

Behavior Imaging and the Study of Autism

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Invited Talk

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HARVARD'S CRISIS • THE POPE'S HOLY SUPPER
Newsweek
 February 18, 2008 \$3.94

Babies And Autism

Why New Research On Infants May Hold The Key to Better Treatment



NATIONAL CENTER ON BIRTH DEFECTS AND DEVELOPMENTAL DISABILITIES
Learn the Signs Act Early.



Health

What to Watch For

Autism on the rise, but early diagnosis can lead to early intervention, and give kids a chance of better life. Here are currently signs, plus a look at treatment and trends.

A TYPICAL BABY
 Children develop at their own pace. It's hard to know when an individual will use a particular skill. Here are some general guidelines to help track your baby's progress.

Autism Spectrum
 Autism: Severe language problems, lack of interest in others, repetitive behaviors, resistance to change, restricted routines.
 Asperger's: Relatively strong verbal skills, but trouble reading social situations and sharing enjoyment. Attractive interests.
 PDD-NOS: Shows no typical autism, but has less severe social impairments.
 Childhood Disintegrative Disorder (CDD): Normal growth for 2 to 4 years, then variable regression of skills.
 Rett Syndrome: Similar pattern as CDD but occurs almost exclusively in girls.

at 7 months

at 1 year

at 18 months

at 2 years

at 3 years

at 4 years

In the Brain
 Studies show that children with autism undergo abnormal brain development from early infancy. Researchers have found affected kids that are only slightly smaller than average, from early evidence they grow, with severe more growing the faster.

Treatments
THERAPY: Child may receive more than one type of therapy, along with speech and occupational therapy.
Applied Behavioral Analysis: Intensive one-on-one drills teach social/ language skills through positive reinforcement.
Fluoxetine: This antidepressant approach improves autistic children.
RYEGRASS: Uses children's individual interests to teach them to read social skills and give insight into others' perspectives.
Special Diets: Some diets to limit social skills and give insight into others' perspectives.
SPICES: Helps build communication skills through the use of pictures.
WDS: Encourages repetitive sharing and empowers parental involvement.

DRUGS: Risperidone treats the core symptoms of autism, but may cause behavioral problems.
Risperidone: This anti-psychotic was shown to decrease aggression and hyperactivity.
SSRIs: Antidepressants like Prozac may reduce repetitive behaviors.
Autism-specific Drugs like Depakote are being tested for treating aggression.
Stimulants: Ritalin may reduce hyperactivity.

Intervention: ALIX BRISMAN AND HIS MOTHER, LISA, WITH THERAPIST JOY GIBBERSON IN ABO. ALIX TREATMENT, CALLED COMMUNIC, USES PLAY TO TEACH COMMUNICATION SKILLS.

\$12,500
 cost for average special-ed student per year

\$18,800
 cost for a student with autism per year

More Information
 Autism Coalition: autismcoalition.org
 Autism Soc. of America: autism-society.org
 CDC: cdc.gov/nbdc/autism/autism.cfm
 Cure Autism Now: cureautismnow.org
 First Signs: firstsigns.org
 Max Alliance for Autism Research: max.org
 NIMH: nimh.nih.gov/publicat/autism.cfm
 Autism rates per 1,000 children ages 0-17: 0-1 1 82-18 81-6

First Signs

WALK NOW FOR AUTISM

More Information

SPECIAL REPORT: MIRROR NEURONS AND THE MIND ALSO: SUPERCONDUCTING EYES • DEAD ZONES • PHONY VIRUSES

SCIENTIFIC AMERICAN

The Dark Ages of the Universe Before Stars

MIRROR NEURONS AND AUTISM

A disorder of brain cells that link others' actions to our own may

BILL HILLARY & 2008 - THE TIP SHEET GIFT GUIDE

Newsweek

Growing Up With Autism

DISCOVER

UNDERSTANDING AUTISM



GOES SCHOOL SODA = EXCLUSIVE: NINTENDO'S NEW GAME

TIME

NEW INSIGHTS INTO THE HIDDEN WORLD OF AUTISM

BOY LASHED IN HIDING: WHAT IS HE PLANNING NEXT?

Newsweek

Why 4 of 5 Autistic Children Are Male

Boys, Girls and Autism

What New Science Tells Us About How Our Brains Work



AUTISM'S FALSE PROPHETS

PAUL A. OFFIT, M.D.

PARADE

Is There Hope for Autism?

JENNY MCCARTHY

Fighting for My Autistic Son

In an emotional memoir the star describes Evan's devastating diagnosis, his surprising breakthrough—and how Jeni Carney helped her lead

THE COMING JOB BOOM • PAKISTAN'S SPY AGENCY • REUNION TV

TIME

INSIDE THE WORLD OF AUTISM

More than one million Americans may have it, and the number of new cases is exploding. What scientists have discovered. What families should know.

AUTISM: THE MUSICAL

"As Riveting As It Is Revolutionary..."

COMING TO HBO MARCH 2008

Autism Quick Facts

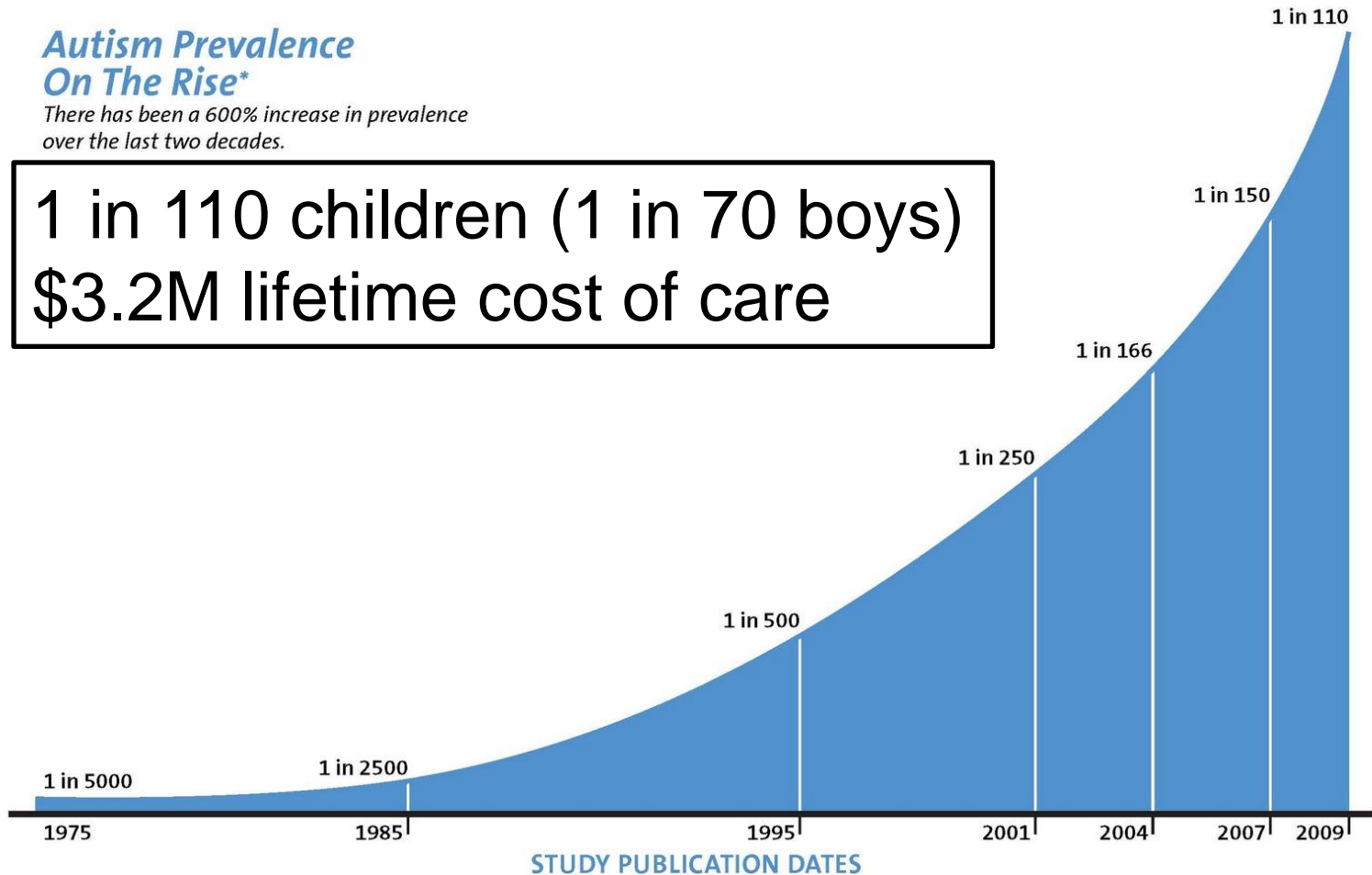
- A developmental brain disorder with a genetic basis, but no biological marker or cure
 - Diagnosis and characterization depends entirely on observable behavior
- Difficulties in forming social bonds with parents, peers, and care-givers
- 30-50% fail to develop spoken language
- Intellectual disability in ~50% of individuals
- First described in 1943 by Leo Kanner

Autism Prevalence on the Rise

Autism Prevalence On The Rise*

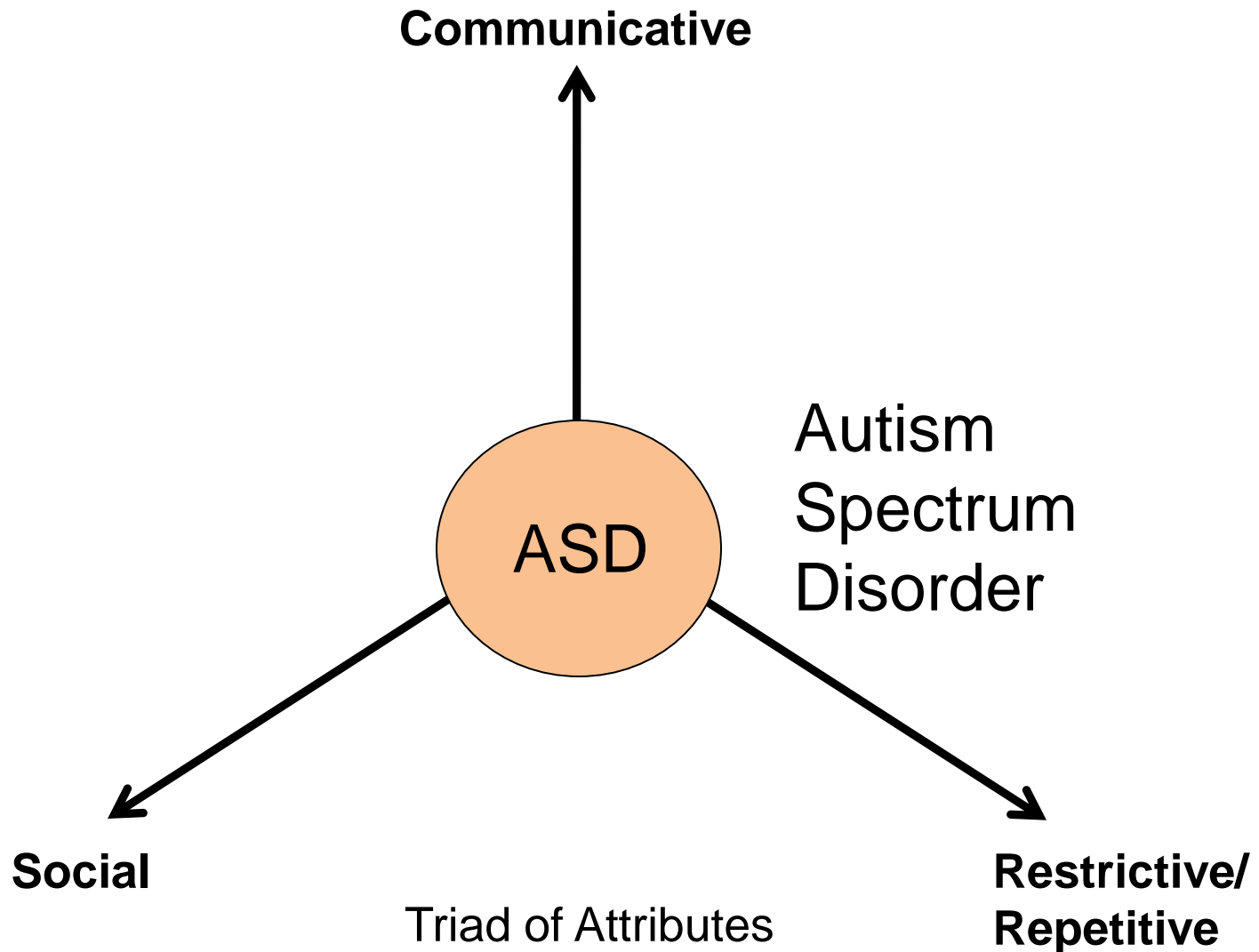
There has been a 600% increase in prevalence over the last two decades.

1 in 110 children (1 in 70 boys)
\$3.2M lifetime cost of care



*Recent research has indicated that changes in diagnostic practices may account for at least 25% of the increase in prevalence over time, however much of the increase is still unaccounted for and may be influenced by environmental factors.

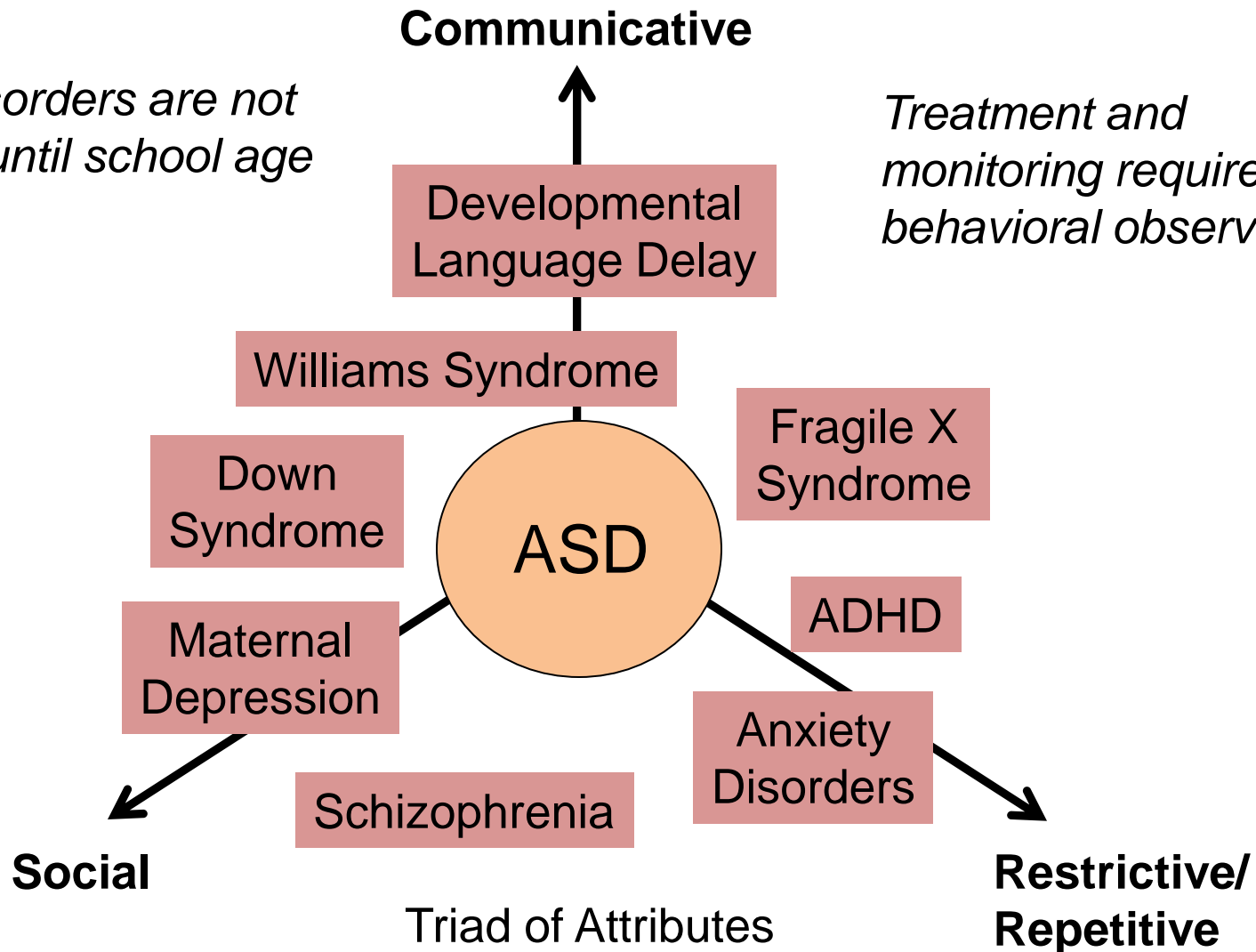
Dimensions of Autism



Behavioral and Developmental Disorders

50% of disorders are not identified until school age

Treatment and monitoring requires behavioral observation



Three Goals

- Early Detection
 - Symptoms are visible before age 2
 - Average age of diagnosis around 4 years
 - *Technology for screening* (3 times before age 3)
- Intensive Therapy
 - Therapy results in measurable improvements
 - Intensity of therapy is a key factor
 - *Technology to aid in delivering therapy*
- Autism Research
 - Social and communicative behavior in children
 - *Tools for large scale collection and analysis of data*

Behavior Imaging

Imaging technologies and medical science

- Orthopedics and dentistry X-RAY
- Neurology MRI / CT

Can we develop imaging technologies for the behavioral sciences?

- Large-scale measurement of behavior
- Capture of behavior under natural conditions
- Visualizations over time and across populations

NSF Expeditions in Computing Program

Computational Behavioral Science:

Modeling, Analysis, and Visualization of
Social and Communicative Behavior

Lead PI: Jim Rehg, Georgia Tech

<http://www.cbs.gatech.edu>



Social Behavior and Autism

Ousley, Abowd, and Arriaga

Rapid-ABC Screener for Autism

- Behaviors:
 - Response to name*
 - Joint attention*
 - Ball game*
- Key properties:
 - Dyadic*
 - Multimodal*
 - Context*
 - Timing*
 - Heterogeneous*
- Assessment: *How hard is it to engage Pablo?*
 - Output: *Score and “felt sense”*



Research Challenges

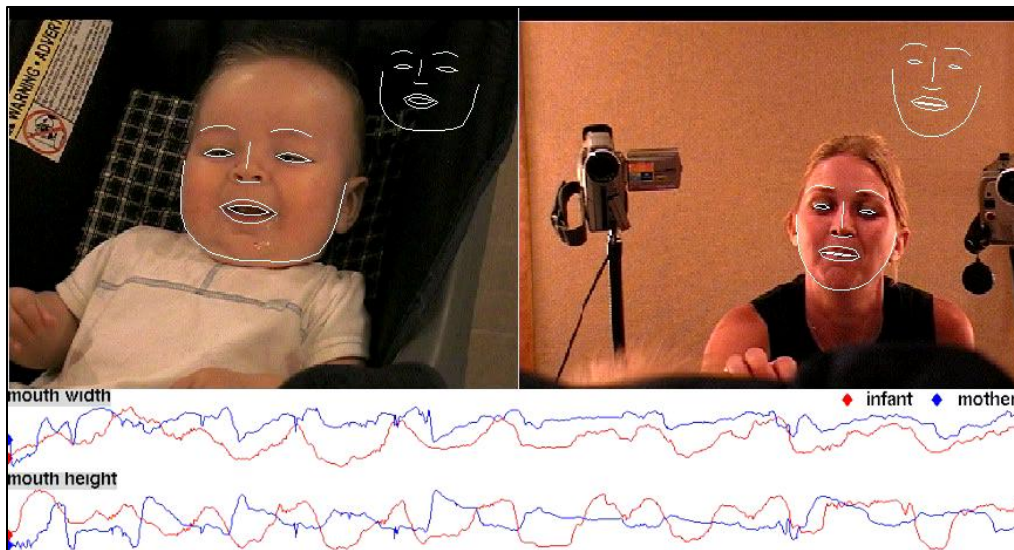
- Measure children's gaze, facial affect, gestures, and behaviors
 - Noninvasively and with minimal calibration
 - In natural settings as well as clinical
- Combine multiple sensing modalities (vision, audio, wearable)
 - Infer emotion, strength of engagement, stress, etc.
- Modeling face-to-face social interactions
 - Automated retrieval of social interactions from large collections

Modeling Issues

- The importance of timing

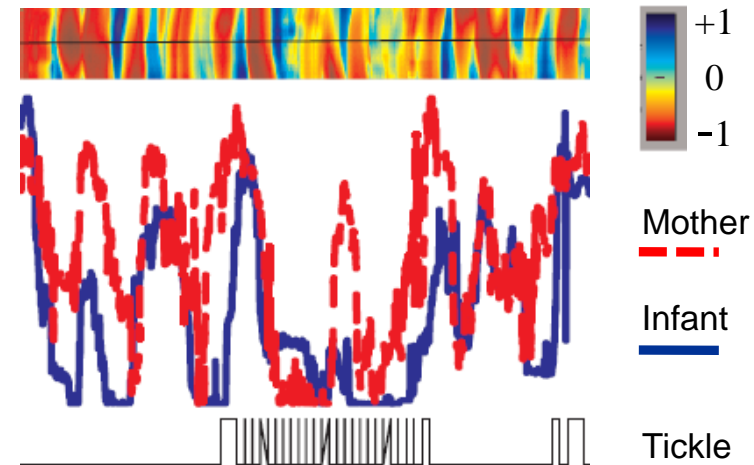
Modeling Issues

- The importance of timing



Cohn and Kanade

Synchrony in Dyadic Smiling



Modeling Issues

- The importance of timing *and context*



Modeling Issues

- The importance of timing and context
- The complexity of patterning

Modeling Issues

- The importance of timing
- The complexity of patterning



- *What game is this?*
- *How is it played?*

Modeling Issues

- The importance of timing
- The complexity of patterning



How many different ways to play Peek-a-Boo?

Modeling Issues

- The importance of timing and context
- The complexity of patterning
- The lack of reliable features

Roadmap

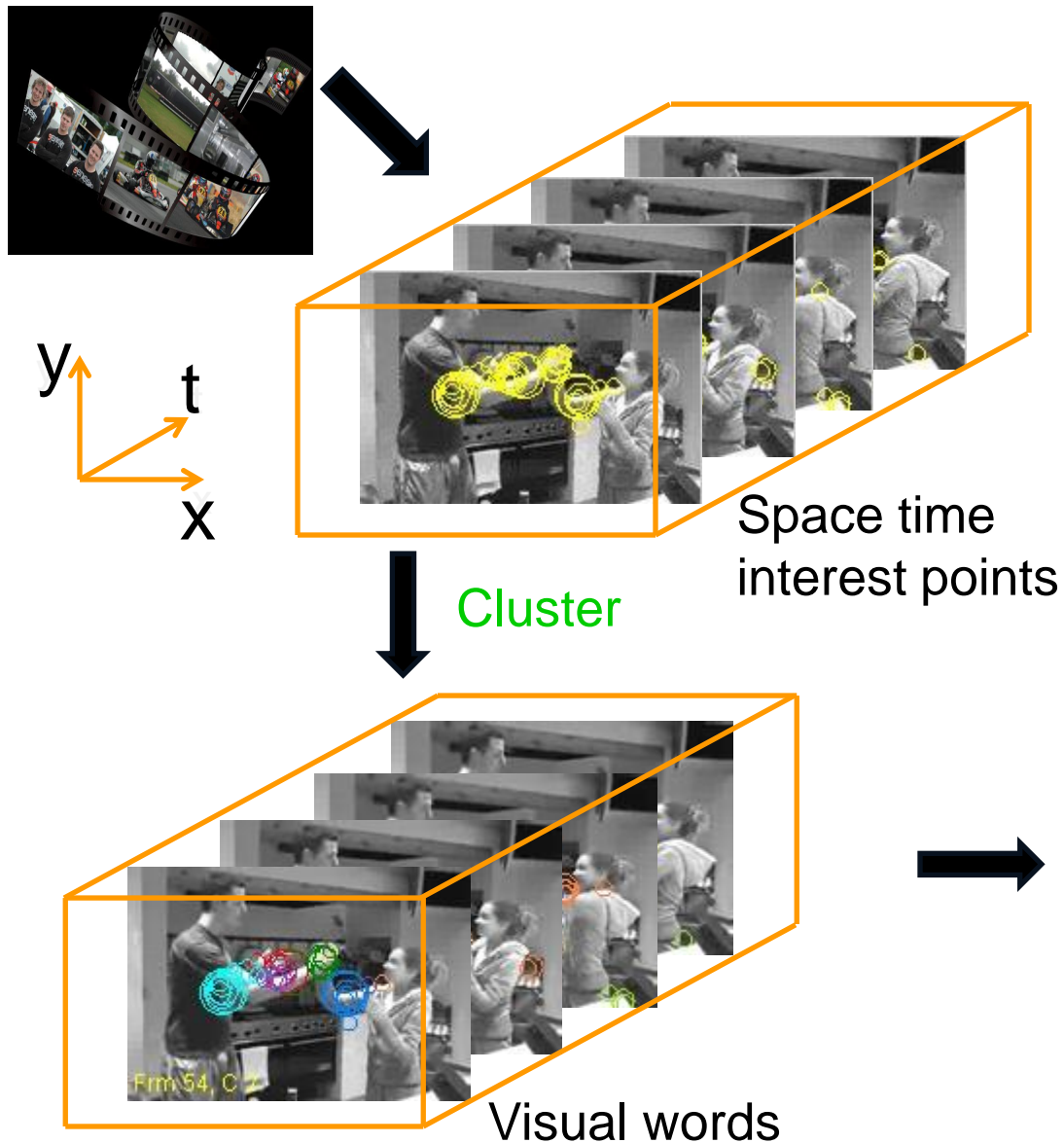
- Opportunities for AI researchers to impact the study of autism
- Modeling challenges associated with social behavior
- **Analyzing social games in video**
 - Using temporal causality in video analysis
 - Pattern-mining approach to social game retrieval
 - Multiple instance learning for social game categorization

Social Game Retrieval



How can we identify social interactions?

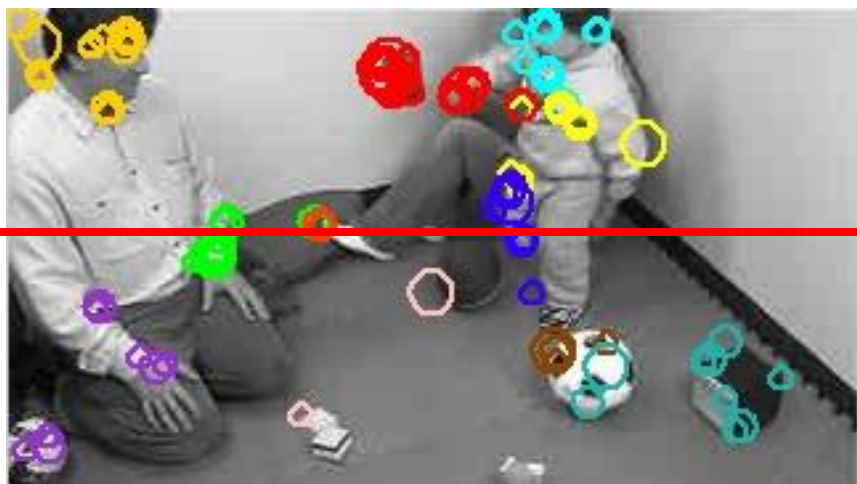
Supervised Learning of Activities



Disadvantages:

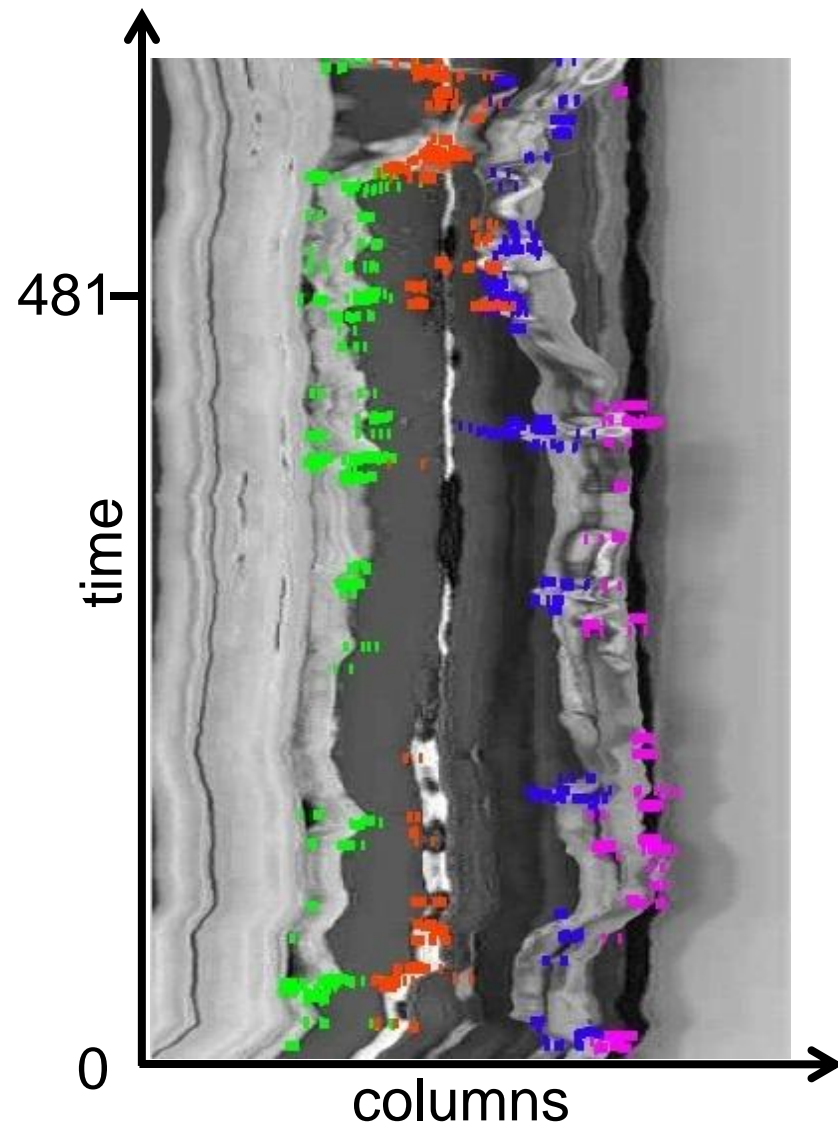
- Large training set
- Unsited for exploration

Temporal Structure of Video

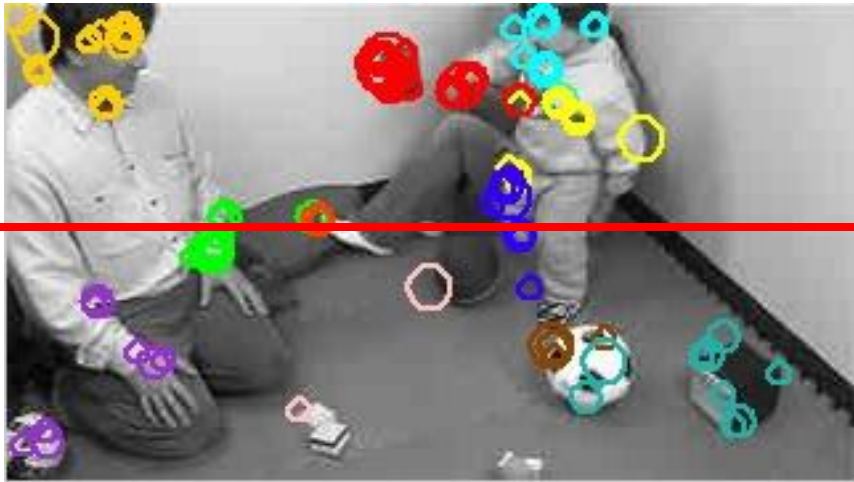


Frame 481

*How to find global structure
without supervision?*

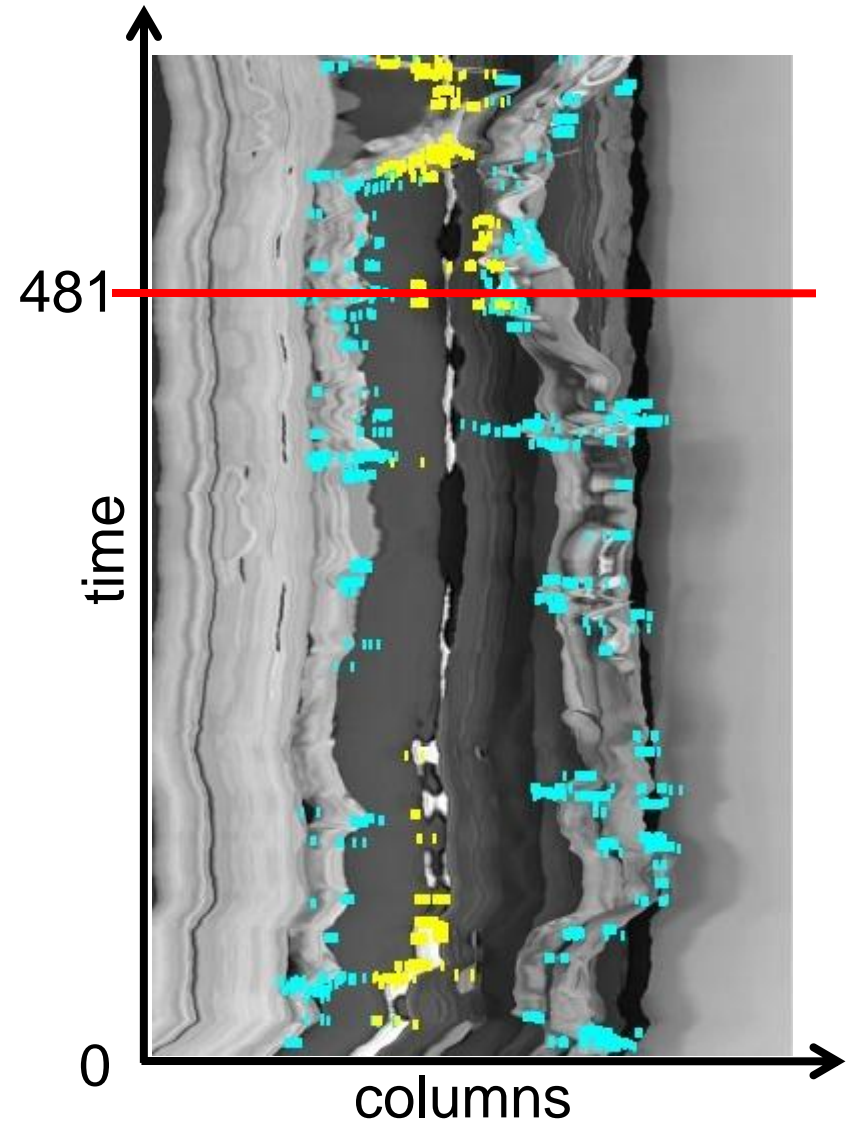


Grouping Co-Occurring Events



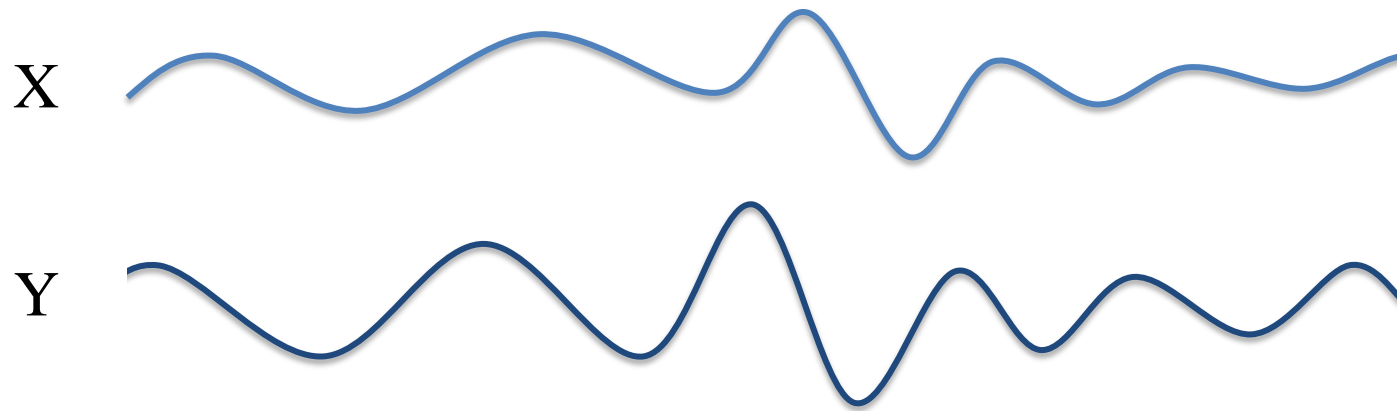
Frame 481

Use event-based temporal causality to group words



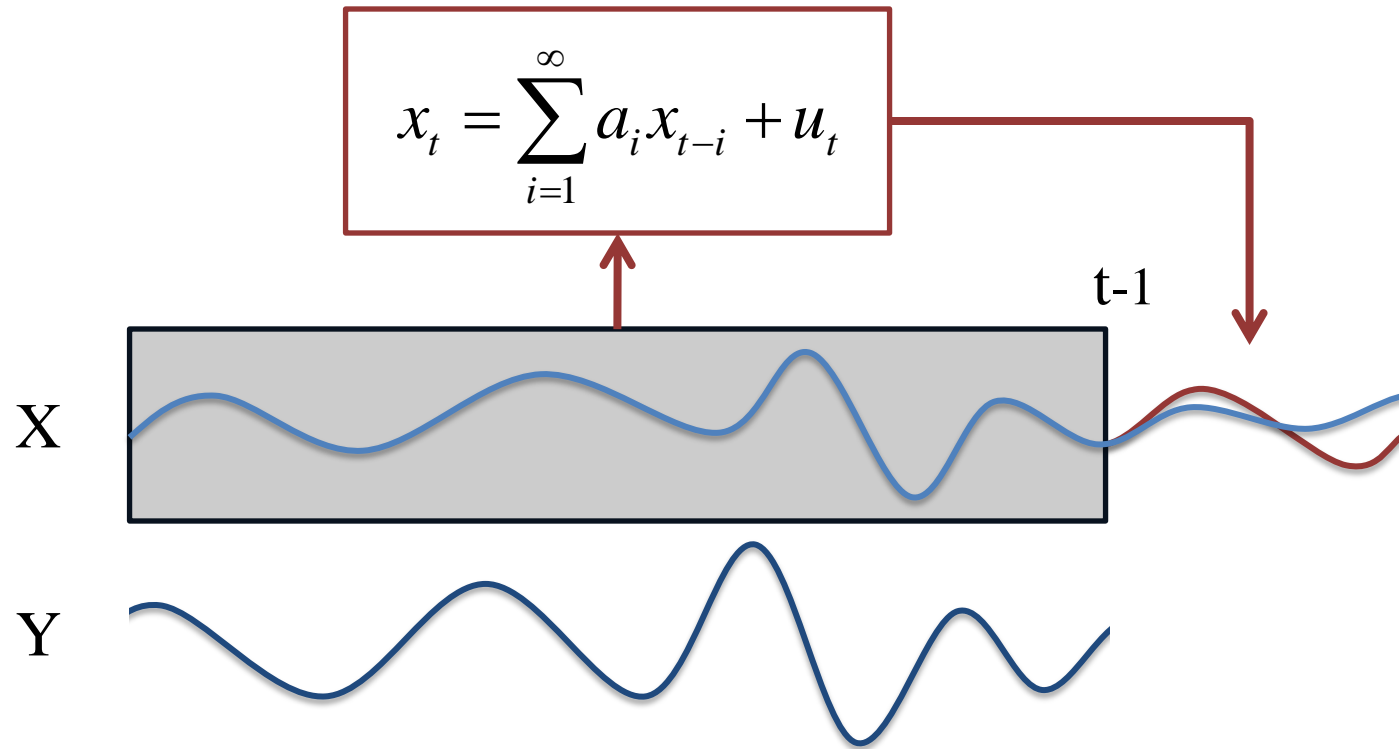
Granger Causality

Clive Granger, 1969 (Nobel prize in Economics)

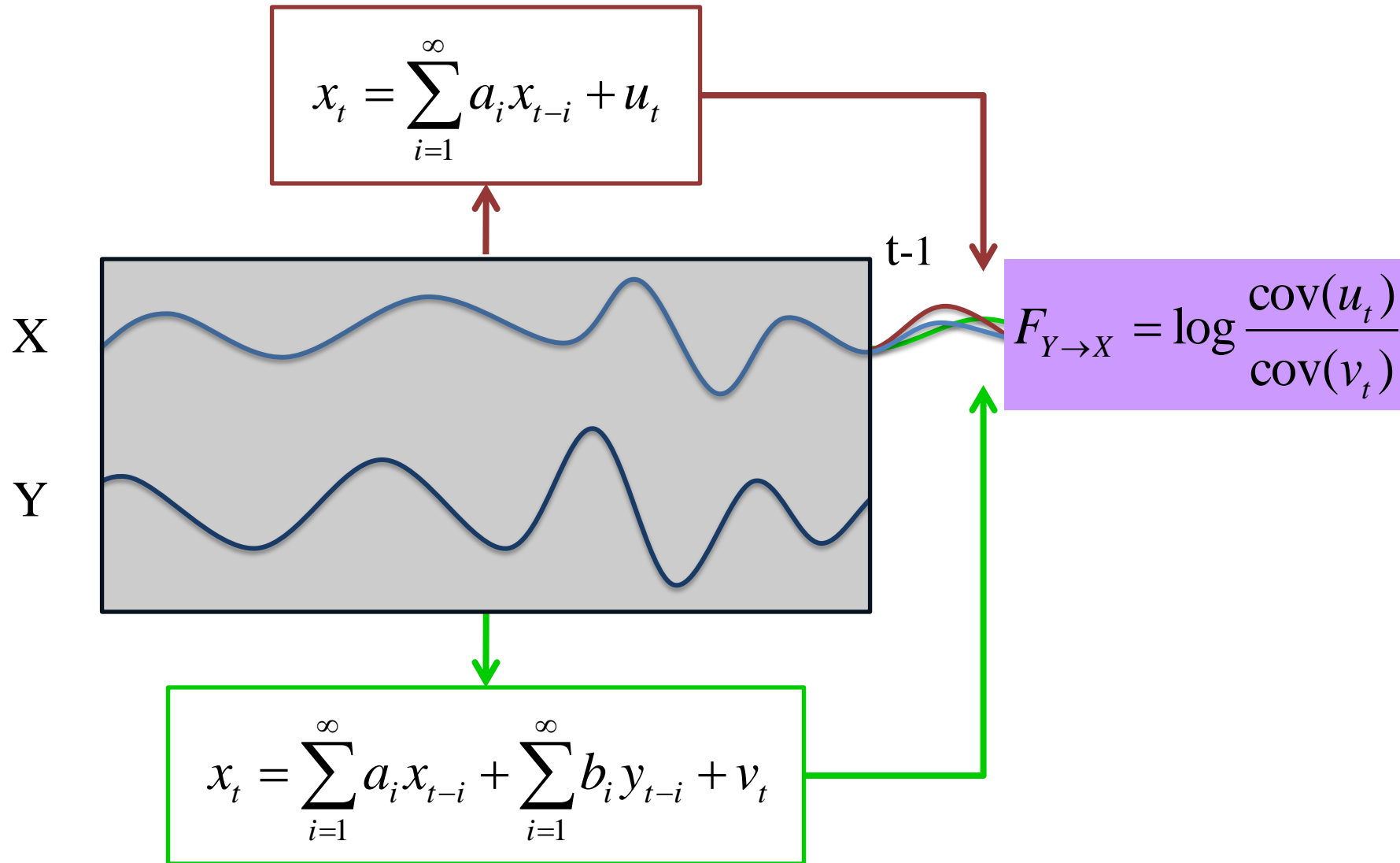


How can we test whether Y causes X ?

Granger Causality



Granger Causality



Event-Based Causality

- Granger causality requires continuous time processes (time series data)
- Undesirable for vision:
 - Continuous tracking is difficult (esp. over long time intervals)
 - Causal relations of interest are expressed in terms of events
 - We want to use visual words representations

Visual Words as Point Processes



Visual Words as Point Processes



$t = 1$



Visual Words as Point Processes

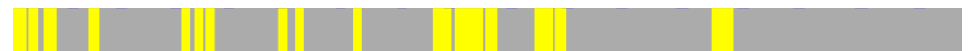


$t = 6$



Visual Words as Point Processes

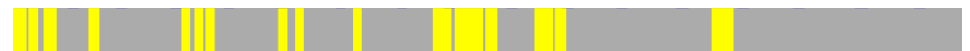
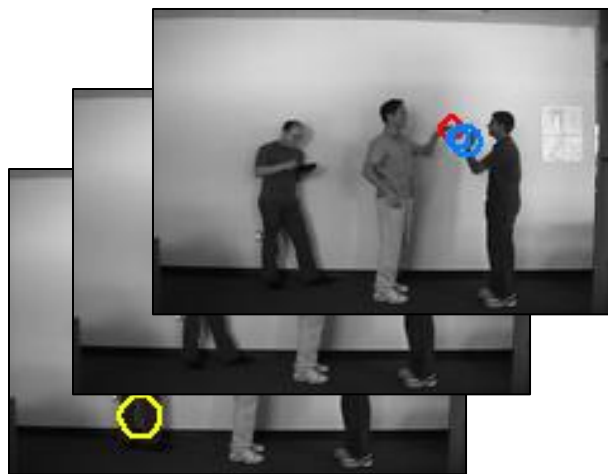
$t = 8$



time

Visual Words as Point Processes

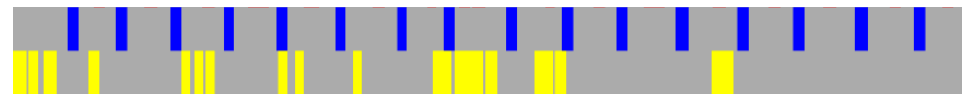
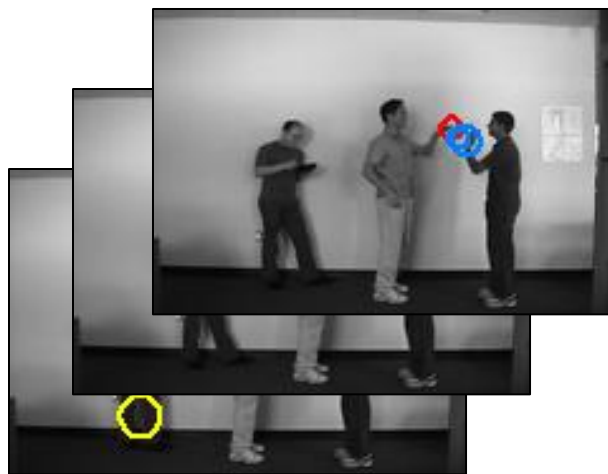
$t = 28$



time

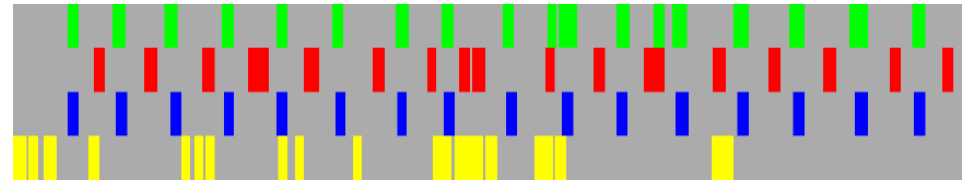
Visual Words as Point Processes

$t = 28$



time

Key Observation



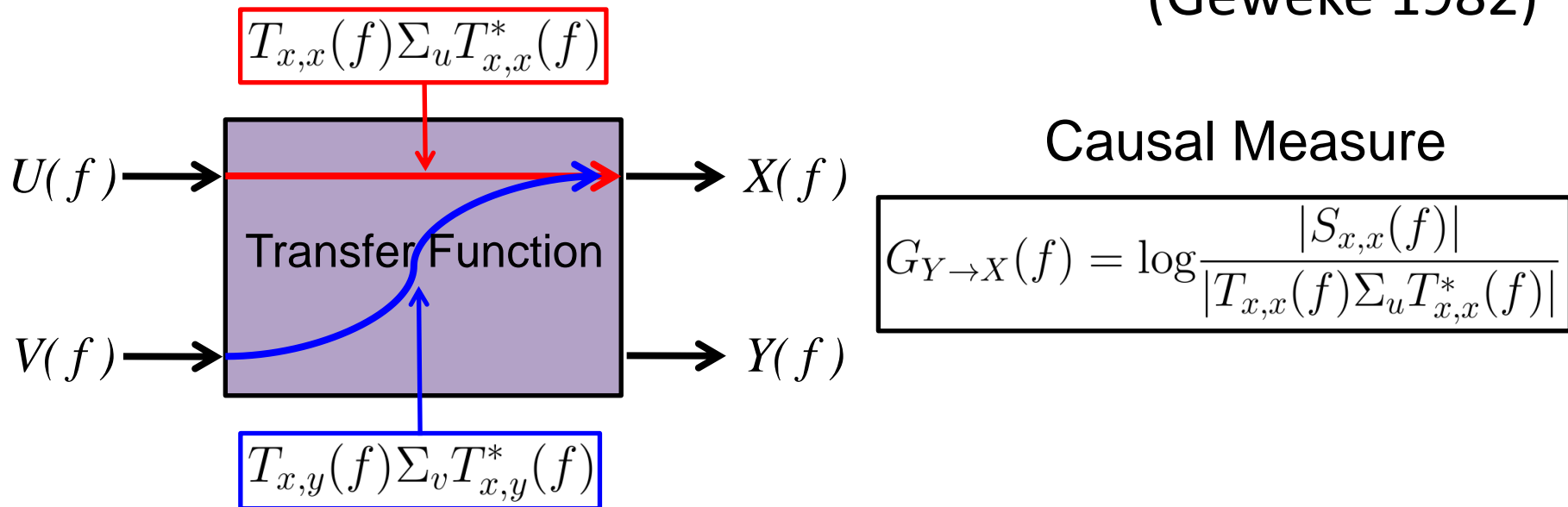
Multiple Point Processes

Space-time Visual Words

Temporal interactions between visual words can be modeled as **correlations between multiple point processes**

Event-Based Granger Causality

A pair-wise test for Granger causality in the spectral domain
(Geweke 1982)



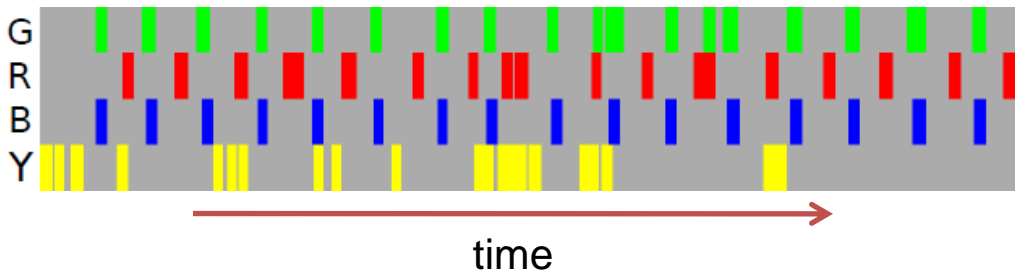
$$S_{x,x}(f) = \underbrace{T_{x,x}(f) \Sigma_u T_{x,x}^*(f)}_{\text{Intrinsic power}} + \underbrace{T_{x,y}(f) \Sigma_v T_{x,y}^*(f)}_{\text{Causal power due to } Y(f)}$$

Intrinsic power

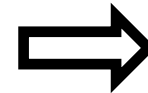
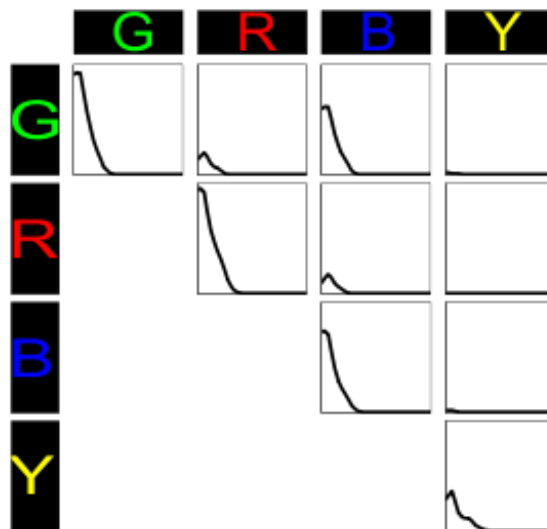
Causal power due to $Y(f)$

Stages in Causal Analysis

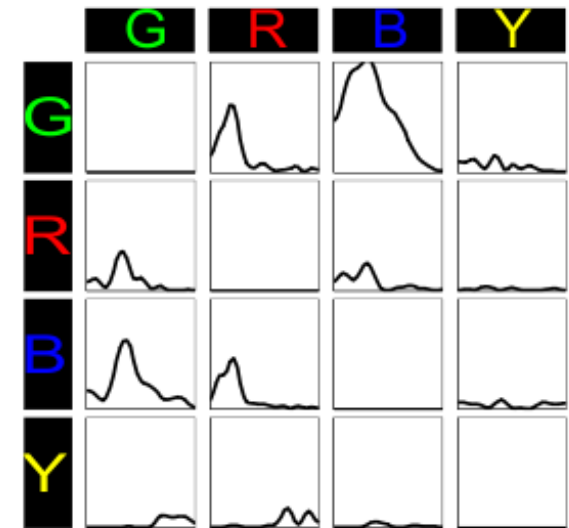
Multiple Point Processes



Spectral matrix



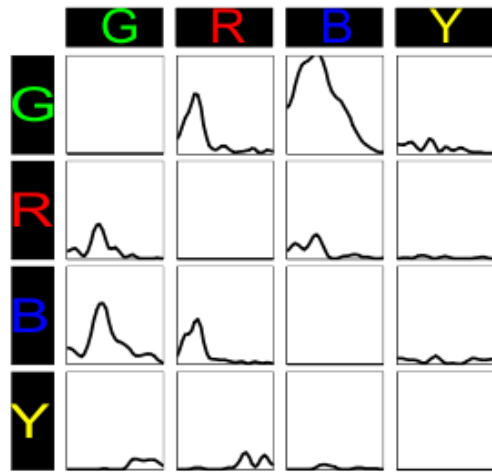
Causal measures



$$\mathbf{S}(f) = \mathbf{T}(f)\mathbf{\Sigma}\mathbf{T}(f)^*$$

Spectral Matrix
Factorization

Stages in Causal Analysis

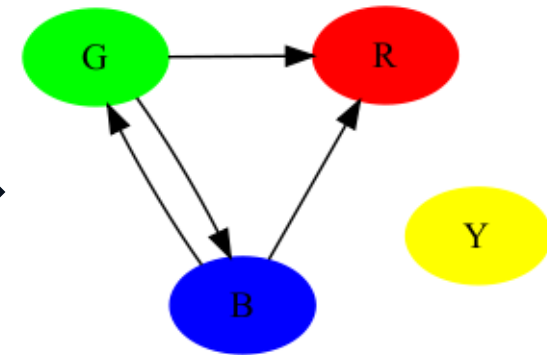


Causal Measures



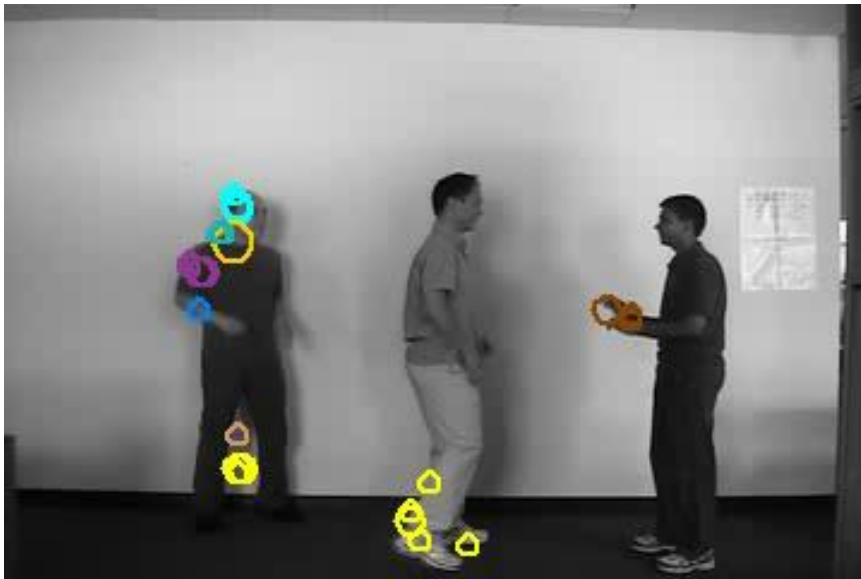
	G	R	B	Y
G	0	0.96	1.97	0
R	0	0	0	0
B	1.41	0.73	0	0
Y	0	0	0	0

Causal Matrix

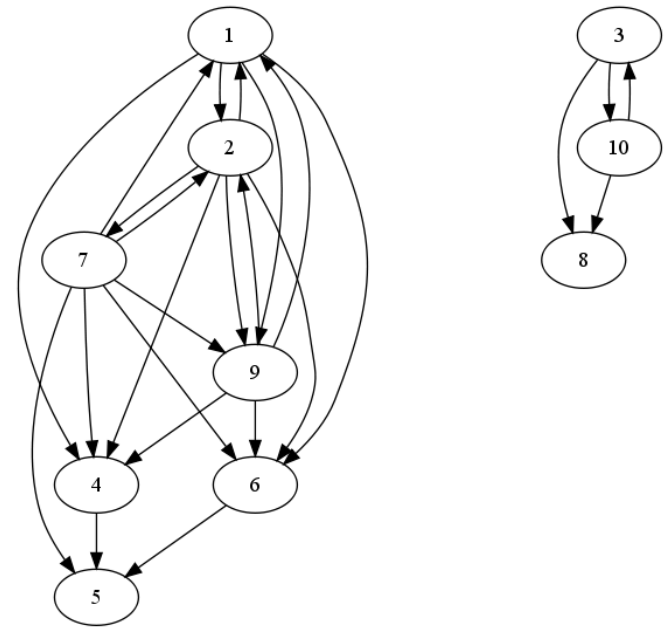


Causal Graph

Causal Sets

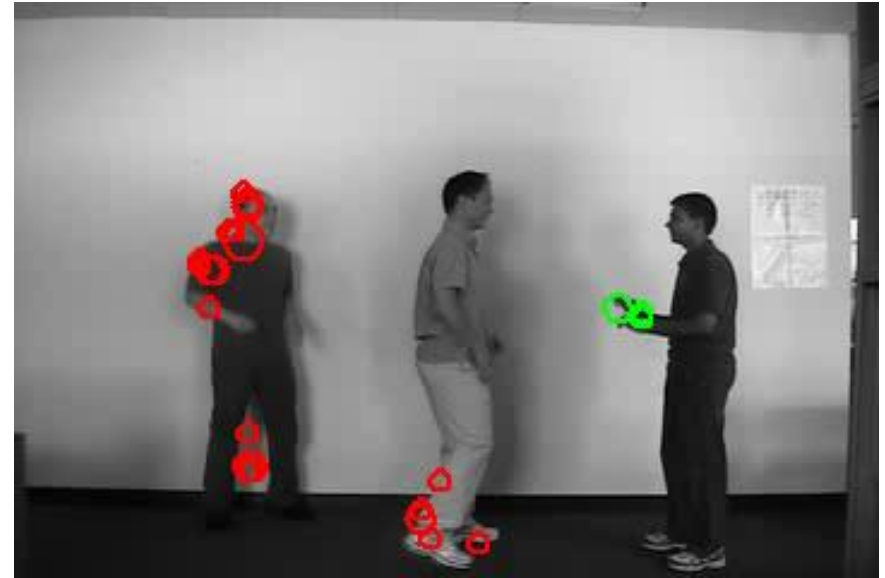
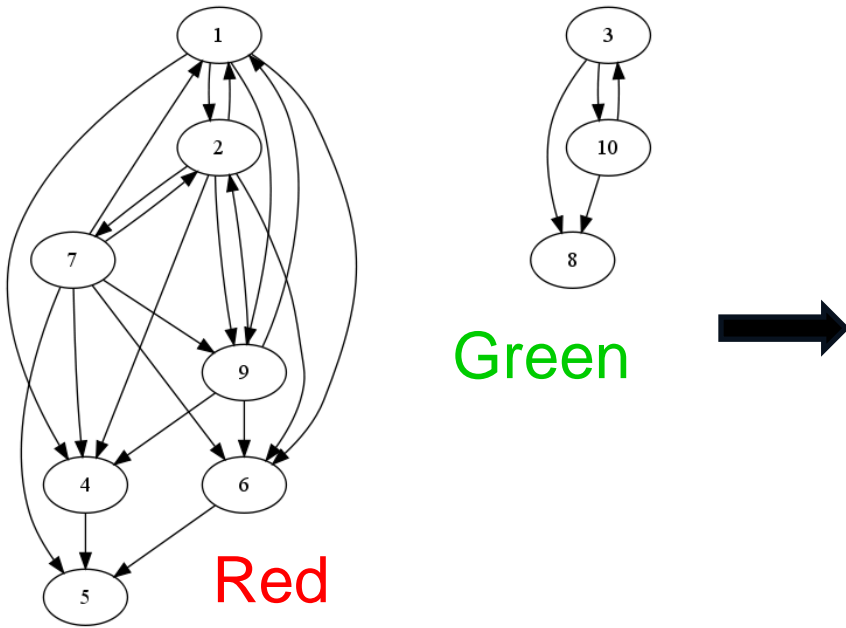


Visual Words



Causal Graph

Causal Sets

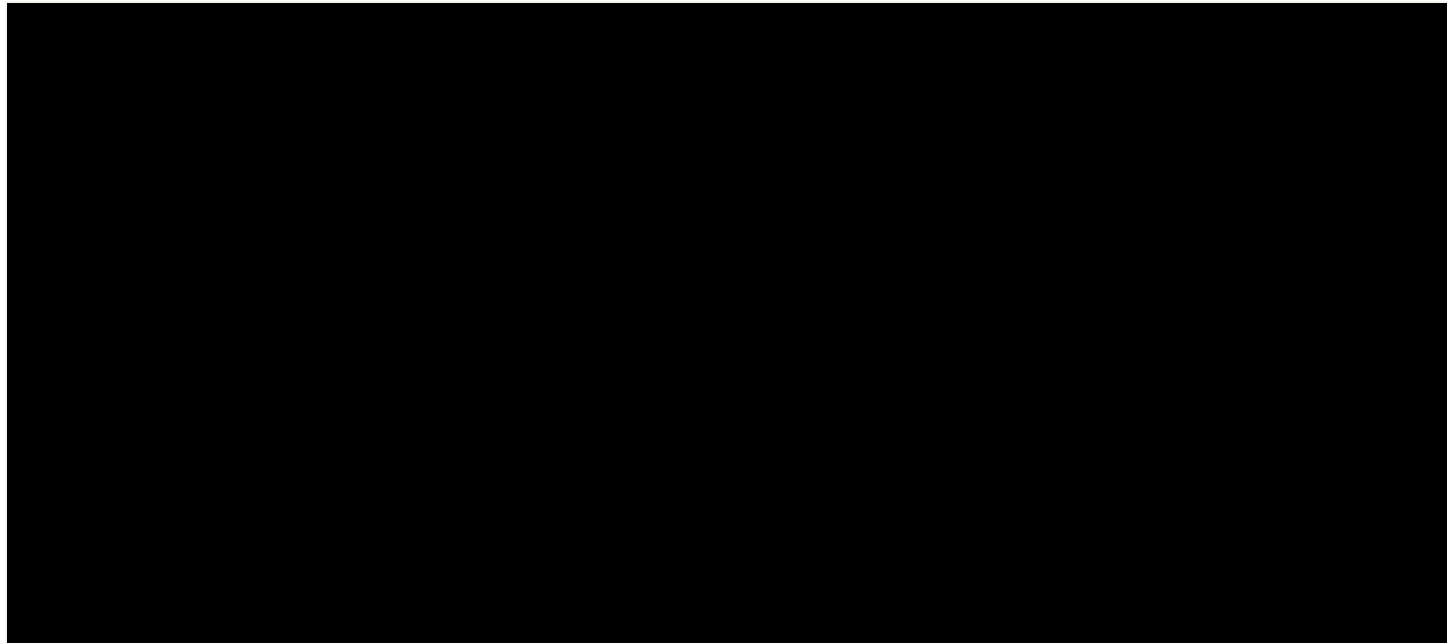


Causal Graph

Causal Grouping

Video segmentation based on *long-term temporal structure*

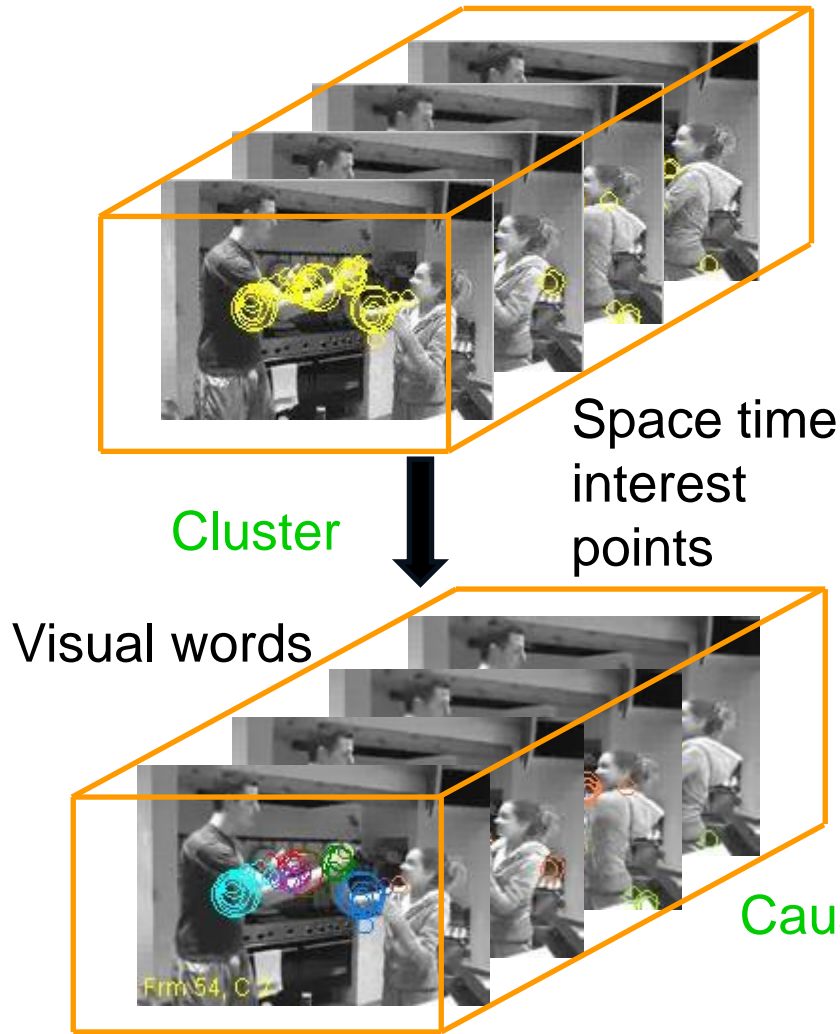
Grouping Results



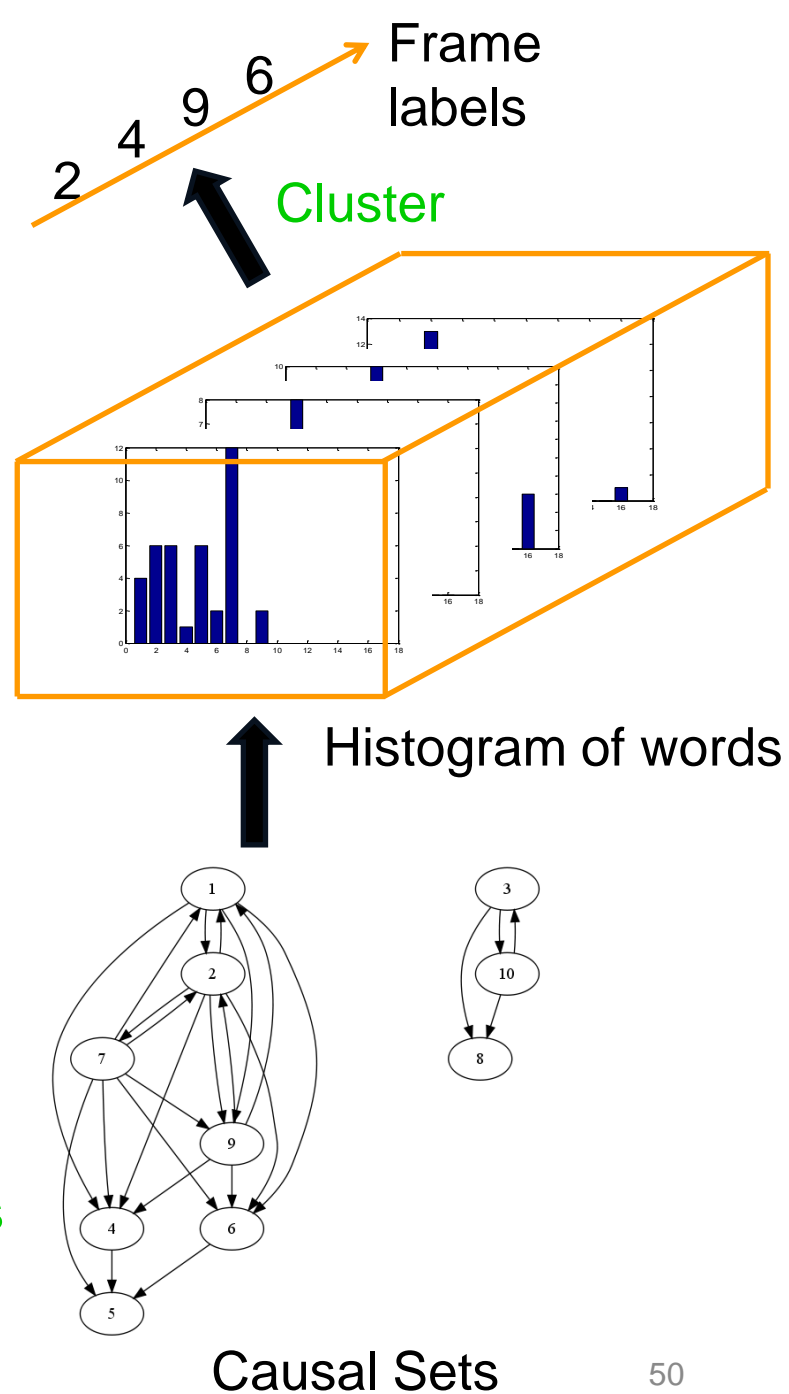
Retrieving Social Interactions

- Encode video frames as sequence of keyframe labels
 - One label sequence for each casual set
- Mine quasi-periodic patterns from sequence to identify social interactions

Quasi-Periodic Coding



Causal Analysis



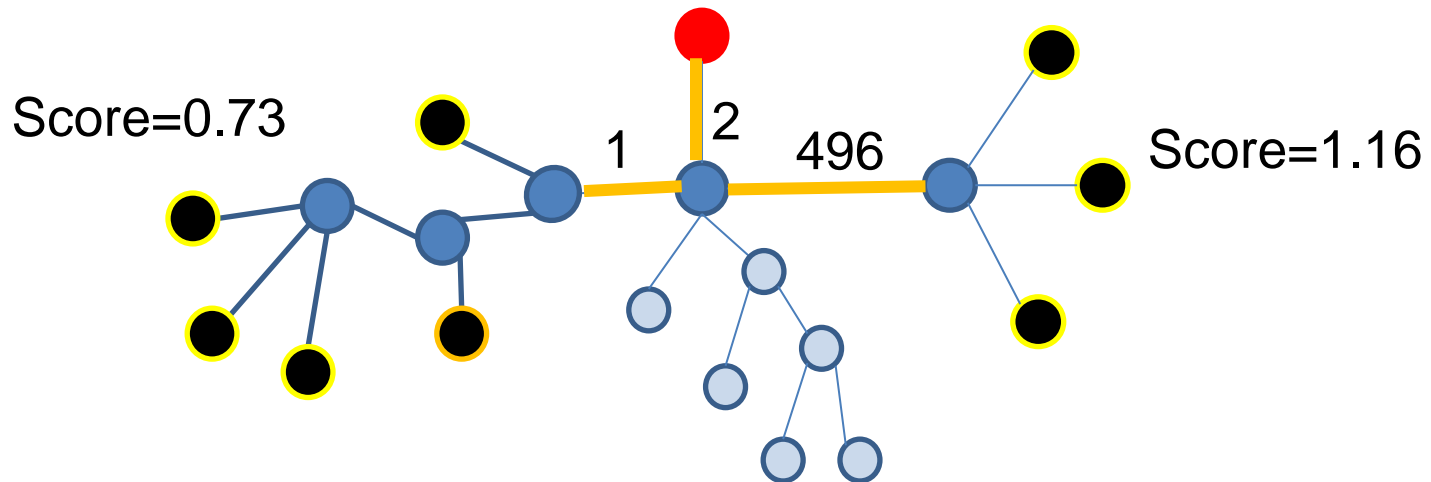
Mining Quasi-Periodic Patterns

↓

... 1 1 2 2 2 2 2 2 4 4 4 4 9 9 9 9 9 9 4
6 6 6 6 6 7 7...

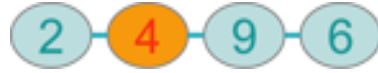
↓

Suffix tree



Heuristic scoring function to identify repeating patterns

Mined Pattern and Corresponding Frames



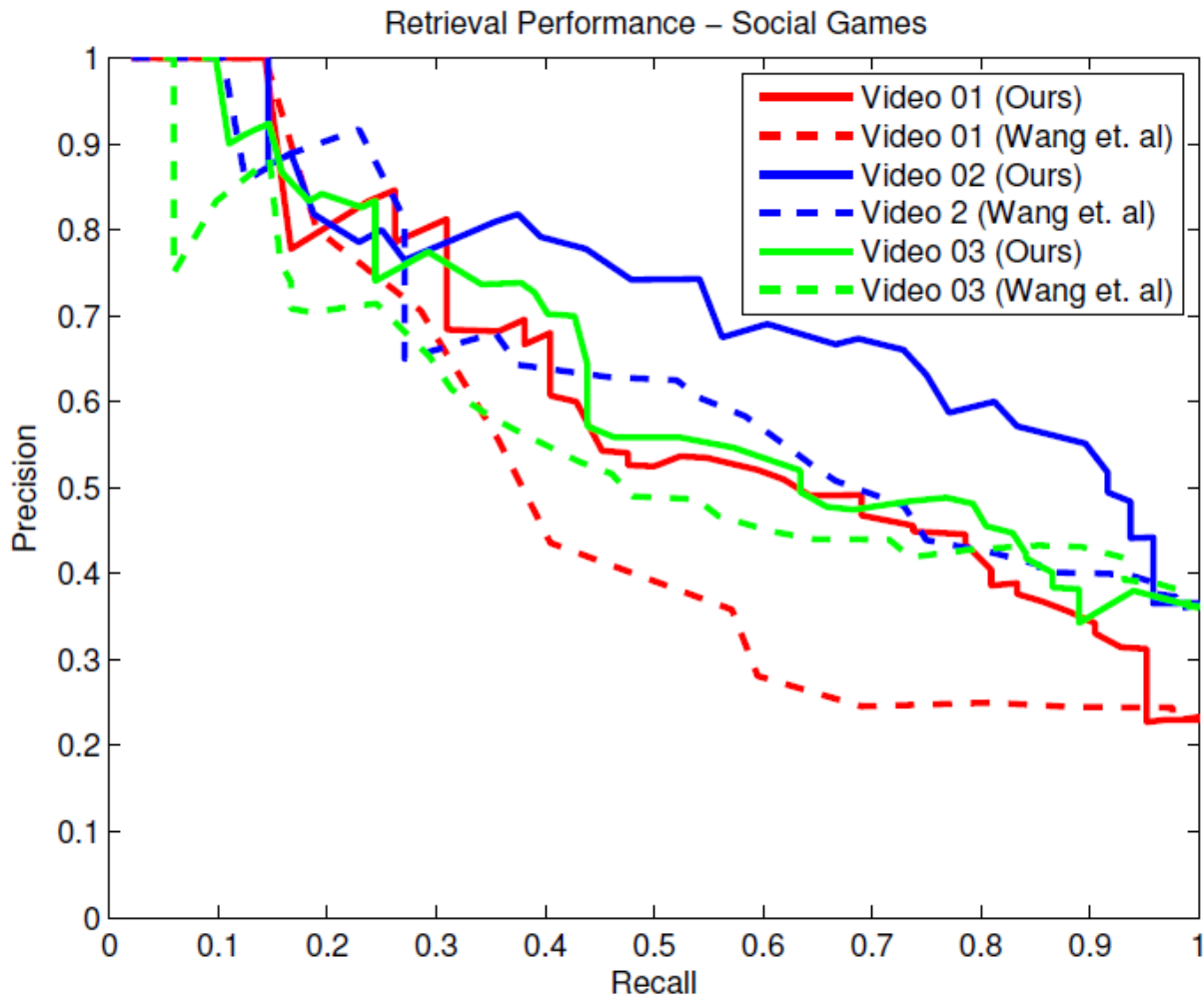
Advantages of Pattern-Mining Approach

- Supports bottom-up analysis and retrieval
- No need to pre-define activities
- No need to learn vocabulary of actions
- Automatically segment the stages of a game

Retrieval Examples

Social Game Retrieval

Retrieval Performance



Categorizing Social Games

- How can we leverage temporal causal analysis for categorization tasks?
- Use Multiple Instance Learning to avoid the need to label each causal set
- Treat each video as a bag, causal sets as instances, apply novel QP-MIL method
- Test on YouTube video clips

Categorization Results

Baby Toss



QP-MIL
➔



Patty Cake



QP-MIL
➔



QP-MIL Results

BabyToss	69.4	5.6	25.0		
BallRoll	2.6	84.2	7.9		
Pattycake	10.1	82.6	7.2		
Peekaboo	15.0	60.0	25.0		
Tickle	3.4	8.6	22.4	3.4	62.1
BabyToss	BallRoll	Pattycake	Peekaboo	Tickle	

Conclusions

- The AI community has great potential to impact the study and treatment of behavioral disorders
- The analysis of social behavior from multi-modal sensor data poses numerous challenges
- The temporal dimension of video has been largely neglected and is important for behavior
- We have presented an approach to video segmentation and retrieval based on temporal causality and quasi-periodic pattern analysis

<http://www.cbs.gatech.edu>