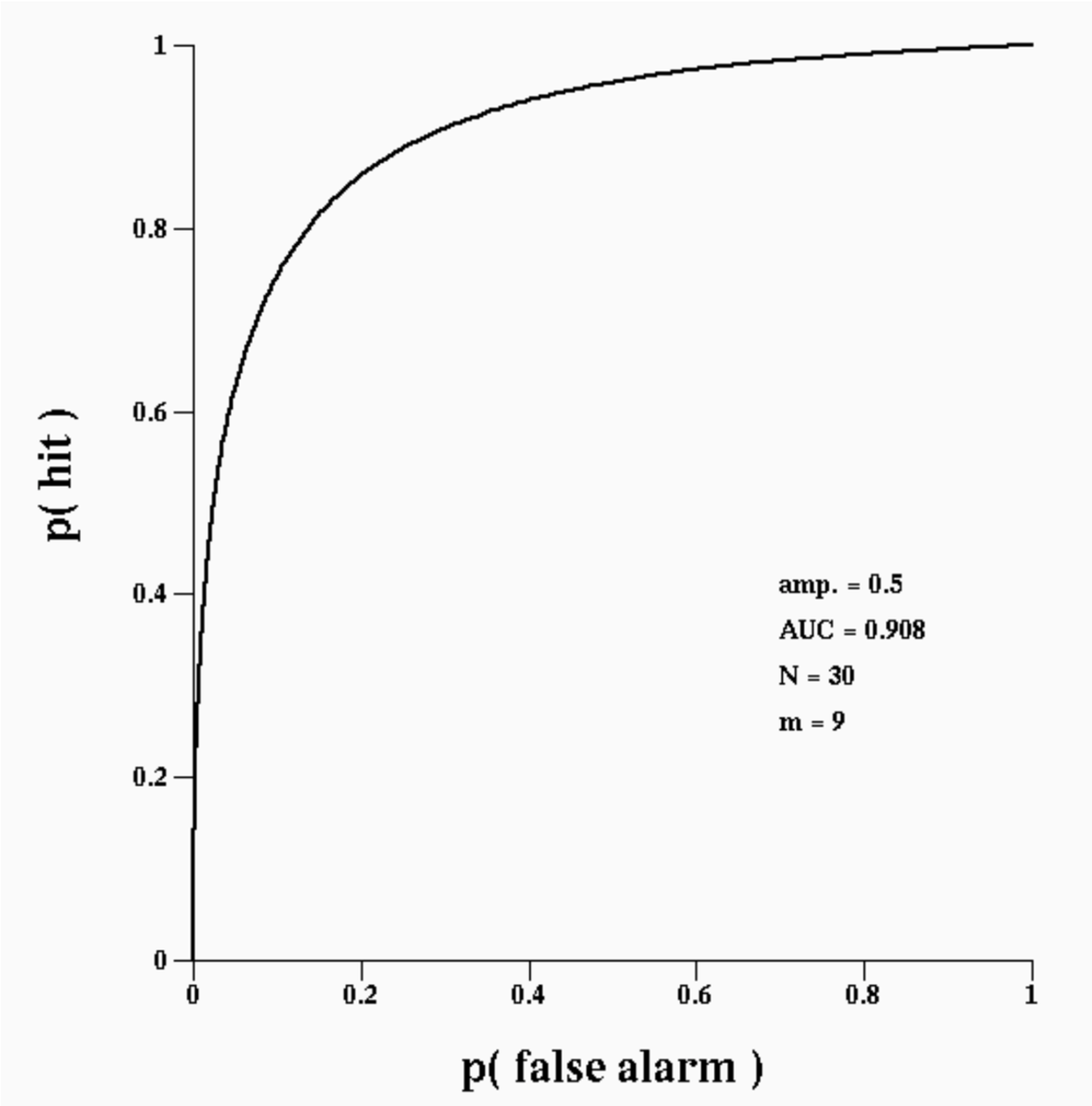
Fitting the observed distribution



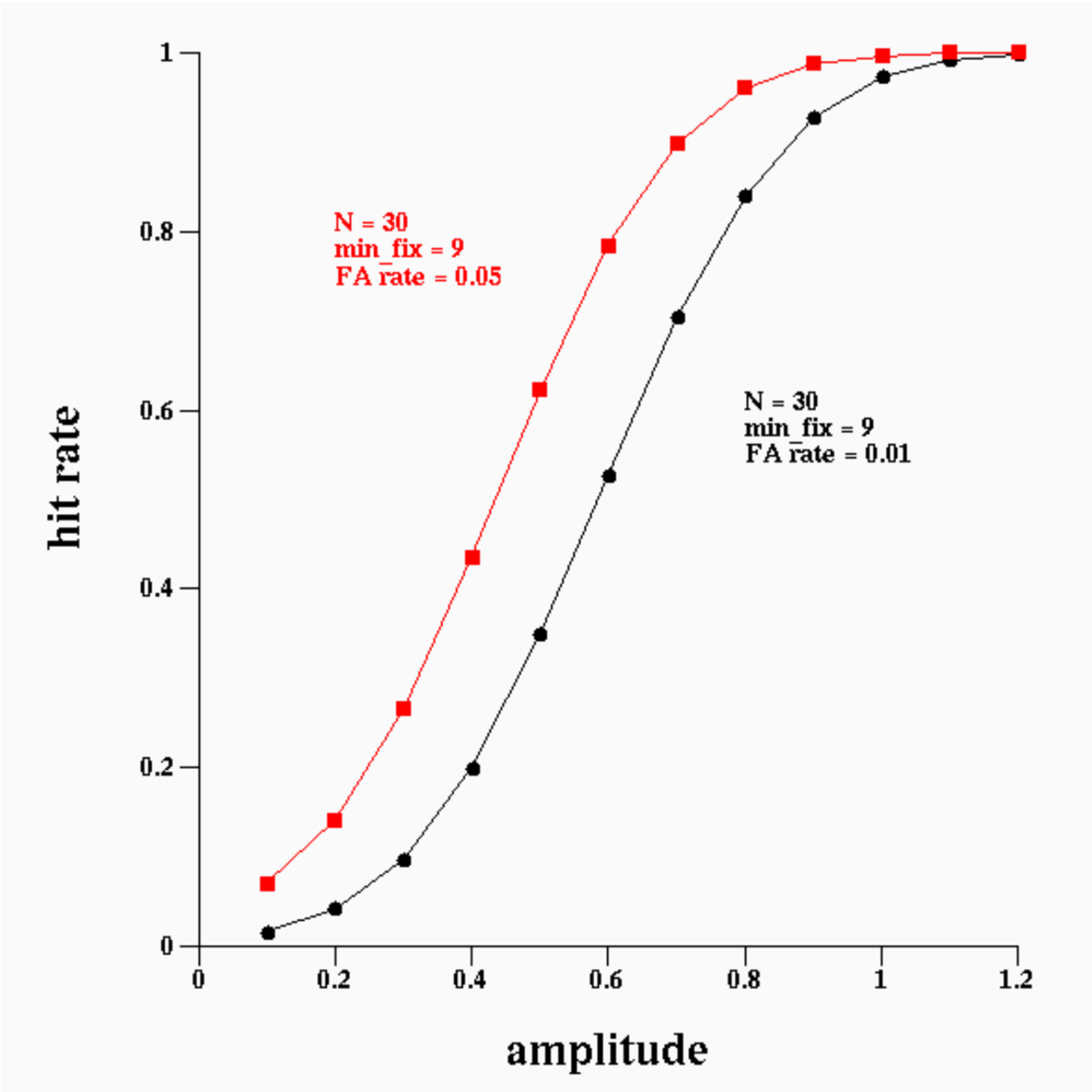
Detecting a small signal



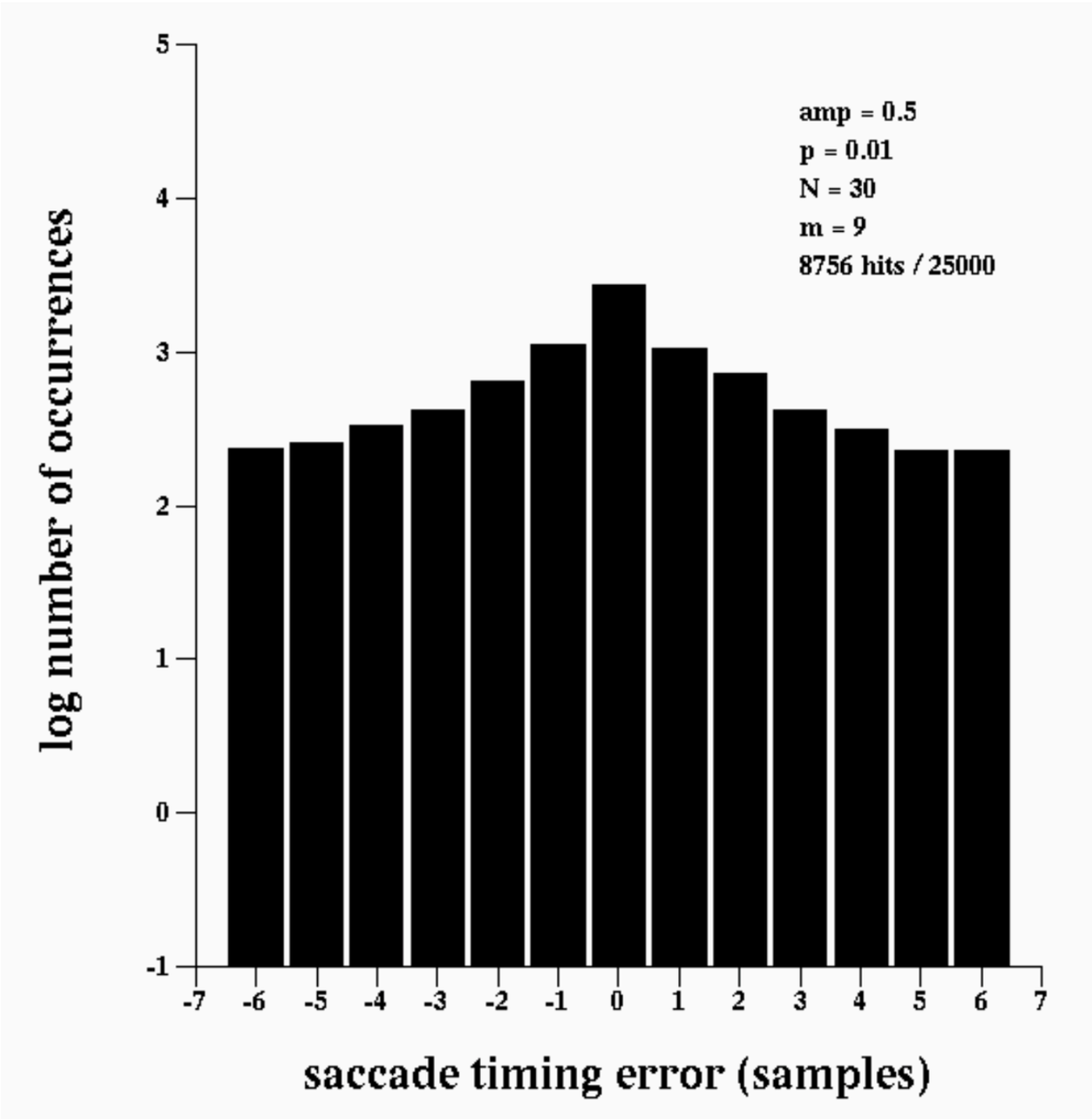
Receiver Operating Characteristic (ROC) curve



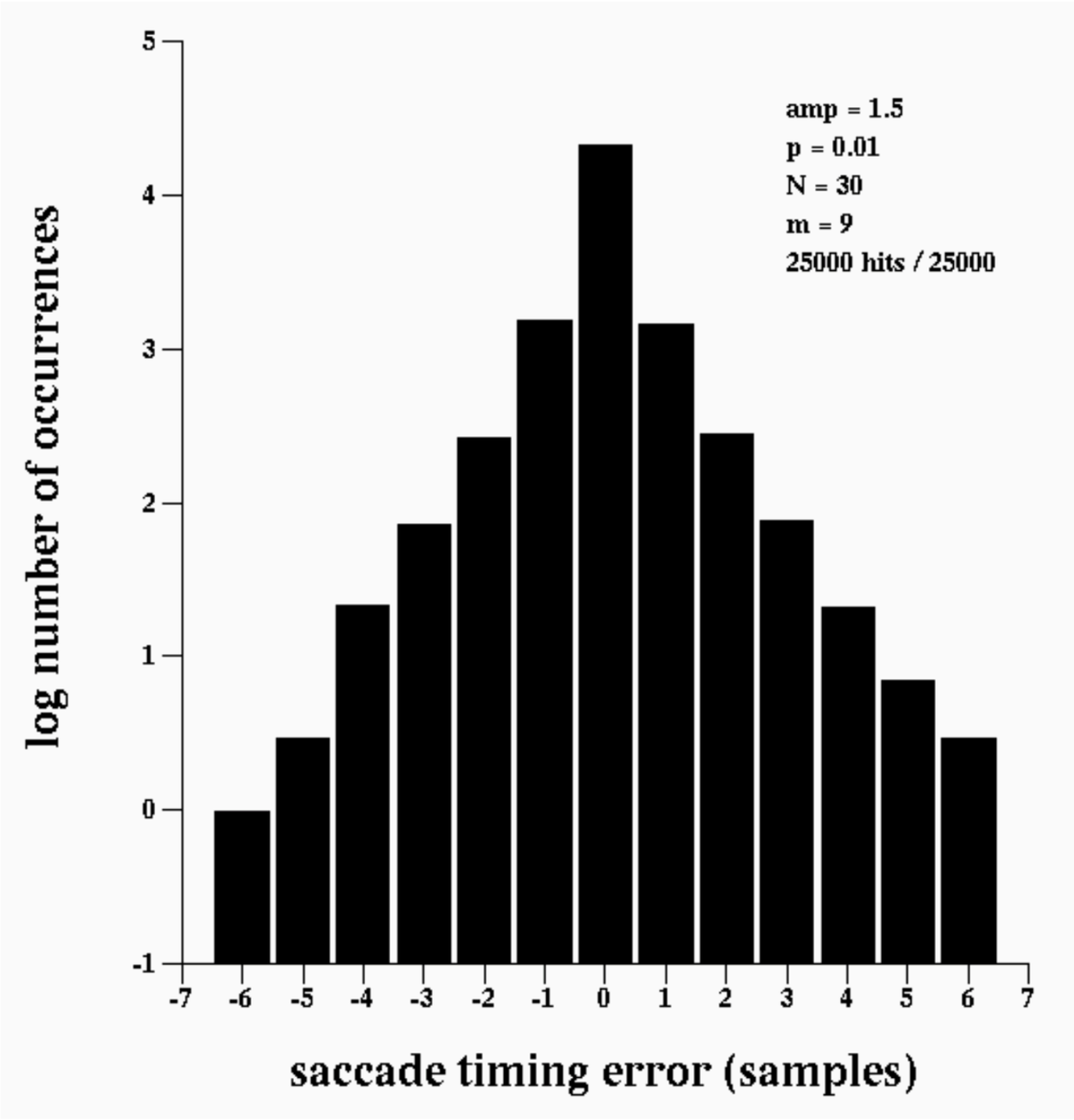
Detectability falls with signal amplitude



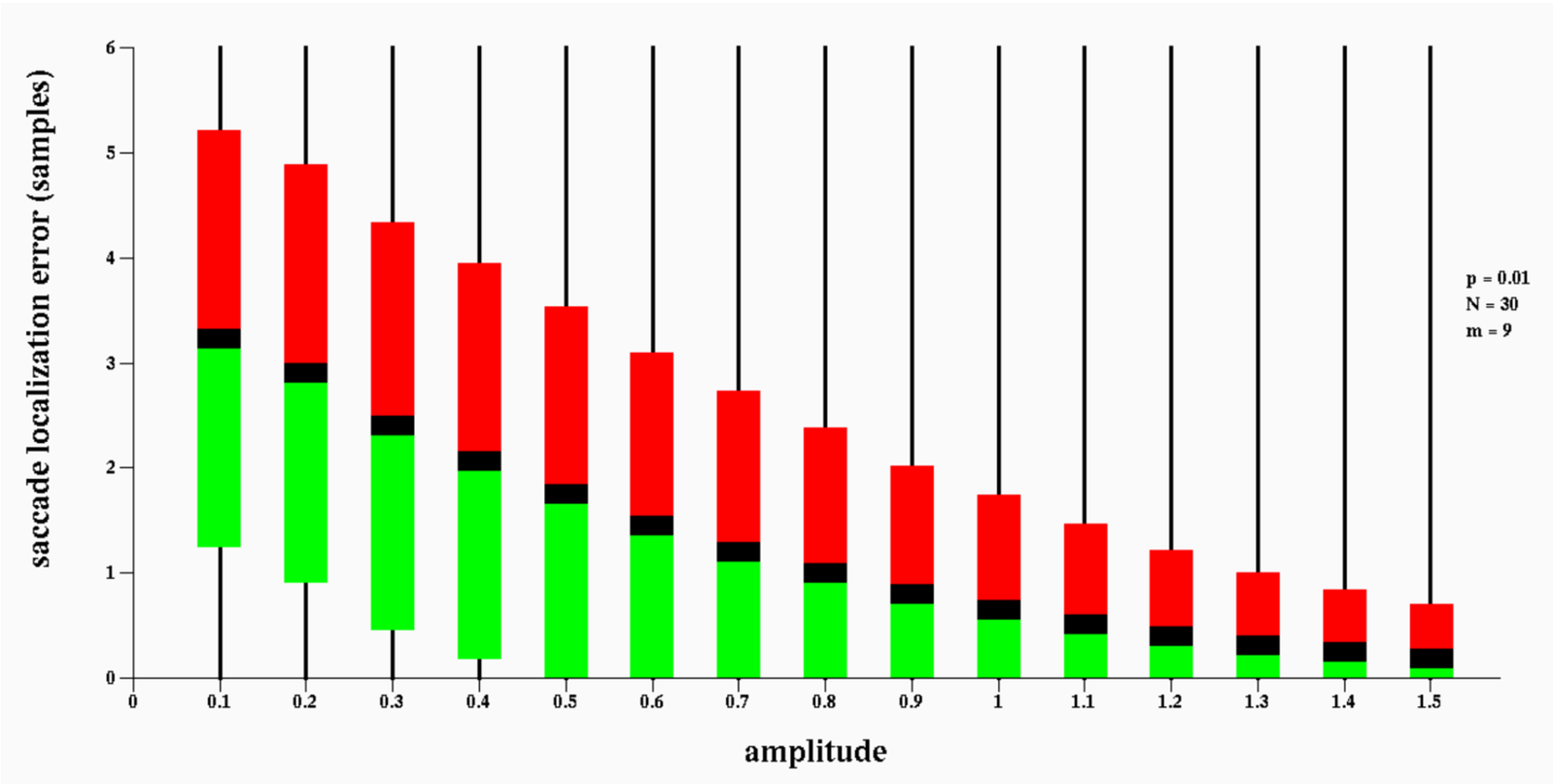
Saccade localization in time is imprecise...



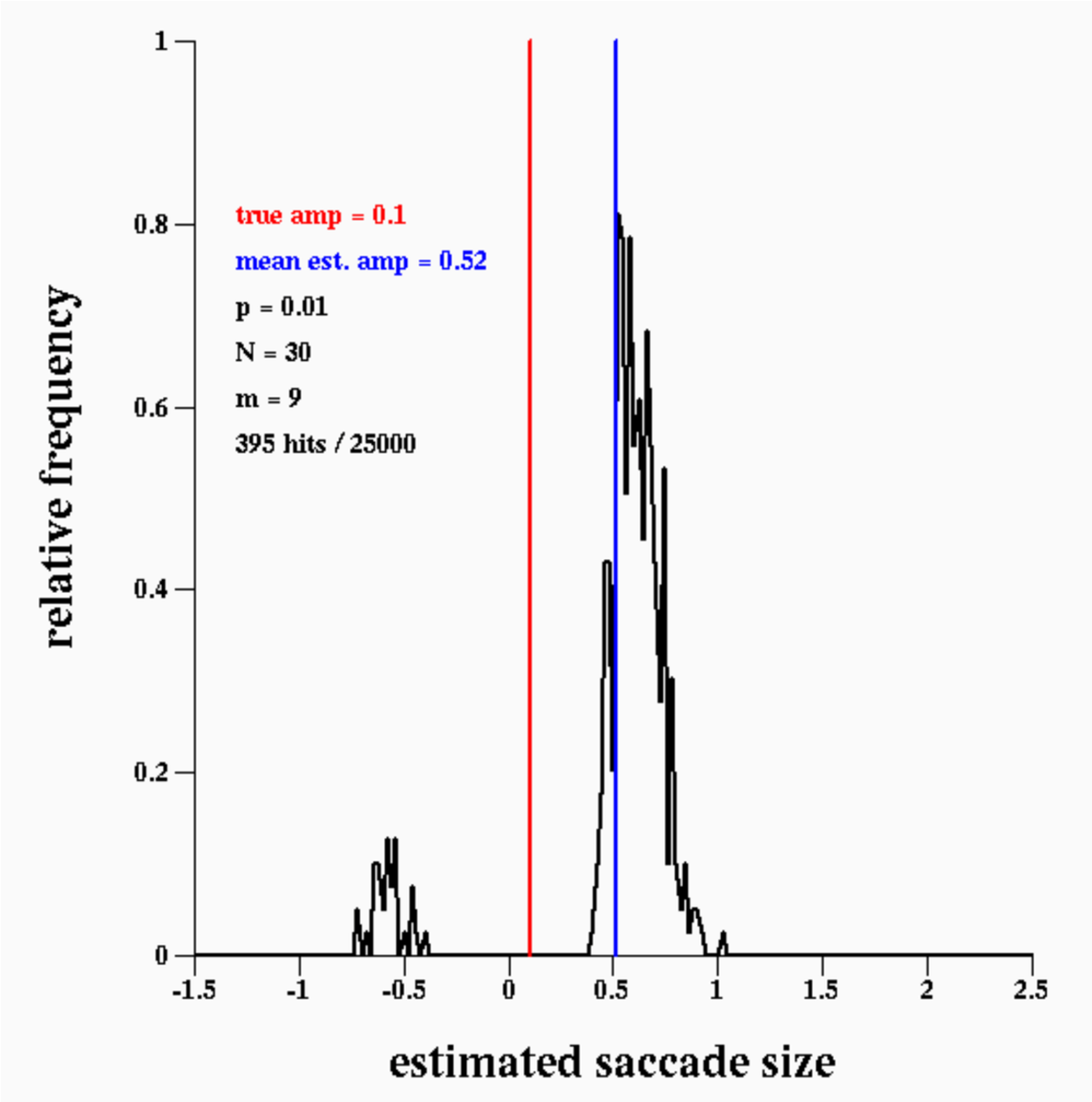
... but improves with signal amplitude



Temporal localization improves with signal amplitude



Saccade amplitudes are overestimated...



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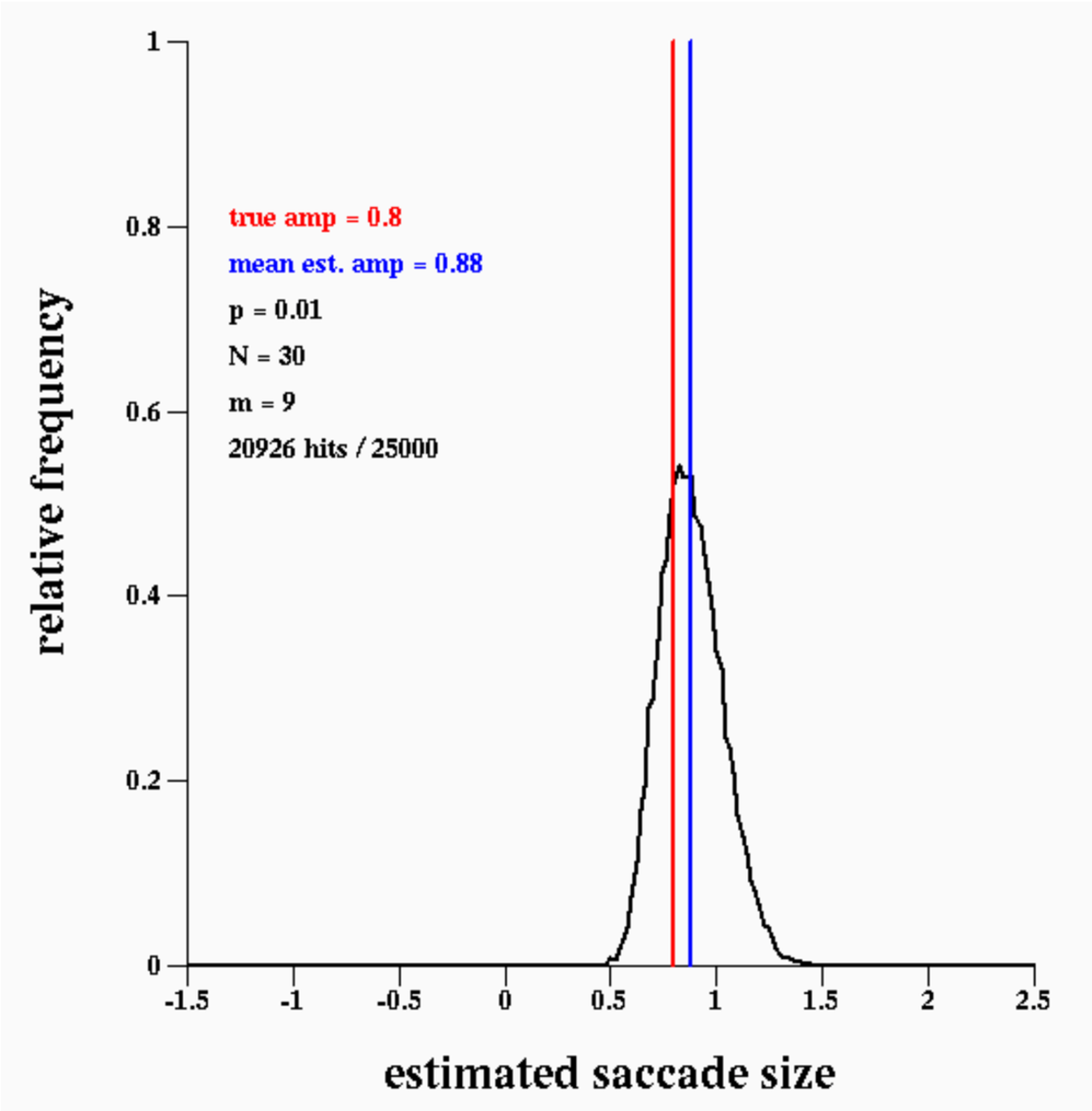
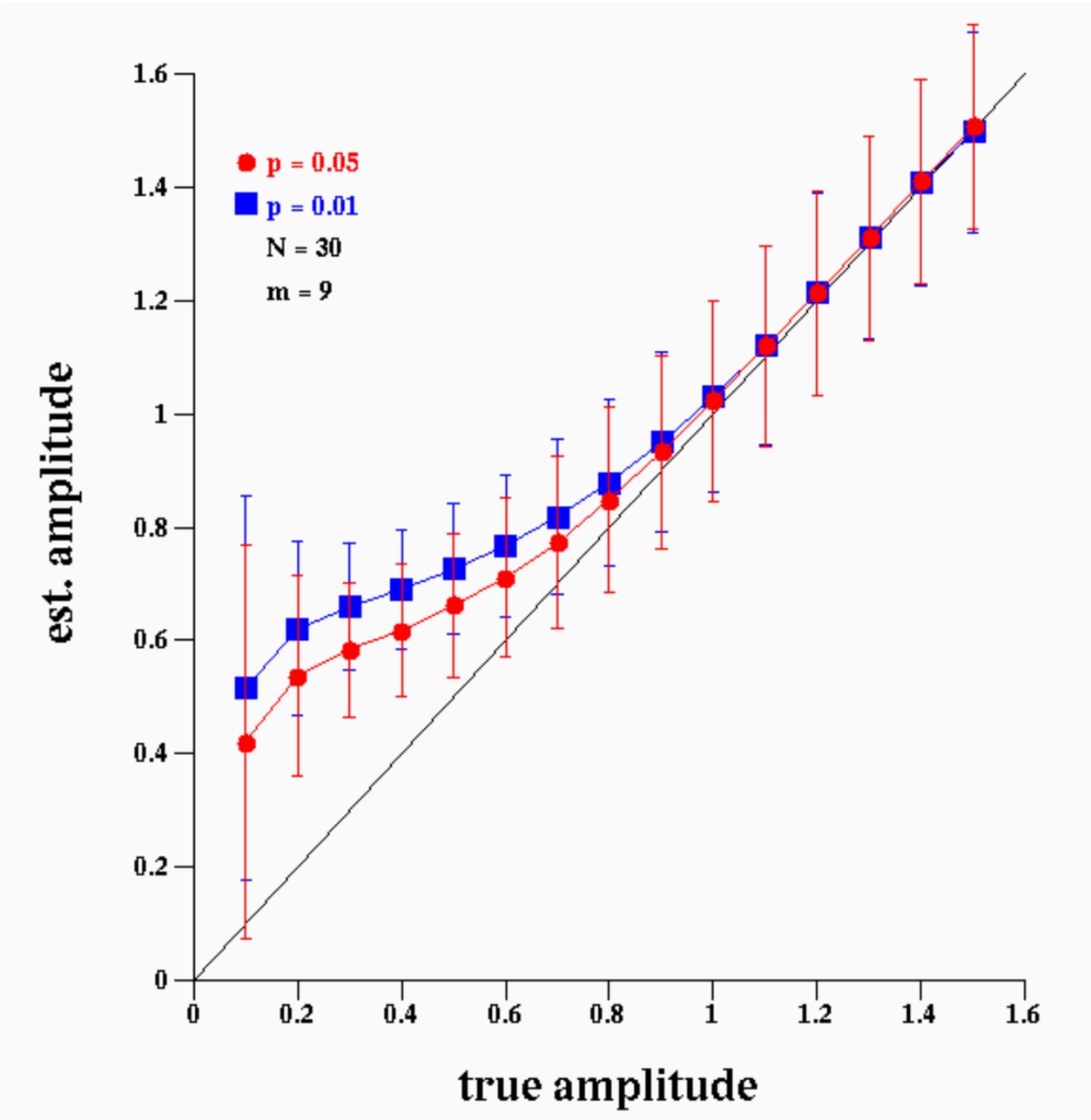


... for amplitudes below the noise standard deviation



Future work

- Generalize to piece-wise linear fits
  - to include pursuit, VOR
- Incorporate drift into simulations
  - only relevant for lowest noise levels
- Investigate effect of sampling rate
  - will require modeling saccade trajectories

Summary

- A modified t-test can be used to detect small saccades in a principled way
- Errors in the estimated time and amplitude of small saccades occurs for amplitudes less than the noise std. deviation
- The amplitudes of small saccades are over-estimated, similar biases may affect human judgements