Measuring and Modeling Shared Visual Attention

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NASA Ames Research Center

UCI, November 2015

My collaborator



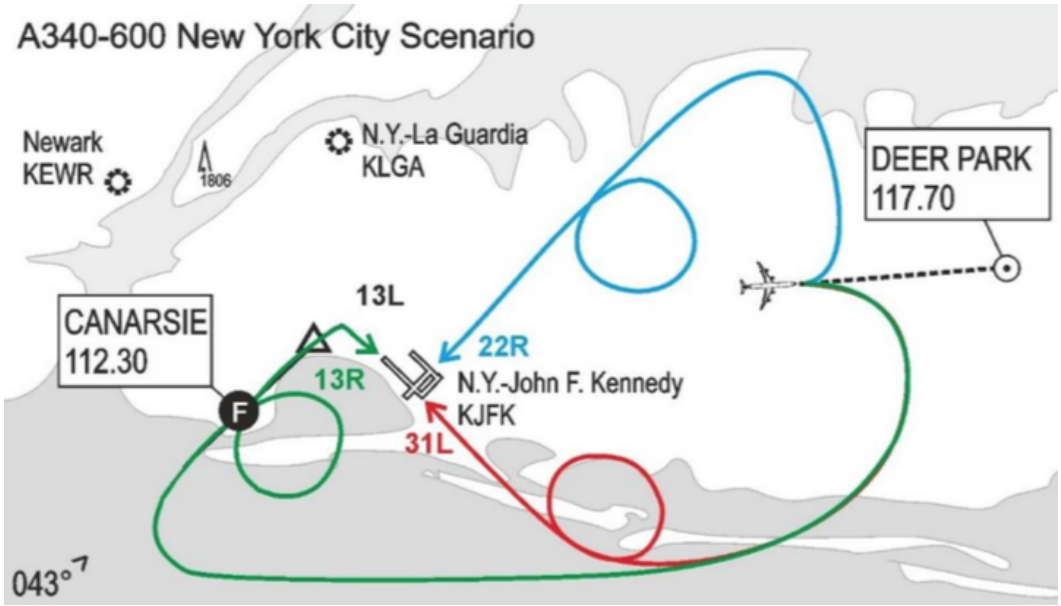
Patrick Gontar
Institute of Ergonomics, TU Munchen

Patrick's experiment

Simulated approach to NYC/JFK with multiple problems

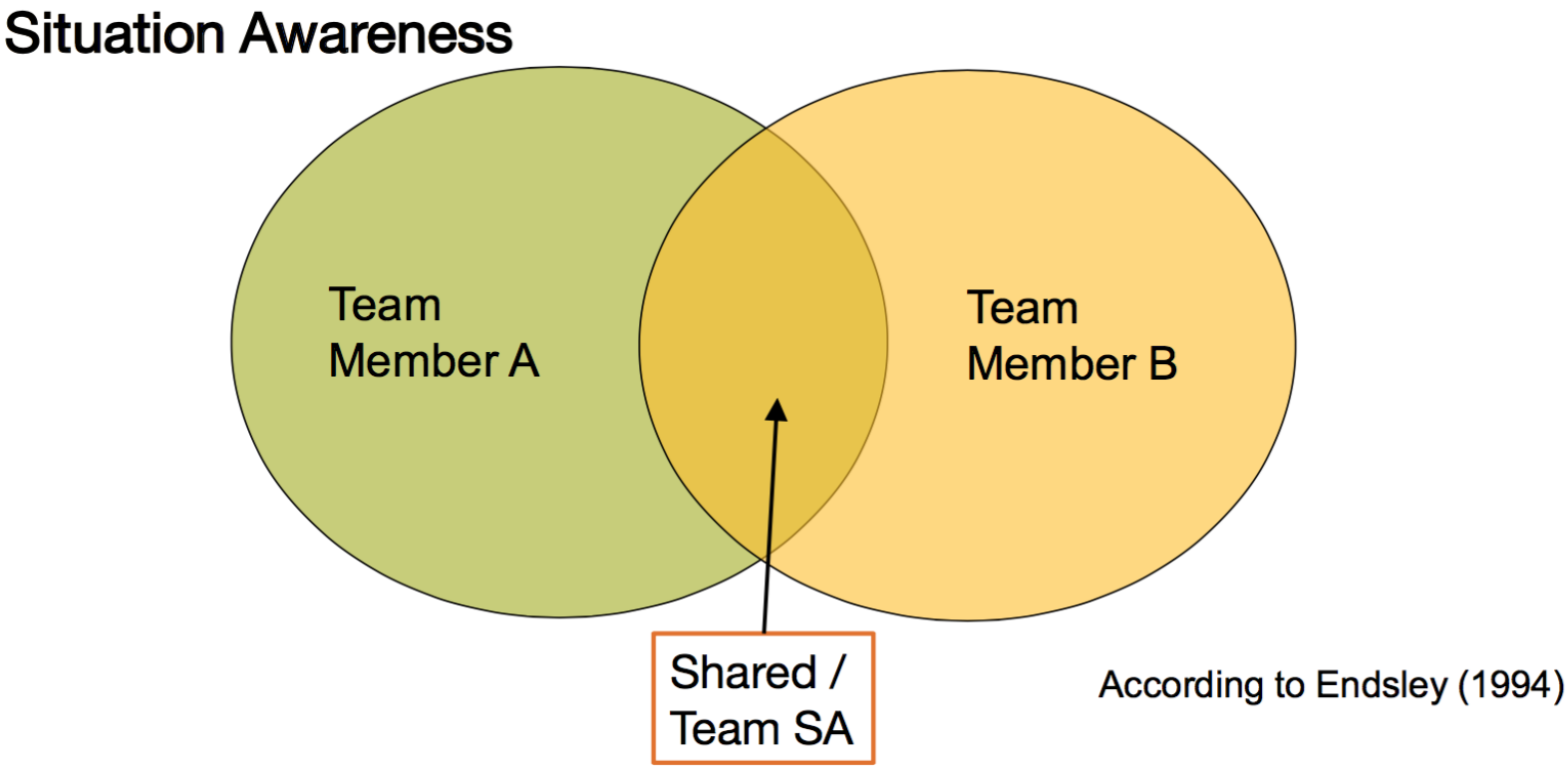
Crews rated by instructor(s)

Objective measures: fuel consumption, time spent/remaining, etc.



Haslbeck, A., Gontar, P. & Schubert, E. (2014). How Can Procedures and Checklists Help Pilots in Abnormal Flight Situations? In N. A. Stanton, S. J. Landry, G. Di Bucchianico & A. Vallicelli (Eds.), Advances in Human Aspects of Transportation. Part II (S. 456-461). AHFE International.

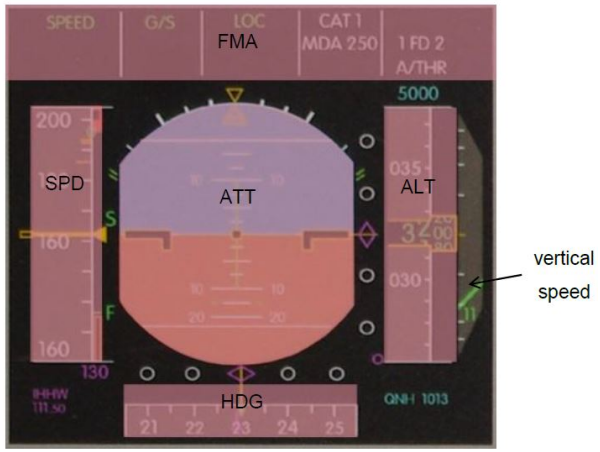
Theoretical framework

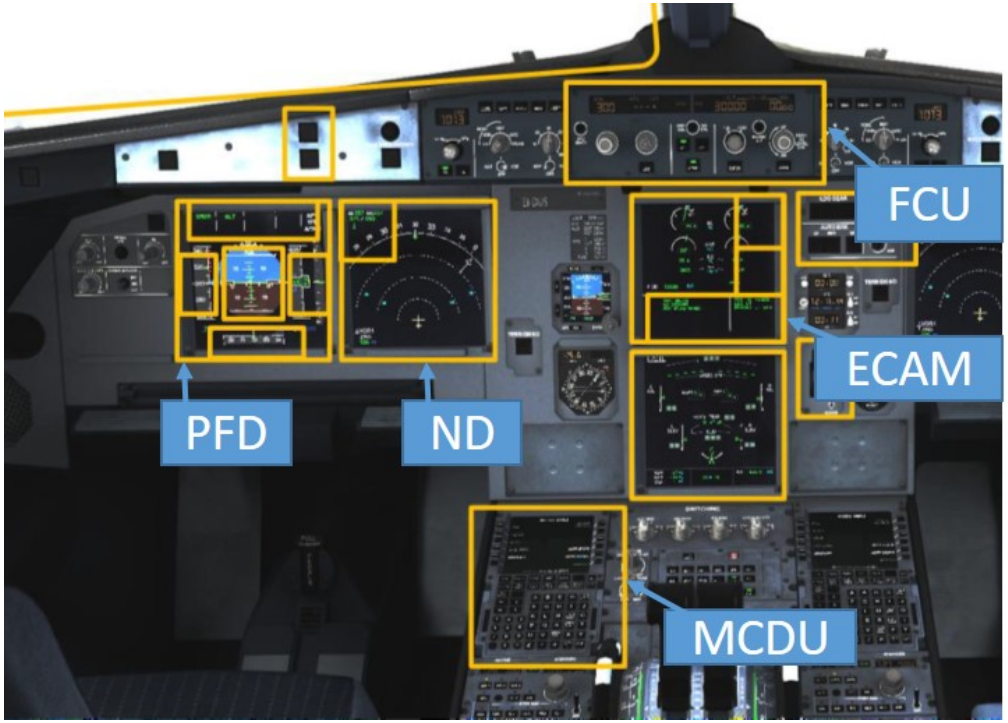


Shared SA = (Team Member A) AND (Team Member B)
Team Bandwidth = (Team Member A) OR (Team Member B)

Eye gaze as a proxy for attention







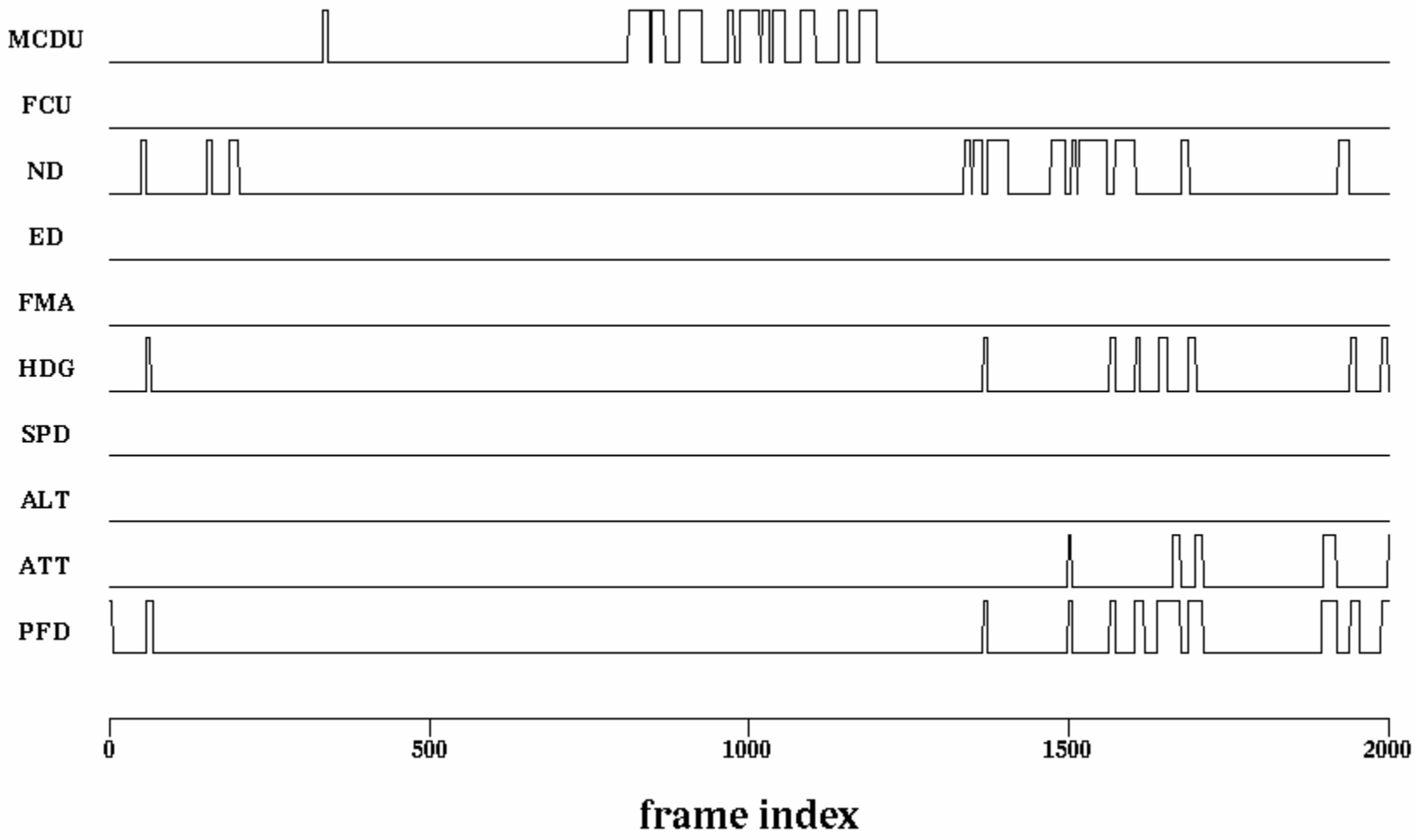
Format of the "raw" data



Index	UseCase	Area	StartFrame	StartTime	EndFrame	EndTime	Duration
1	Anfang - Ende	MCDU	334	00:00:13.360	340	00:00:13.600	00:00:00.240
2	Anfang - Ende	MCDU	811	00:00:32.440	844	00:00:33.760	00:00:01.320
3	Anfang - Ende	MCDU	848	00:00:33.920	867	00:00:34.680	00:00:00.760
4	Anfang - Ende	MCDU	891	00:00:35.640	925	00:00:37.000	00:00:01.360
5	Anfang - Ende	MCDU	967	00:00:38.680	975	00:00:39.000	00:00:00.320
6	Anfang - Ende	MCDU	986	00:00:39.440	1016	00:00:40.640	00:00:01.200
...							

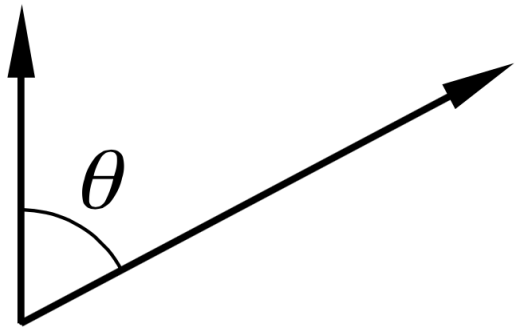
Data sorted by "UseCase" (phase of flight) and "Area"

Converting the data back to a time series



Geometric interpretation

$$r = \frac{\vec{u} \cdot \vec{v}}{|\vec{u}|\,|\vec{v}|} = \cos\theta$$



A problem with simple point-wise correlation



A B A B A B A B A B
B A B A B A B A B A

$r = 0$

A B A B A B A B A B
A B A B A B A B A B

$r = 1$

Solution: temporal filtering



A B A B A B A B A B
B A B A B A B A B A

$r = 0$

A B A B A B A B A B
A B A B A B A B A B

$r = 1$

A/B A/B A/B A/B
A/B A/B A/B A/B

$r = 1$

A scale-space correlation image



32 seconds

tour

Nice (?) pictures - but so what?



- How do we interpret the numbers?
- What is a significant correlation?
- What do we expect from random chance?
- How do we choose an appropriate scale value?

Two approaches to parsing scan-paths



- Saccade-finding

  looks for velocity/acceleration above a threshold

  performs poorly when SNR is low

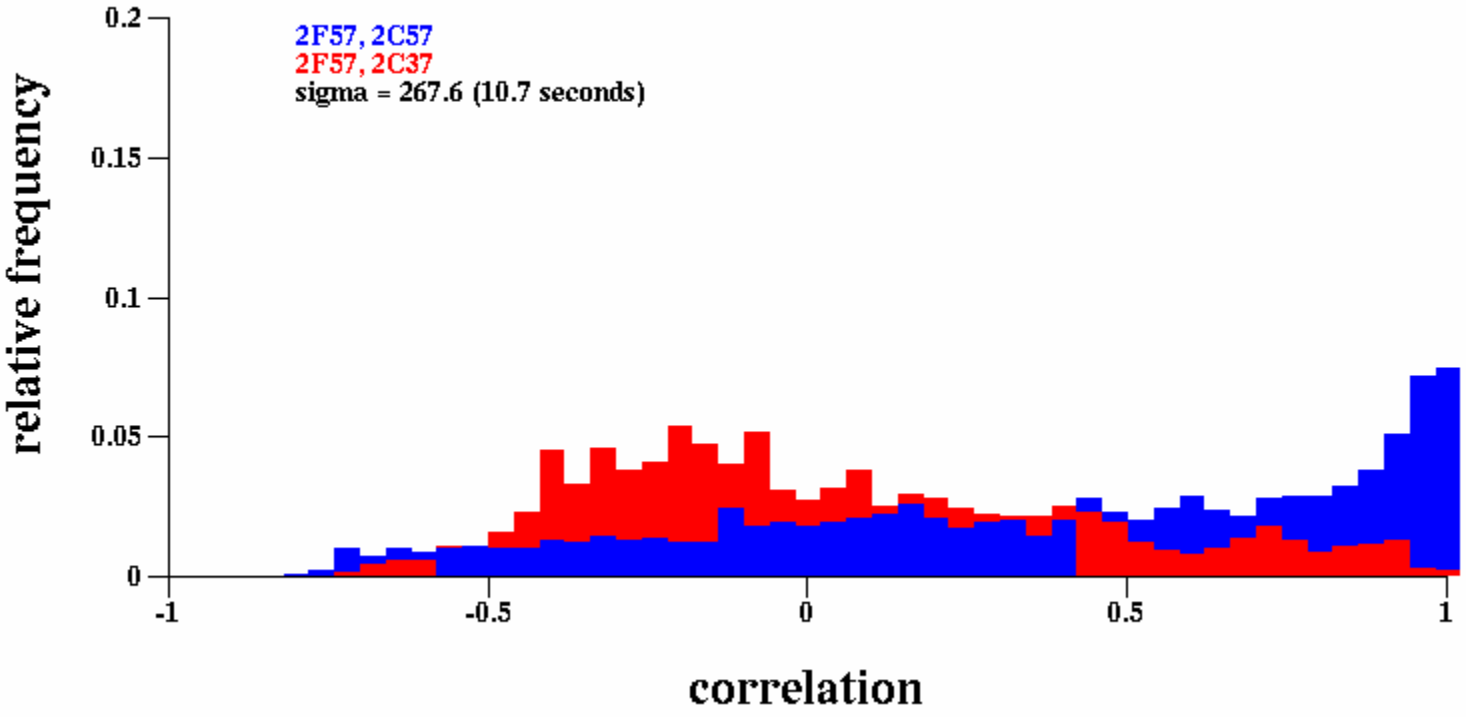
- Fixation-finding

  looks for groups of samples with similar values

  may depend on arbitrary threshold ("dispersion" algorithm)

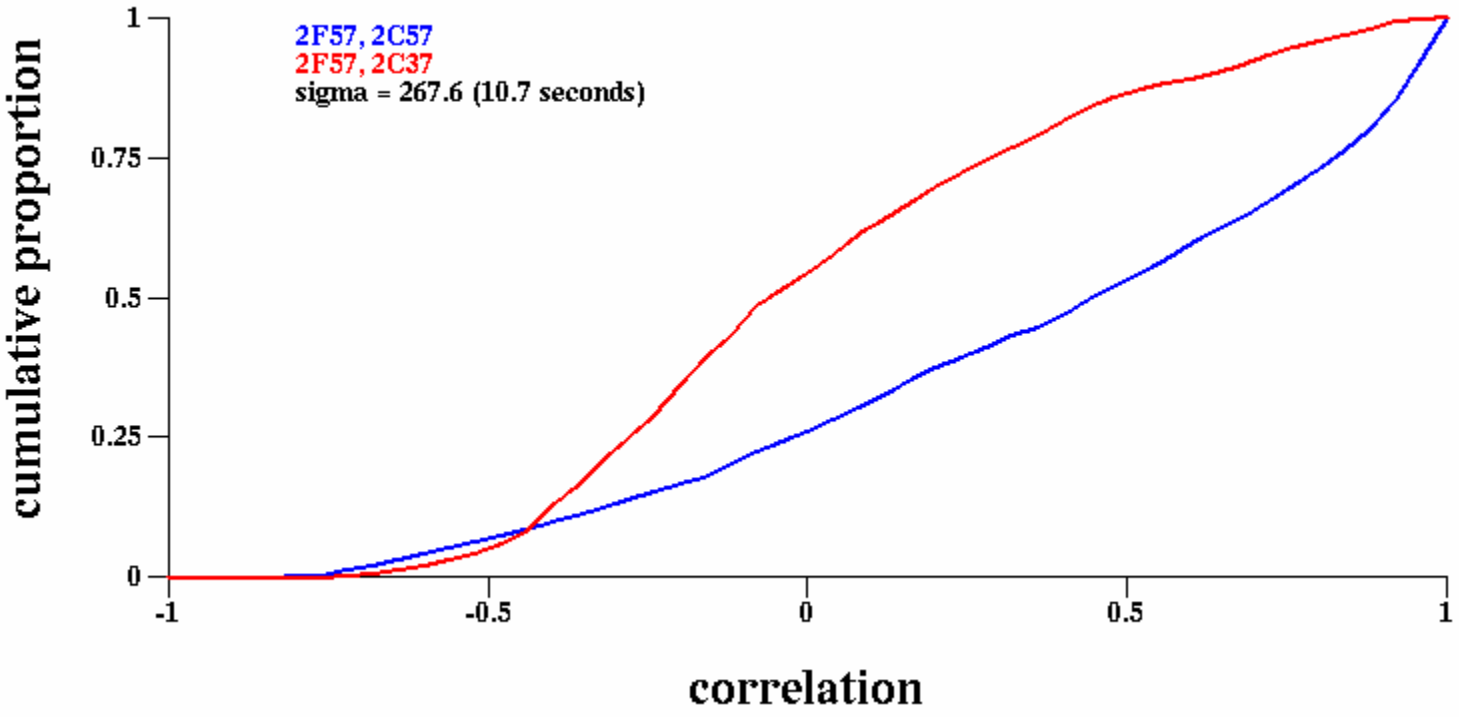
Randomization test

- Compare correlation distributions between matched and mis-matched crews

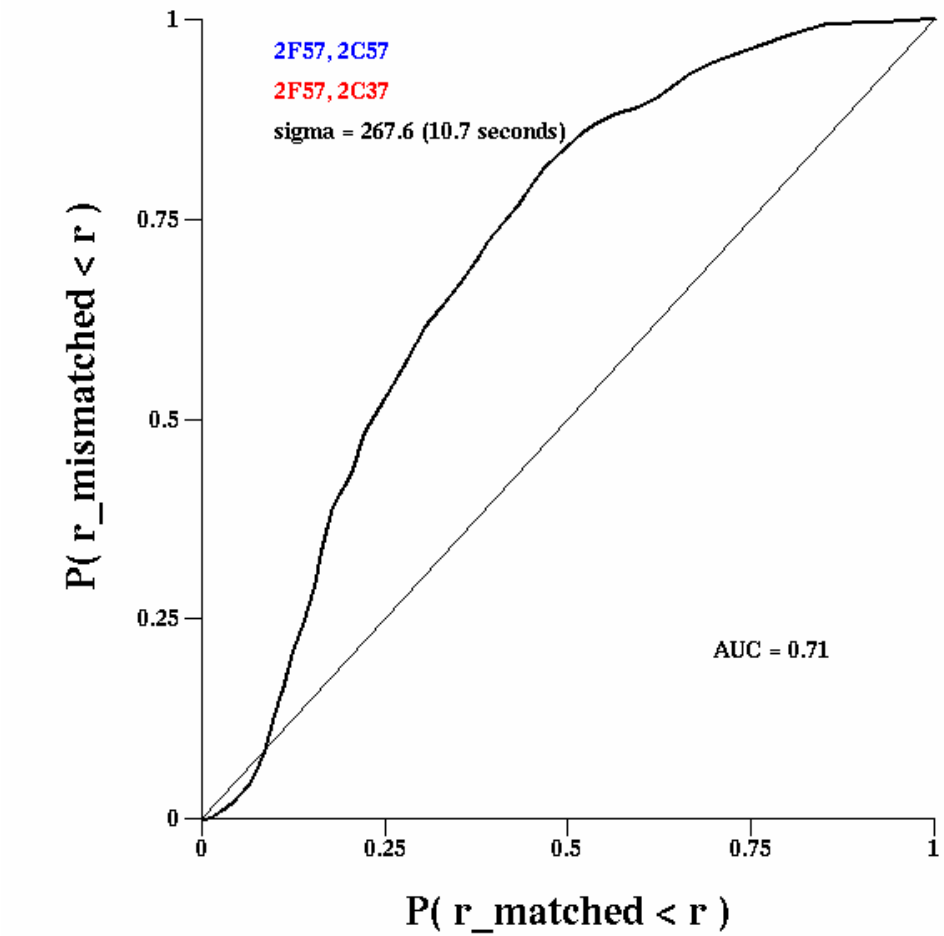


Randomization test

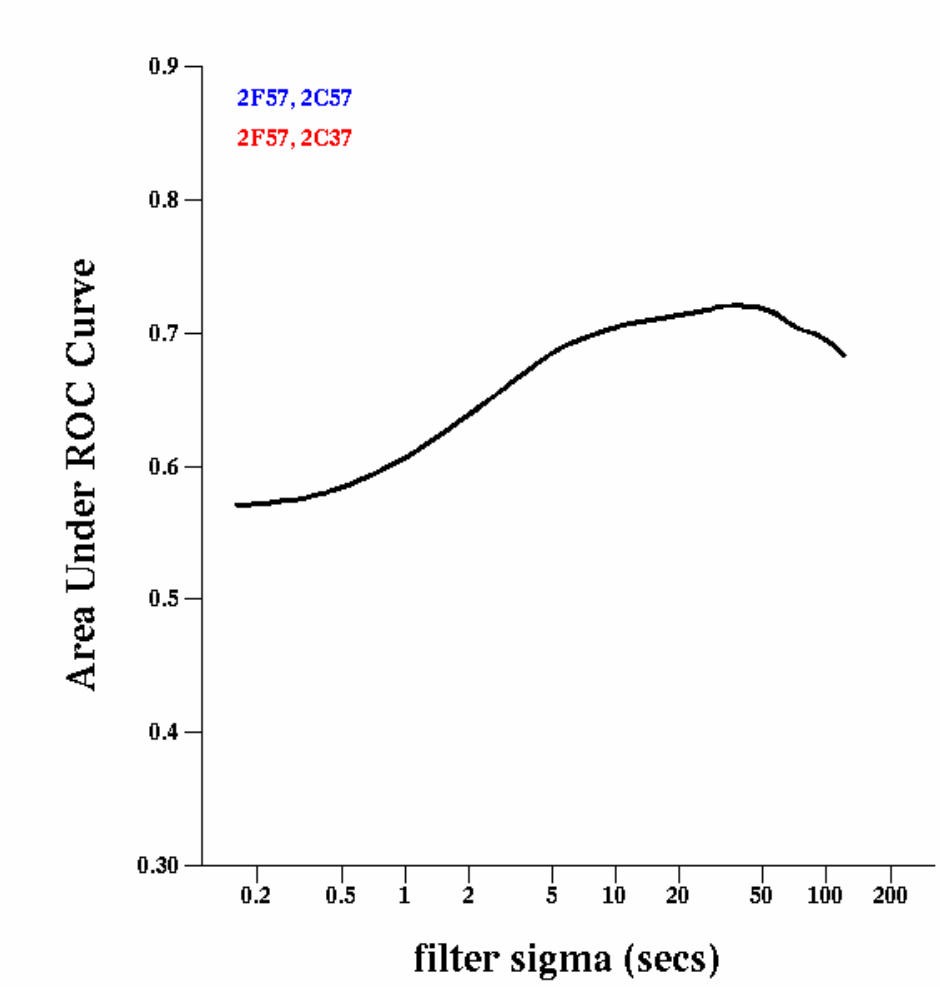
- Compare correlation distributions between matched and mis-matched crews



Randomization test



Randomization test



Some familiar questions



- How do we interpret the numbers?
- What is a significant correlation?
- What do we expect from random chance?
- How do we choose an appropriate scale value?

A Markov model of fixation sequences

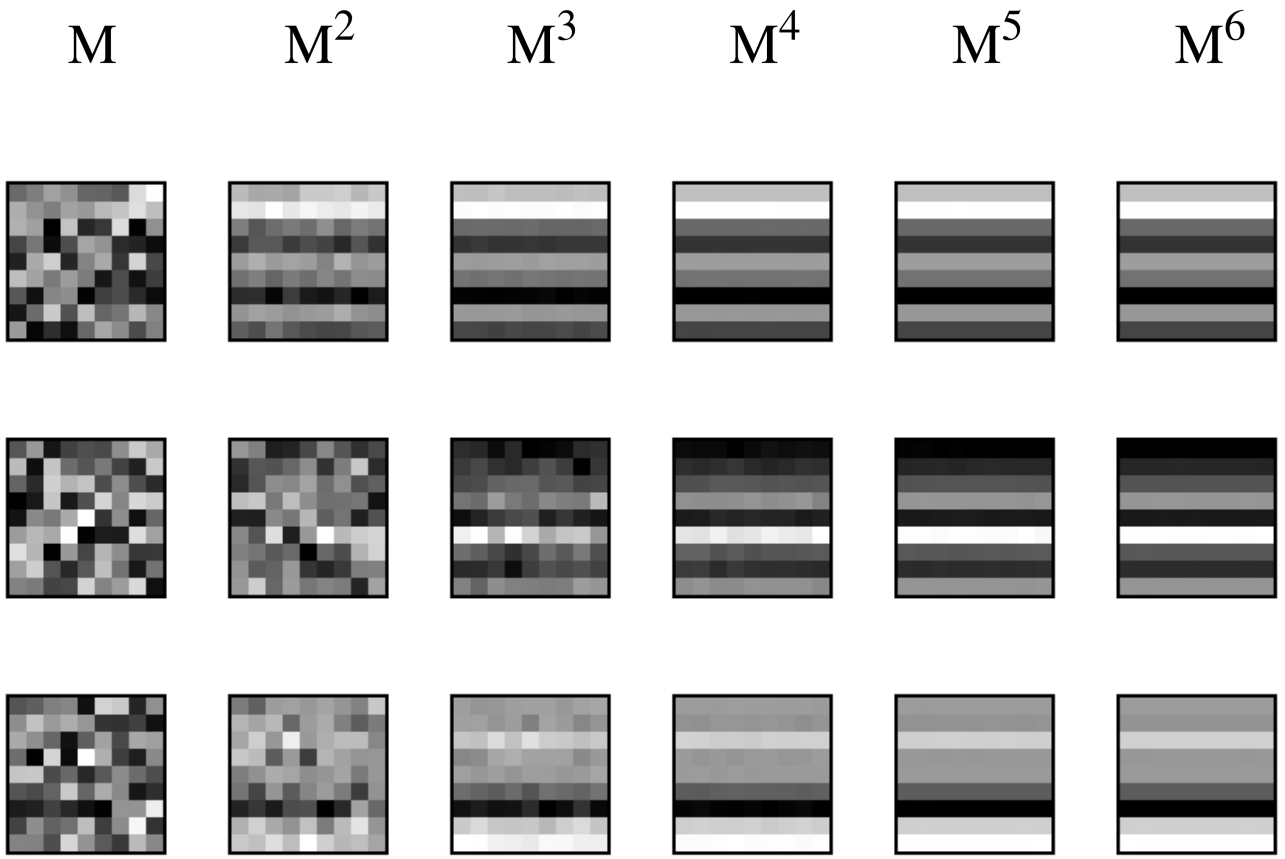


- Probability of next state depends only on current state

$$\mathrm{P}(\,\mathrm{s}(t+1)=i \mid \mathrm{s}(t)=j\,)=\mathrm{m}_{ij}$$

$$\mathrm{P}(\,\mathrm{s}(t+2)=i \mid \mathrm{s}(t)=j\,)=\sum_{k=1}^{\mathrm{N}}\mathrm{m}_{ik}\mathrm{m}_{kj}$$

Example Markov models

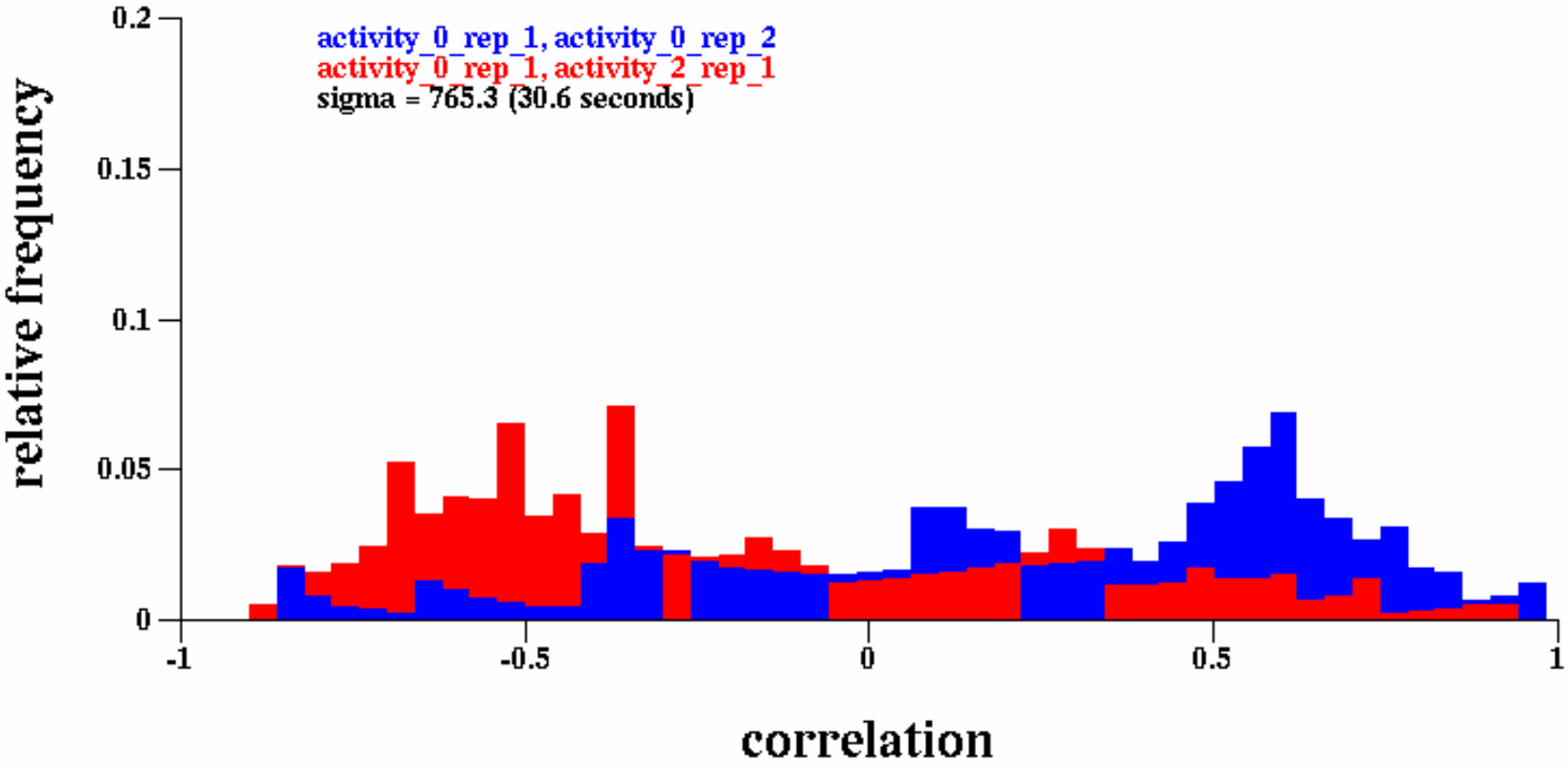


Synthetic data experiment details

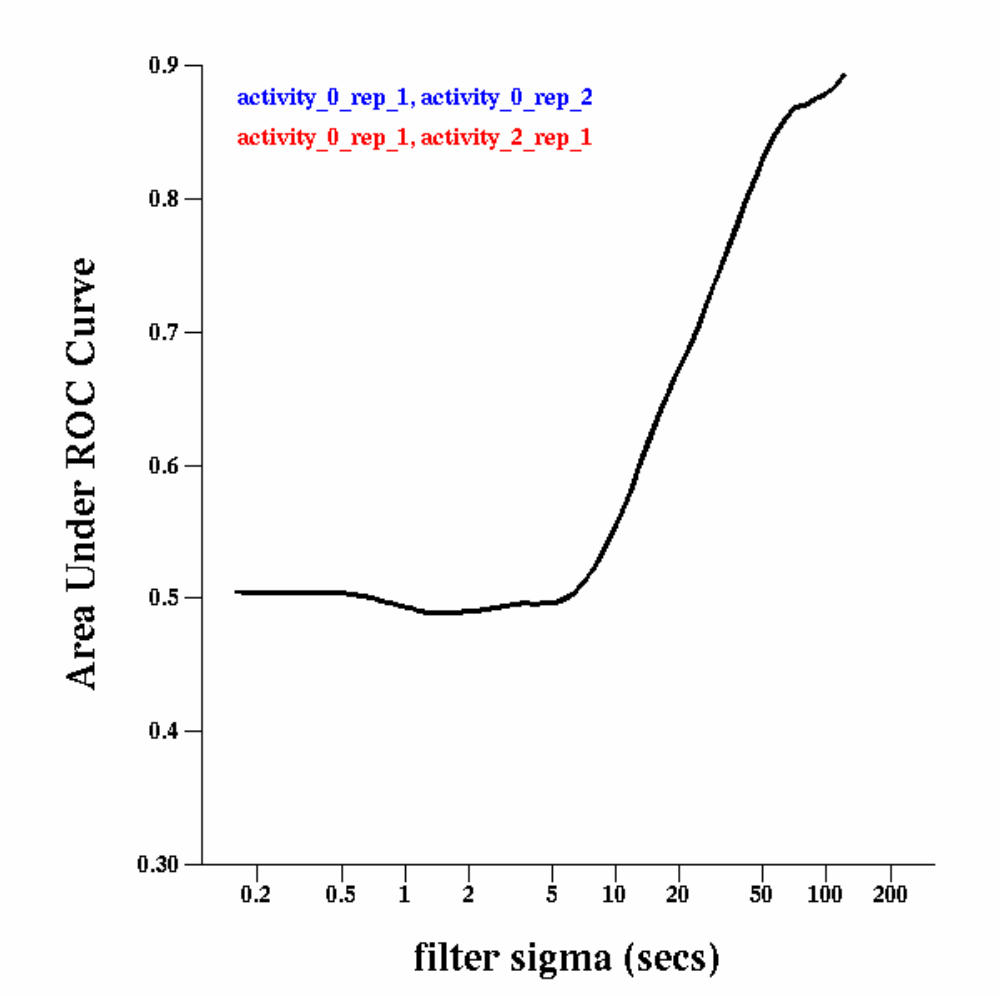


- 10 randomly generated activities
- 2 sample records for each activity
- Compare correlation statistics of matched/mismatched pairs

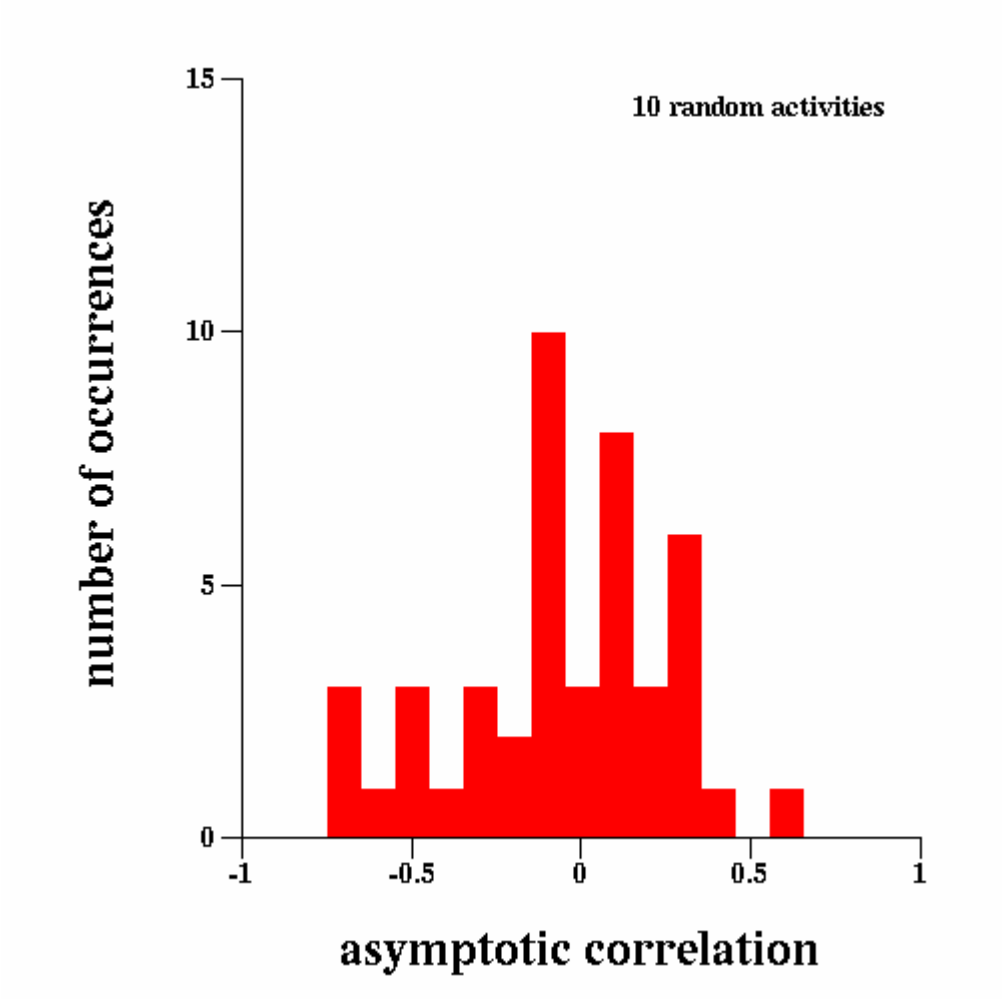
Synthetic data experiment results



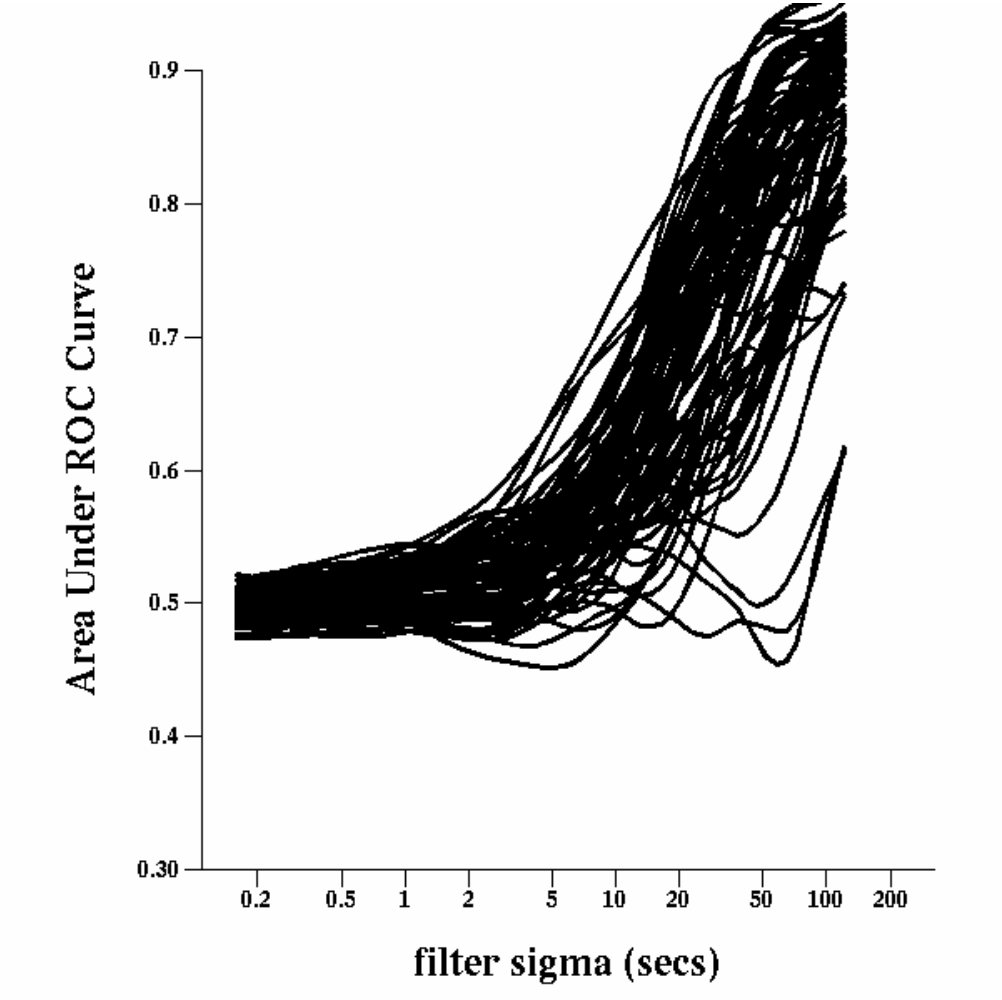
Synthetic data experiment results



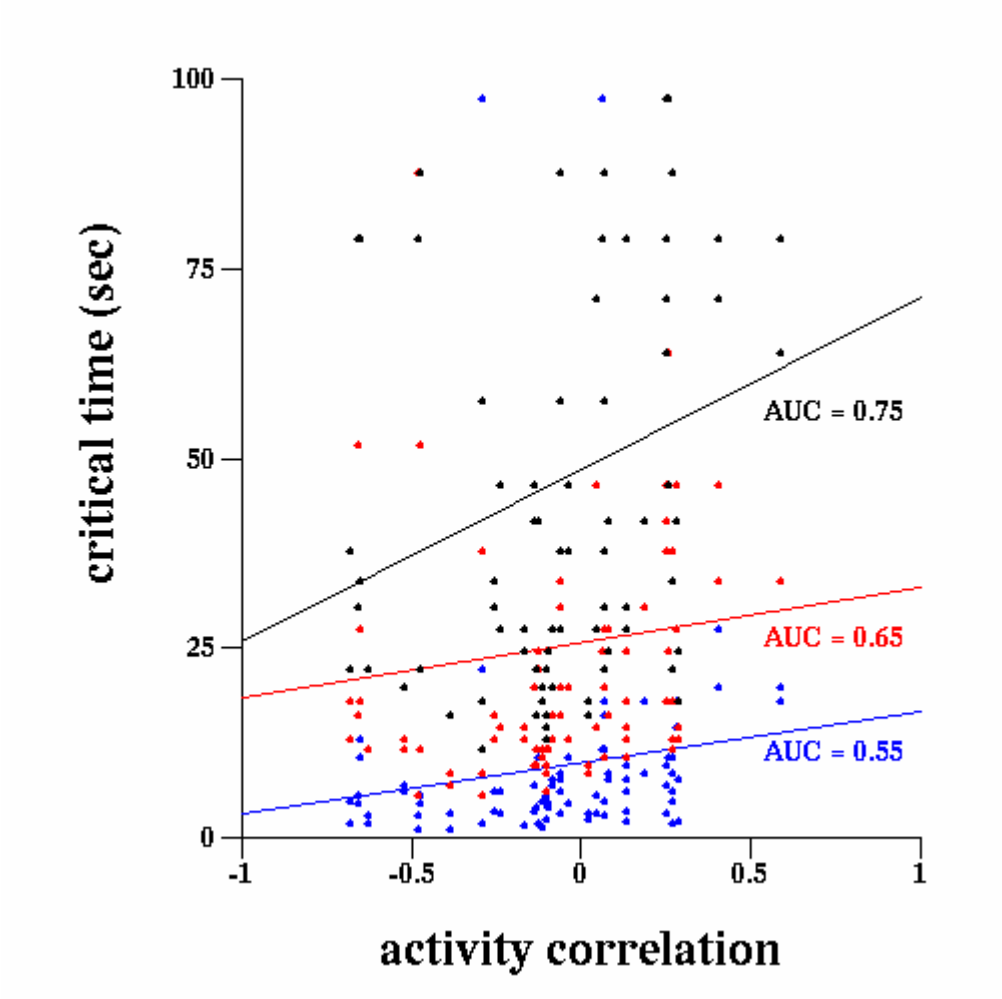
Synthetic data experiment results



Synthetic data experiment results



Synthetic data experiment results



Some familiar questions



- How do we interpret the numbers?
- What is a significant correlation?
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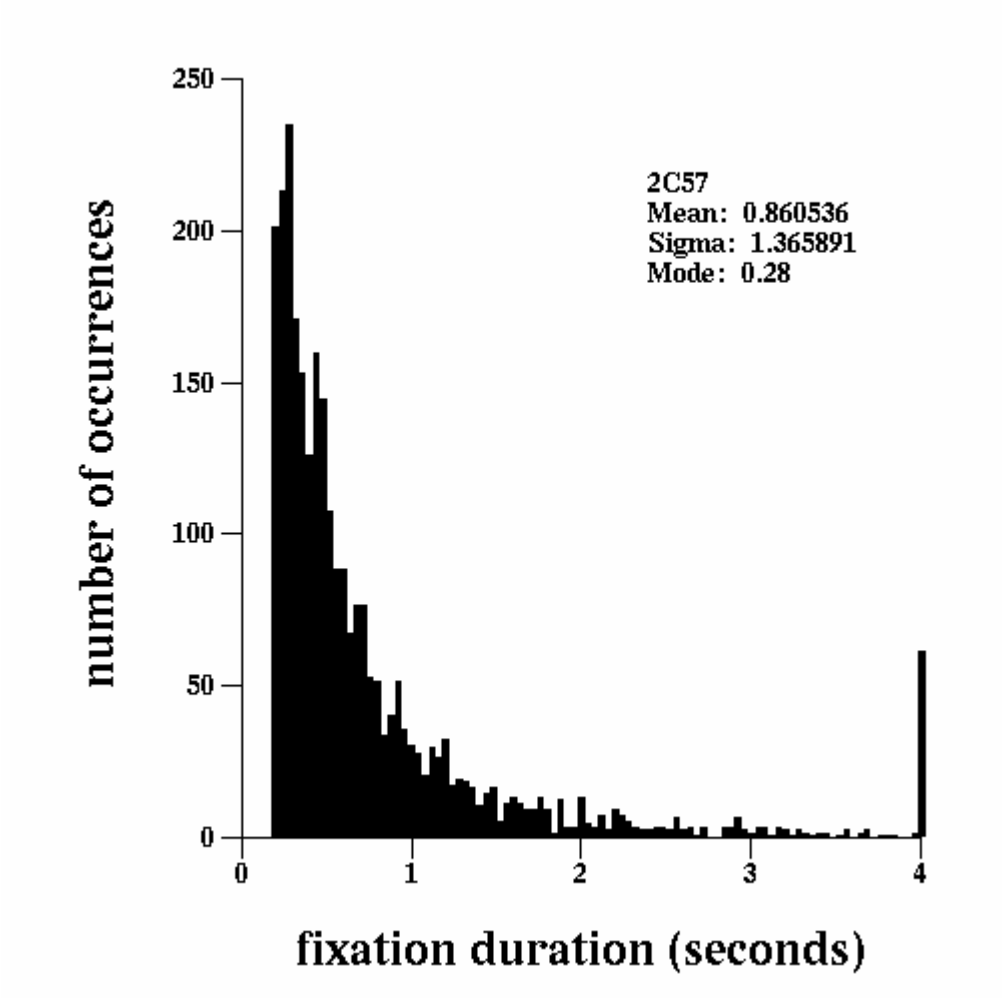
Chi-square approach (thanks to A. Ahumada)



- Null hypothesis: observations drawn from same distribution
- Choose time window
- Convert from time series to fixation counts

  (using average fixation duration)

Observed fixation durations



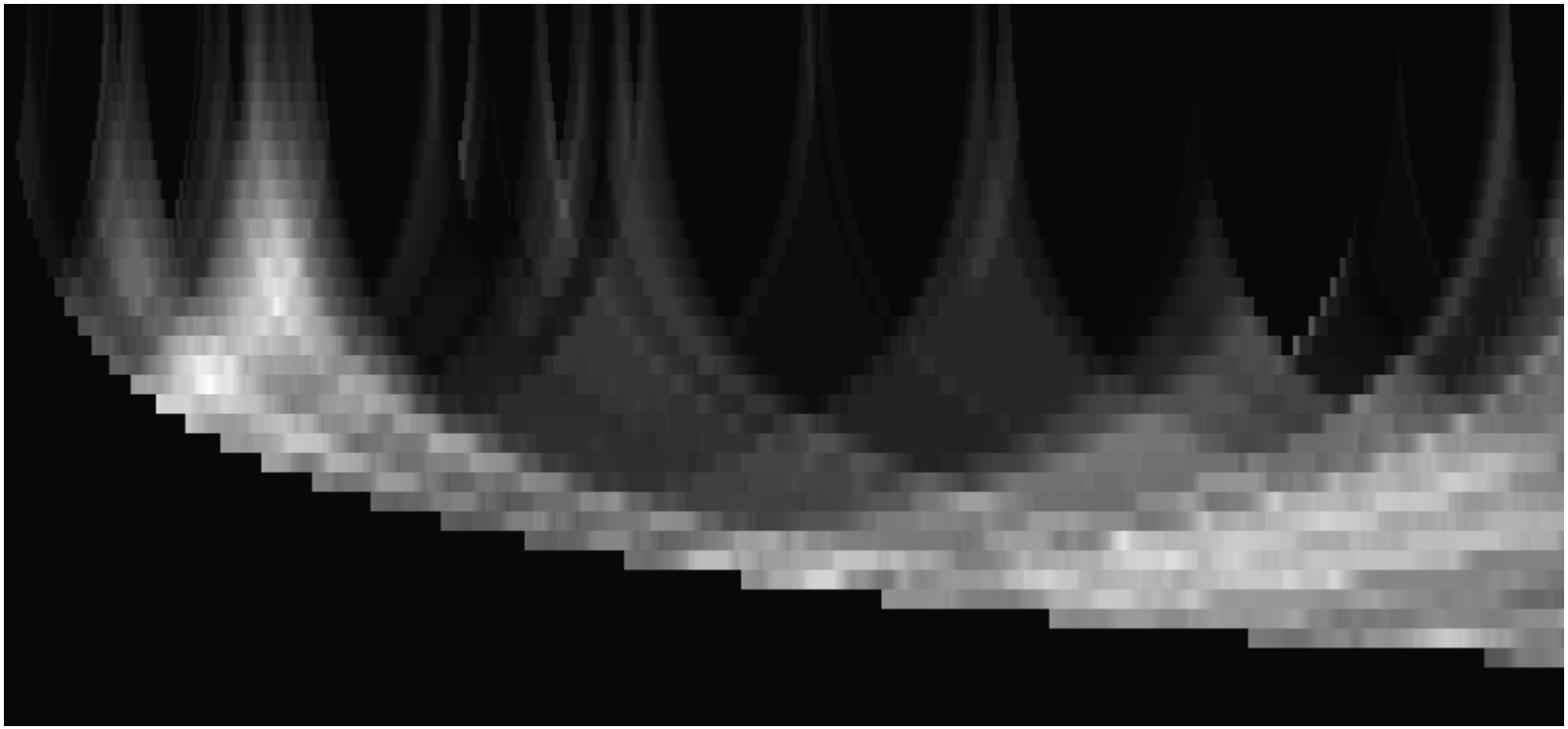
A 21 second example



	2F57	2C57	total	frac.	expected	
PFD	12	13	25	0.338	8.108	16.892
ATT	1	2	3	0.041	0.973	2.027
ALT	3	6	9	0.122	2.919	6.081
HDG	3	1	4	0.054	1.297	2.703
FMA	4	2	6	0.081	1.946	4.054
ND	0	22	22	0.297	7.135	14.865
SP	1	0	1	0.014	0.324	0.676
Wind	0	4	4	0.054	1.297	2.703
total	24	50	74			

$$s = \sum_i \frac{(o_i - e_i)^2}{e_i} = 23.85 \qquad p = 0.0012$$

A 21 second example



The TOPICS model (Steyvers et al. 2004)



Topic: P(word)	Activity: P(behavior)
Document: P(topic)	Interval: P(activity)
Fix number of topics	Fix number of activities
Solve for topics	Solve for activities
Solve with Gibbs sampling	

- Issue: where to segment intervals?

A bit of wisdom from Larry Cormack



"A week in the lab can save you an hour in the library."

Patrick goes to Bielefeld

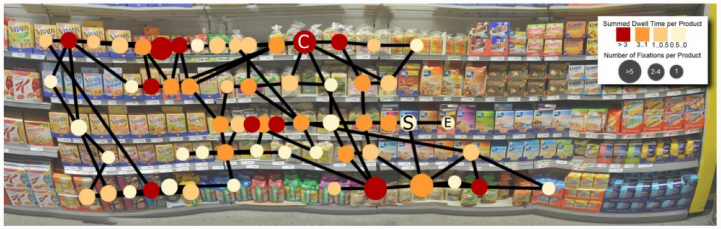


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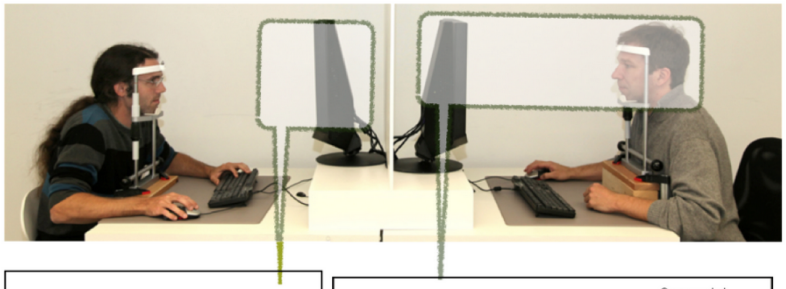
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COMPUTER-HUMAN INTERACTION IN LEARNING AND INSTRUCTION CHILI

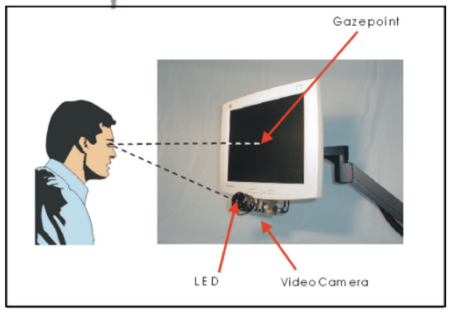
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Dual eye-tracking



```
for (c = 1; c < size; c++)
{
  if (array[c] > maximum)
  {
     maximum  = array[c];
     location = c+1;
  }
}
```



- Classroom Orchestration
- Vocational Education Technologies
- Tangible Interaction
- Eye-tracking
  - Dual eye-tracking
  - Annotations
  - Eye-tracking and MOOCs
  - Eye-tracking and classroom orchestration
- MOOCs Research
- Meeting Technologies
- Robots for Education and Daily Life
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...CHILI?

At the Computer-Human Interaction in Learning and Instruction (CHILI) lab, we research innovative technologies that support learning in the classroom.

CONTACTS

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Recurrence Quantification Analysis (RQA)



CHAPTER 2

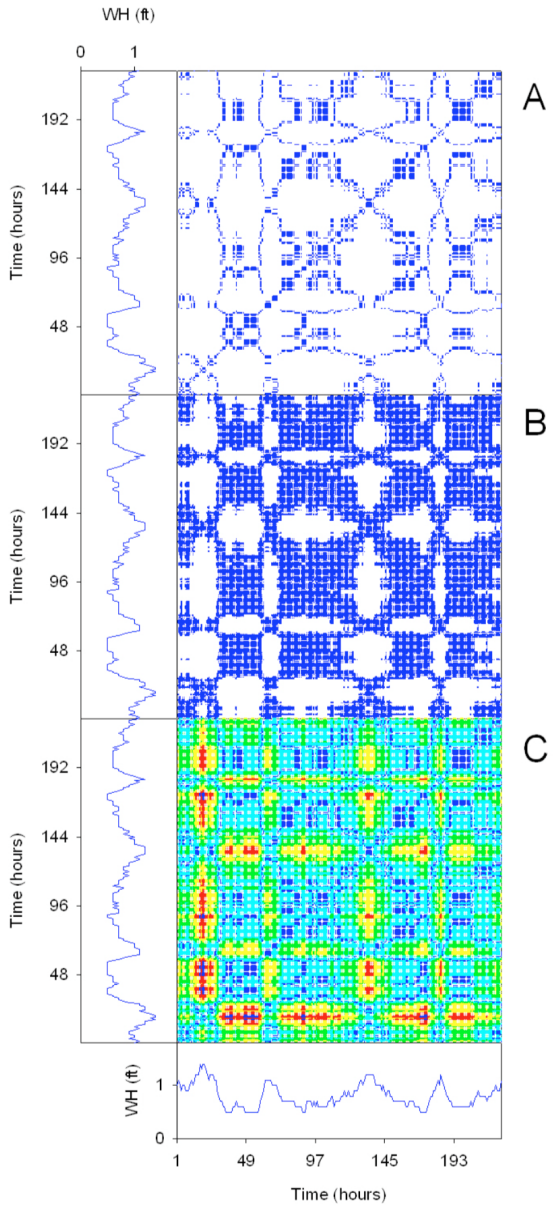
Recurrence Quantification Analysis of Nonlinear Dynamical Systems

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In: Tutorials in contemporary nonlinear methods for the behavioral sciences, (Chapter 2, pp. 26-94), M.A. Riley, G. Van Orden, eds., 2005.

Conclusions



- We have demonstrated methods for comparing scan paths

  based on similarity (correlation) and dissimilarity (Chi-square)

- Results suggest that shared attention in the cockpit

  occurs in intervals < 1 minute

- Text analysis methods (TOPICS, LSA, etc)

  may enable blind discovery of "activities"

- Methods may be applicable in other training scenarios