Detection of Anticipatory Dynamics between a pair of Zebra Fish

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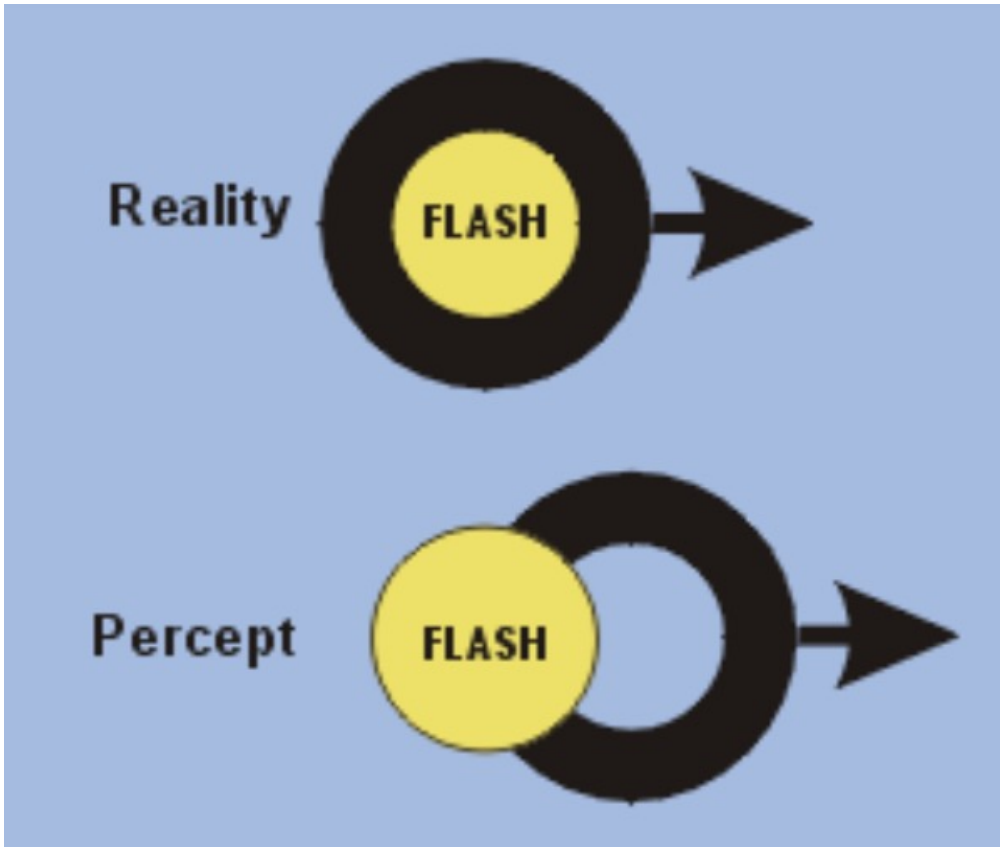
Content

- What is anticipatory dynamics?
  - Perception: temporal order is NOT causal order
  - causal order → direction of information flow
- What is social interaction?
  - anticipation of expected behavior
- Zebra fish social interaction experiments
  -- anticipation in a zebra fish pair?
  - information flow detection
    (mutual information and transfer entropy)
- Summary

Motion Anticipation: Flash-Lag



Perception:
we see the “future” ?

https://slideplayer.com/slide/11470660/

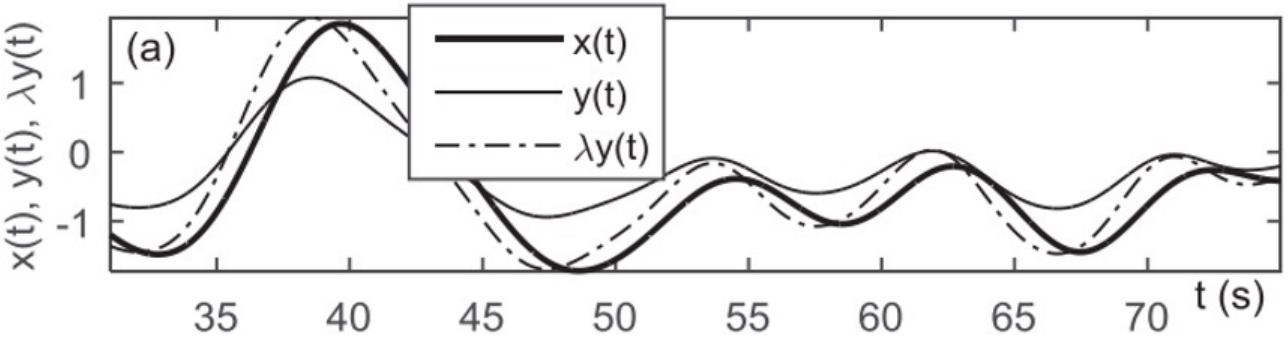
Voss' anticipatory relaxation dynamics

perception

Slow varying input signal

$$\dot{y}(t) = -\alpha y(t) + K[x(t) - y(t-\tau)]$$

delayed negative feedback



y(t) is ahead of x(t) by using its own past corrected by x(t)

Voss, Henning U. "Signal prediction by anticipatory relaxation dynamics." *Physical Review E* 93, no. 3 (2016): 030201.

Examples of Anticipatory Dynamics

- Compensate for the slow neural response
- Retina can anticipate moving objects
- Prey / Predator interaction
- Social interaction

Social Rules and Anticipation

- Social rules provide a framework for expected or anticipated behavior
- Anticipations are the expectations or predictions that arise within this framework: expecting others to do the same
- Changes in environment → sensory input → decision making based on social rules → action→ Social behaviors

Sensory input → Action: Information processing

Reynolds' model of flocking of bird-oid object (boid)

- Separation: Each boid steers to avoid bumping into nearby flockmates.
- Alignment: Steer towards the average heading of neighbors; used by Vicsek in 1995 PRL
- Cohesion: Boids attempt to stay close to nearby flockmates, creating a cohesive group movement

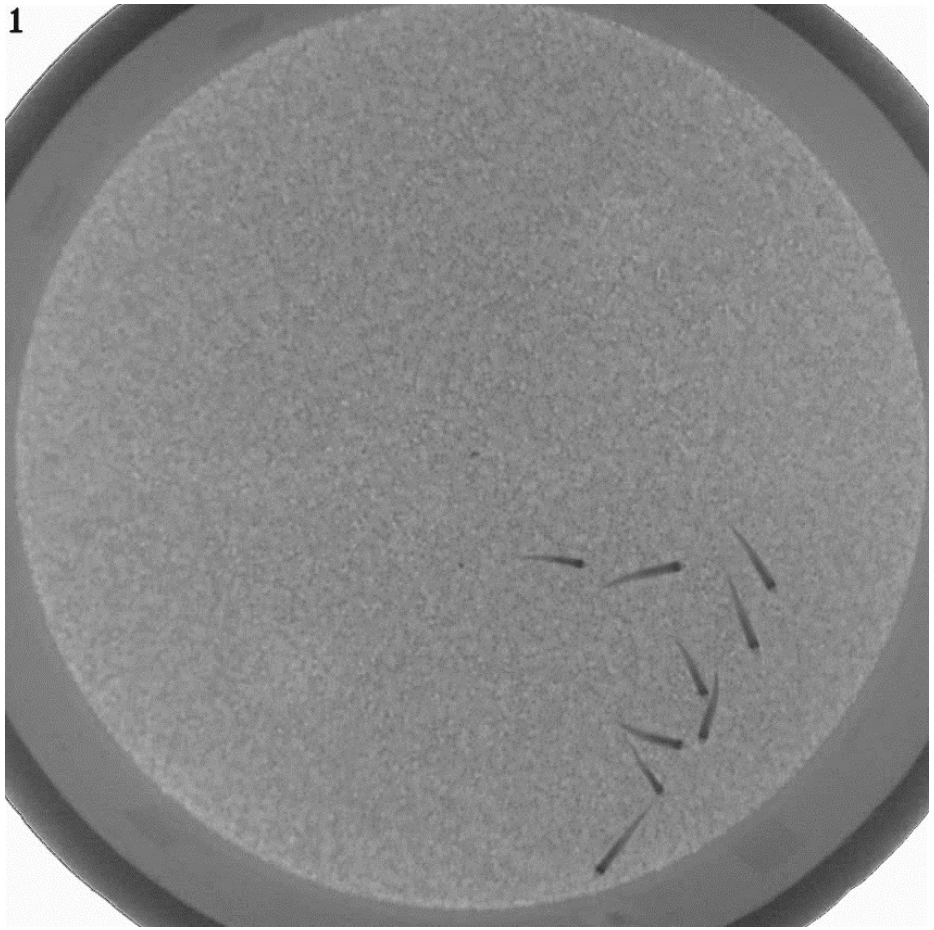
These social rules are anticipations

ComputerGraphics,Volume21, Number4, July 1987

Reynolds Boid video

ComputerGraphics,Volume21, Number4, July 1987

Schooling of zebra fish:
a social behavior? Role of AD?



Anticipation in zebrafish pair?

A pair of zebrafish – two time series of trajectories

Capture by CCD from images

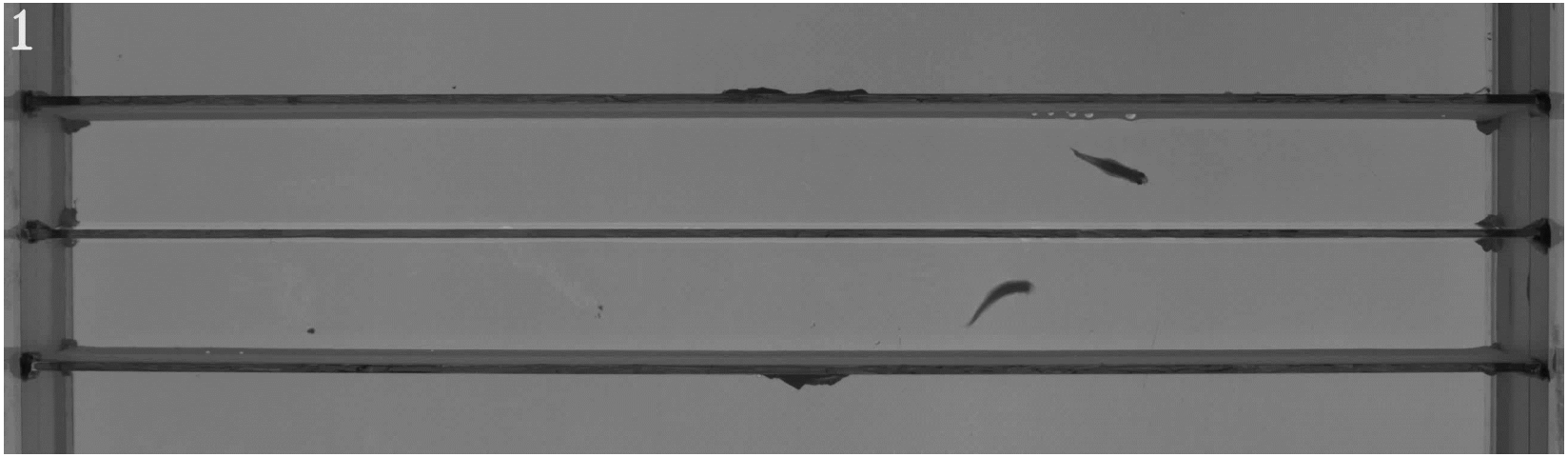
Establish events order of these two time series

Cross-correlation or time lag mutual information

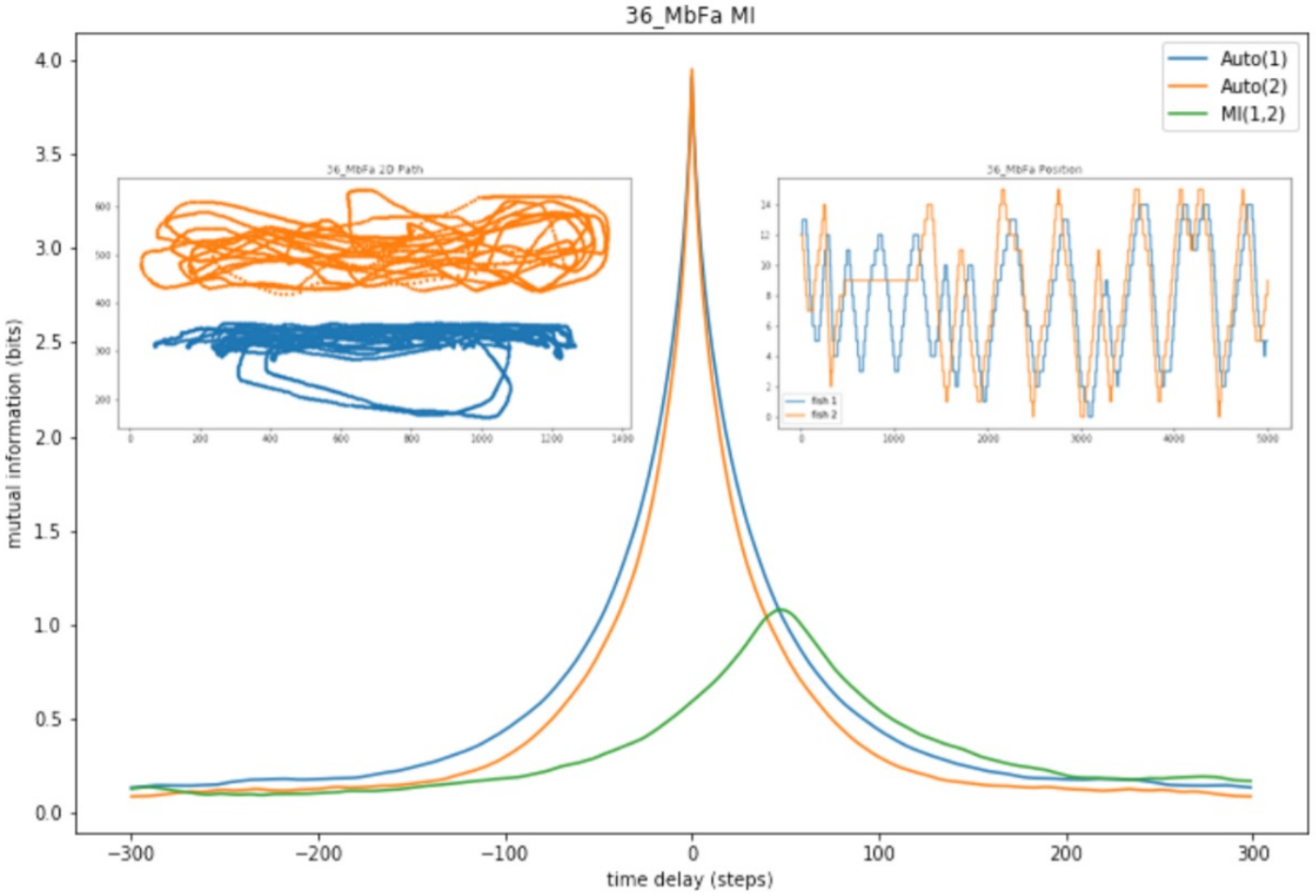
Determine direction of information flow between them

Granger Causality, Transfer entropy, …

Zebrafish separated by a window

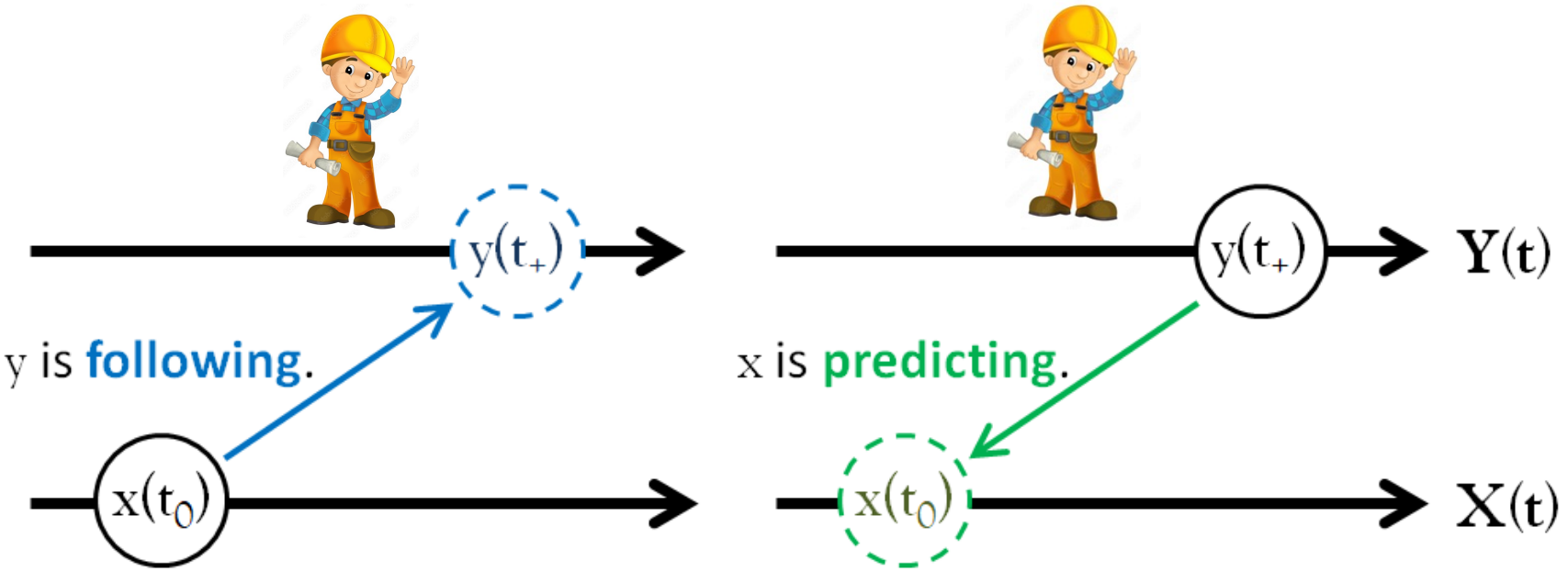


Time lag mutual information



Time step = 1/30 s

Anticipation and Temporal order

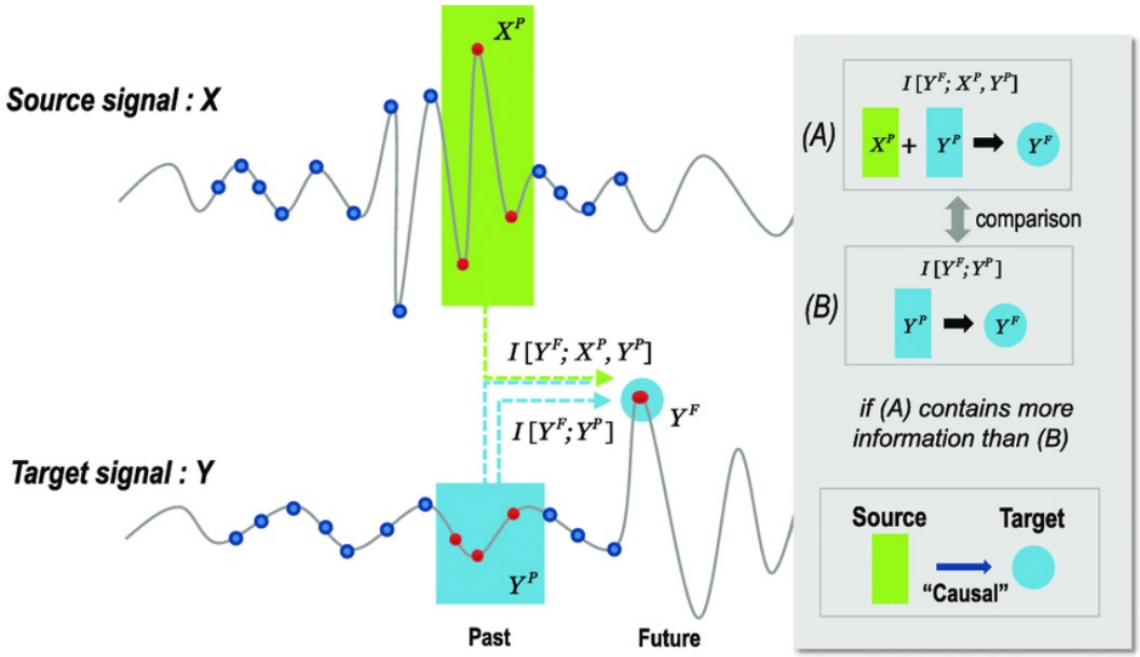


"Whenever I am here,
my master will come to me"

" My master will come home soon,
everyday he comes at this time"

Causal order → direction of information flow

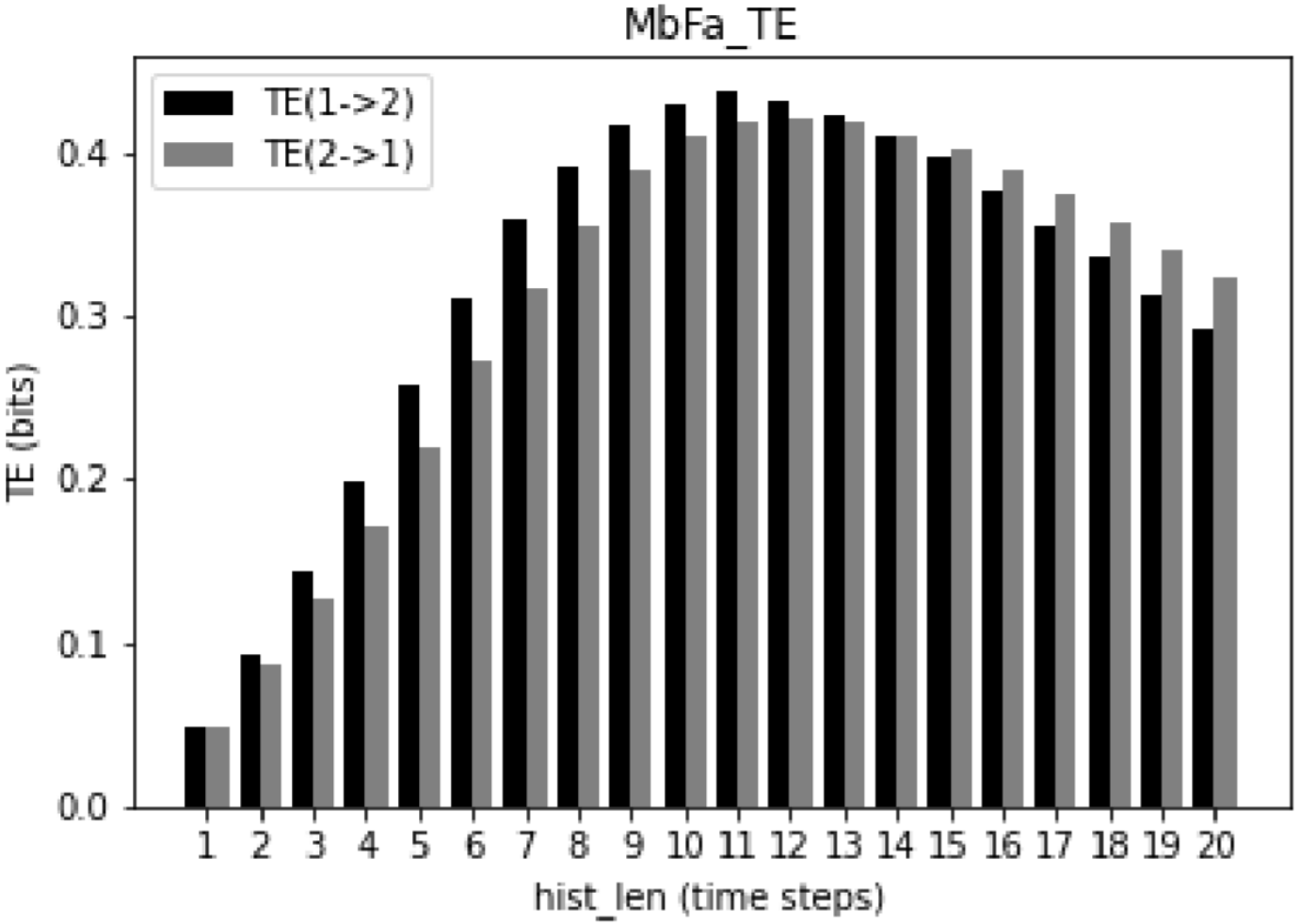
Transfer Entropy: extension of Granger causality



$$T_{X \to Y} = H\left(Y_t \mid Y_{t-1:t-L}\right) - H\left(Y_t \mid Y_{t-1:t-L}, X_{t-1:t-L}\right)$$

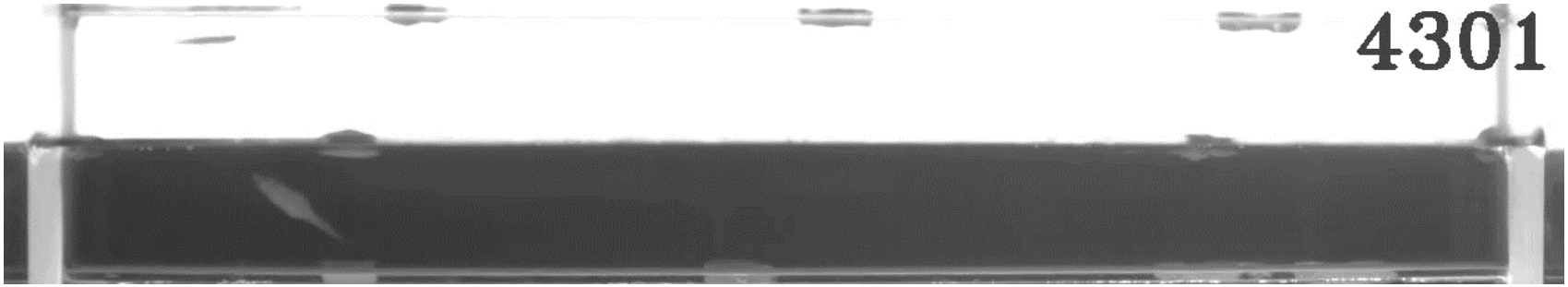
https://www.researchgate.net/figure/Schematic-illustration-of-transfer-entropy-Symbolic-transfer-entropy-measures-the-causal_fig1_236929181

History Length dependence of TE

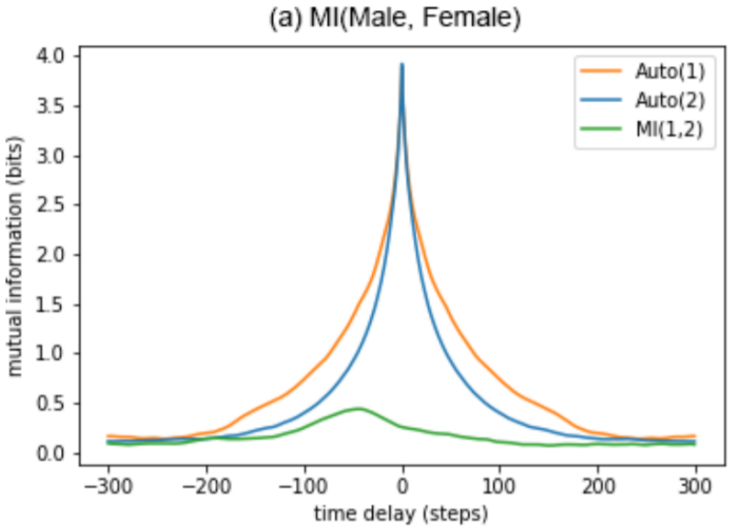


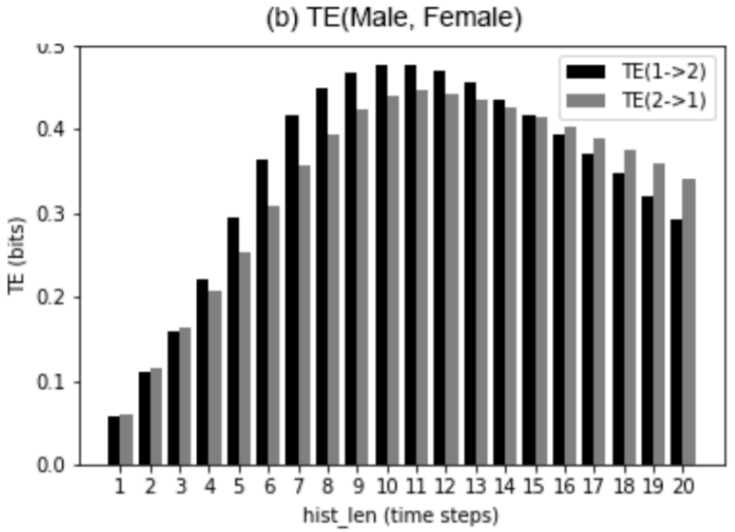
Time step = 1/30 s

One-way mirror experiment
Known source of information

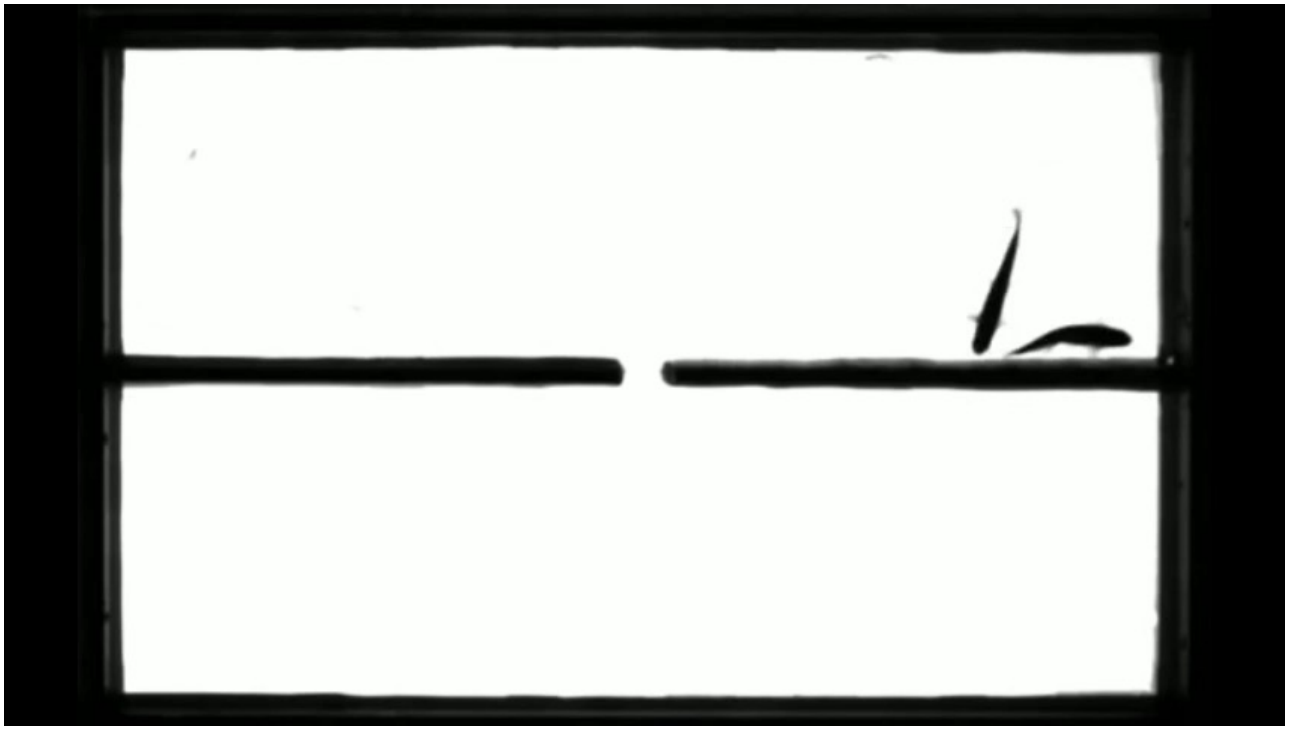


One-way mirror experiment: problem of history length

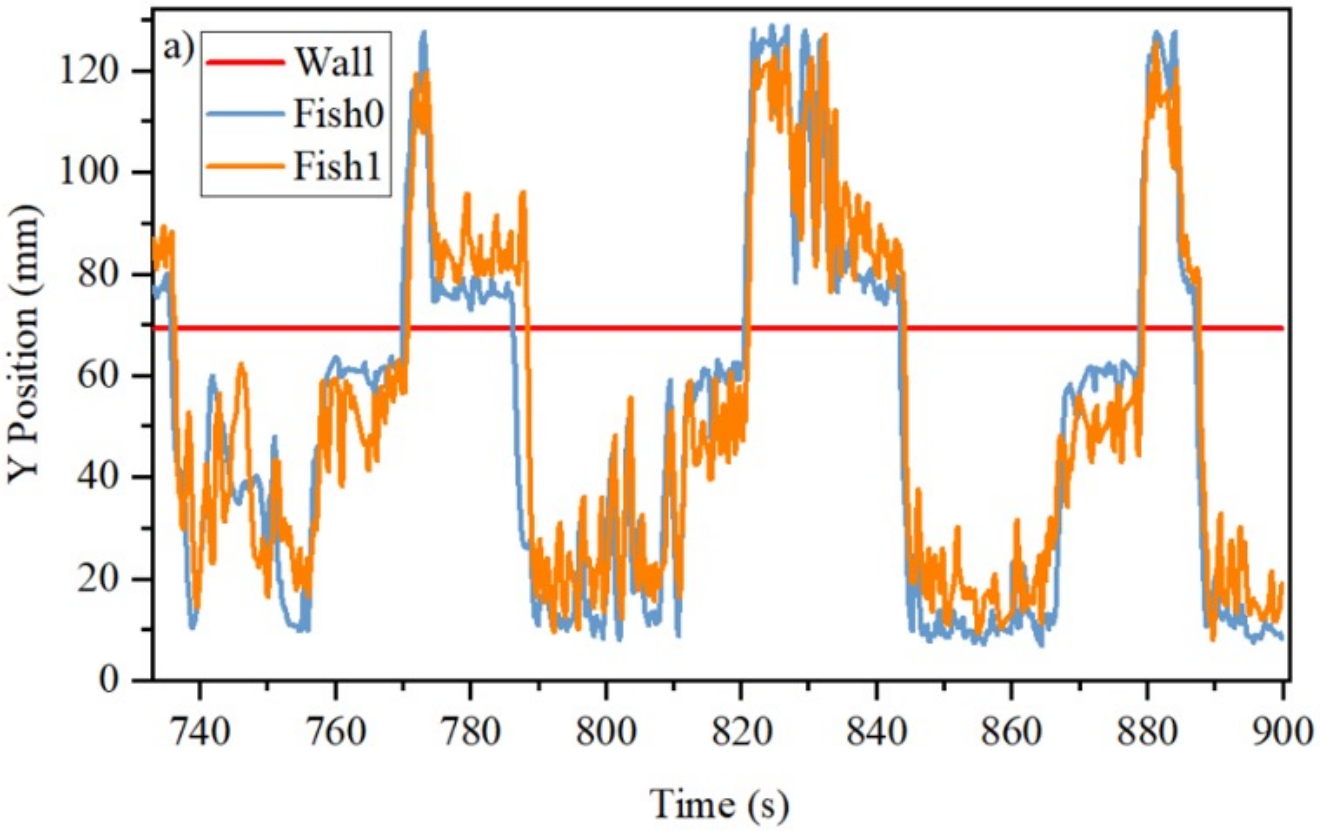




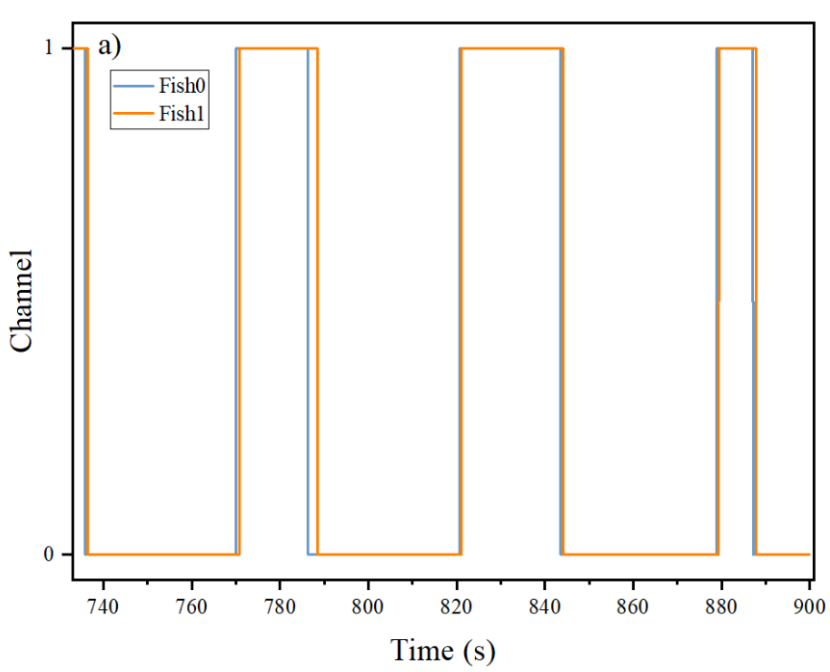
Two fish in a tank with a door

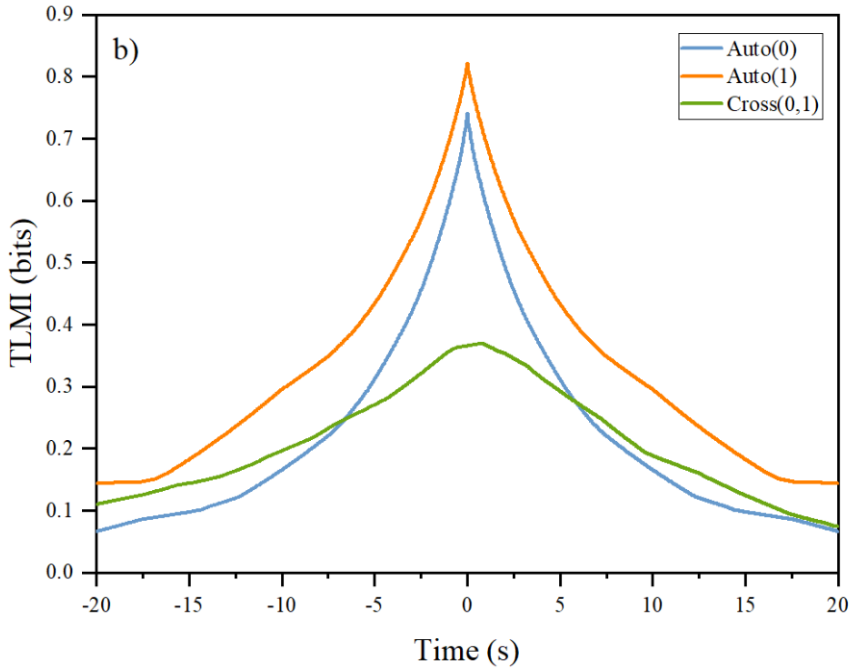


Trajectories in Y direction



Y state and its TLMI





AD detection

- X and Y components of the trajectories give different information
- A fish can decide to which tank it will go (Y direction) and is the information source.

AD is detected when peak position of TLMI for X and Y components are different in sign.

TABLE II: Summary of Experiment Data

	Fish	Properties of cross xTLMI			Properties of cross yTLMI		
	Pair	Peak Position(s)	Peak Height(%)	Decay Time(s)	Peak Position(s)	Peak Height(%)	Decay Time(s)
1	A	-0.83	0.22	0.57	-1.10	0.41	6.13
2	B	0.63	0.09	0.53	-3.87	0.35	7.90
3	B	-0.23	0.31	0.53	-0.53	0.48	6.03
4	C	-0.60	0.12	0.87	-0.73	0.19	3.97
5	D	0.50	0.09	0.47	-3.30	0.28	9.30
6	D	-0.63	0.12	0.60	-11.17	0.20	19.97
7	E	-0.77	0.20	0.40	-1.43	0.36	19.97
8	F	0.47	0.13	0.50	-0.53	0.26	2.53
9	F	-0.27	0.16	0.53	-1.13	0.19	2.47
10	G	-0.63	0.22	0.63	-1.73	0.39	13.47
11	H	-0.60	0.26	0.63	-1.37	0.26	4.67
12	I	-0.30	0.17	1.23	-0.67	0.22	7.40
13	J	-0.43	0.25	0.47	-0.53	0.34	4.93
14	L	0.57	0.23	0.83	-0.33	0.30	17.53
15	L	-0.67	0.27	1.03	-1.33	0.31	9.47
16	M	-0.40	0.21	0.87	-1.43	0.23	3.73

Summary of experiments

- Anticipatory dynamics (AD) observed in the social interaction between Zebra fish
- Most interactions are “following”
- Roles of source/receiver are not constant
- Both GC and TE detect causality as temporal order

→ new tools are needed to detect AD

if it is possible!

- Leaders might be present in a school of fish

Summary for AD

- For anticipatory dynamics (AD), causal events are not ordered by time but by information flow
- Possible because of information processing
- AD can be implemented by a delayed negative feedback mechanism which can lead to negative group delay

  (Poster P2 in next week: Anticipation in a Retina)
- Social rules are anticipations