Components of Bottom-Up Gaze Allocation in Natural Scenes

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http://ilab.usc.edu/rjpeters/pubs/2005_VSS_Peters.pdf

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introduction

Eye movements provide an overt measure of the internal allocation of spatial attention.

Here, we use human eye movement recordings to test ***computational models*** of ***bottom-up spatial visual attention***.

method

Eye movement psychophysics:
- 3 image categories, 110 images per category
- 4 subjects, 3 sec. free-viewing per image

Computational models:
- lower bound given by **pixel-shuffled control**
- and **image-shuffled control**
- upper bound given by **inter-observer control**
- saccade location predictions made by
- **baseline salience model**
- **enhanced salience model** includes more
- detailed physiological mechanisms

Analysis metrics:
- quantify the statistical correspondence between
- human saccade targets and the predictions of
- salience models and control models

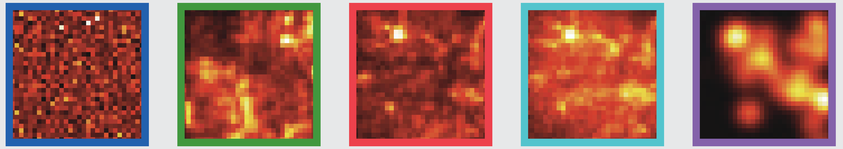
results

- **baseline salience model** predictions are far better than chance levels (**pixel-shuffled** and **image-shuffled** controls)
- physiological interactions among orientation-tuned units (**enhanced salience model**) play a significant role in gaze allocation
- model predictions reach 50-90% of upper bound derived from **inter-observer control**
- strength of bottom-up influences on eye movements decays over time
- "center bias" varies with image category

images

models — *trying to predict human eye movements*

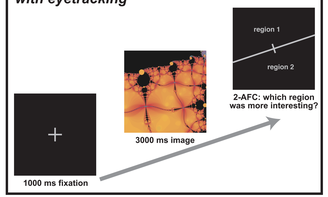
pixel-shuffled control | image-shuffled control | baseline salience | enhanced salience | inter-observer control



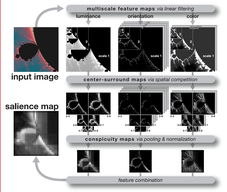
pixel-shuffled control for image A =
- randomly scramble pixels from
- image A's salience map

image-shuffled control for image A =
- take salience map from
- a different image B

free-viewing psychophysics task with eyetracking



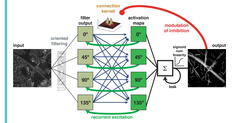
baseline salience model



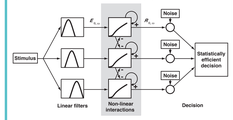
- multiple image features extracted in parallel channels
- features are subject to coarse global competition
- all features combine to give a single salience map

enhanced salience model

long-range orientation interactions for contour facilitation

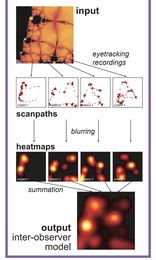


short-range orientation interactions (cross-orientation suppression)

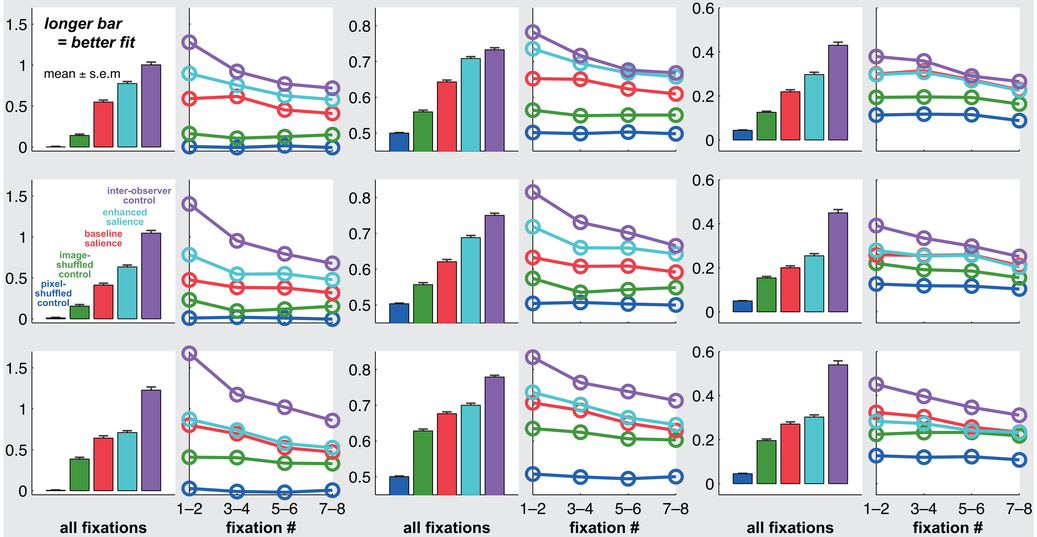


inter-observer control

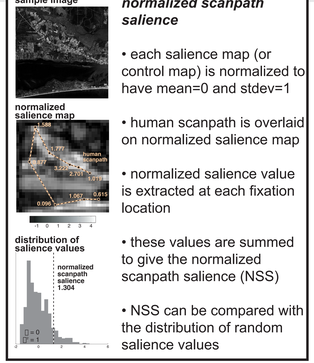
try to predict each subject's saccade locations from the average of the other subjects



metrics — *measuring the performance of the models*



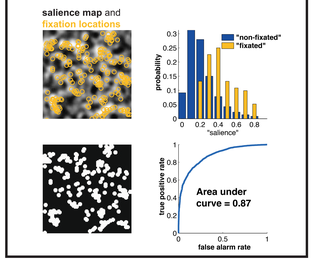
normalized scanpath salience



- each salience map (or control map) is normalized to have mean=0 and stdev=1
- human scanpath is overlaid on normalized salience map
- normalized salience value is extracted at each fixation location
- these values are summed to give the normalized scanpath salience (NSS)
- NSS can be compared with the distribution of random salience values

receiver operating characteristic
- *assuming a simple threshold:*

how well can fixated and non-fixated locations be distinguished?



Kullback-Leibler distance
- *with no assumptions about decision criteria:*

how well can fixated and non-fixated locations be distinguished?

$$KL = 0.5 \cdot \sum_i p_i(\mathbf{f}) \cdot log\left(p_i(\mathbf{f}) / p_i(\mathbf{nf})\right) + 0.5 \cdot \sum_i p_i(\mathbf{nf}) \cdot log\left(p_i(\mathbf{nf}) / p_i(\mathbf{f})\right)$$