On the use of Sheep to Model Pedestrian Evacuation through Narrow Doors

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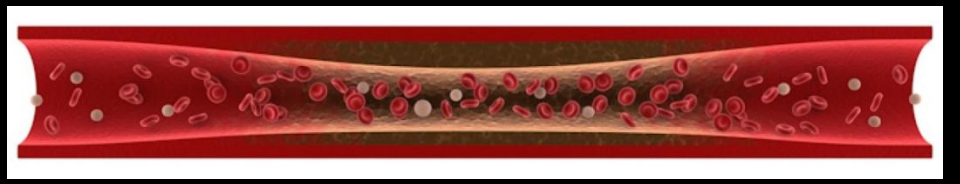
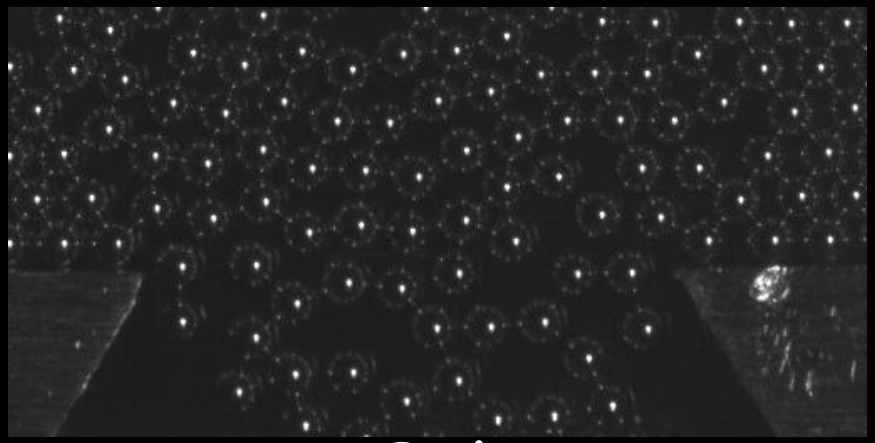
Flow through bottlenecks



Blood vessels



Grains

PRE 68, 030301 (2003)
PRL 107, 278001 (2011)
PRL 108, 248001 (2012)
PRL 109, 068001 (2012)
PRL 114, 238002 (2015)

Pedestrian flow through bottlenecks

- Scarce available data from real cases (and complicated geometries that prevent generalization)
- Experiments are difficult (and expensive)
- Mostly, the number of people involved is small
- Competitiveness is difficult to achieve

NUMERICAL MODELS

ANIMAL EXPERIMENTS

Animals passing through bottlenecks

Ants

Safety Science 72 (2015) 274–282

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Faster-is-slower effect in escaping ants revisited: Ants do not behave like humans

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ARTICLE INFO

Article history:
Received 22 July 2014
Accepted 19 September 2014

Keywords:
Emergency
Evacuation
Egress
Ant egress
Crowd egress
Faster is slower
Pedestrian evacuation
Pedestrian dynamics

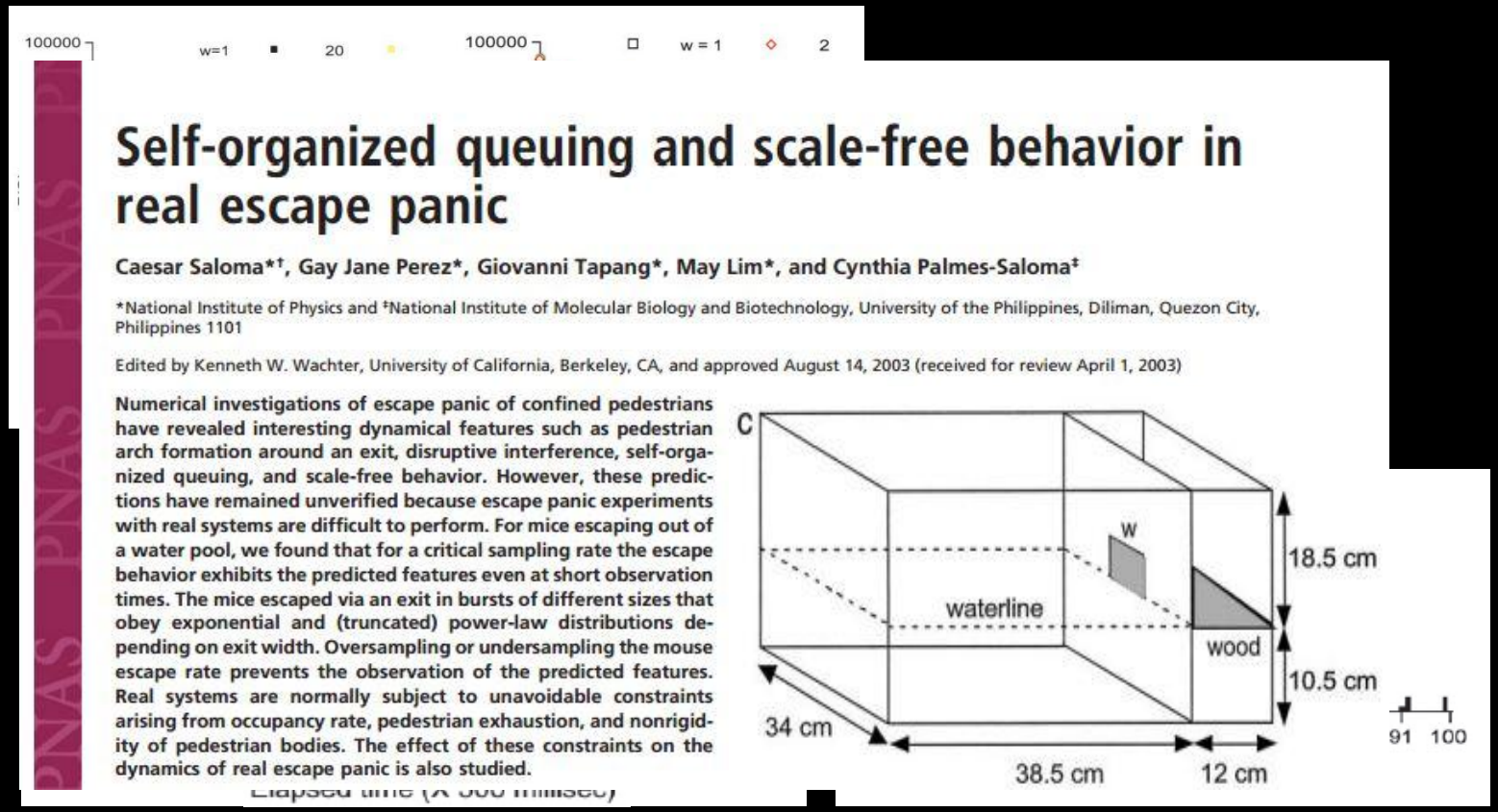
ABSTRACT

In this work we studied the trajectories, velocities and densities of ants when egressing under controlled levels of stress produced by a chemical repellent at different concentrations. We found that, unlike other animals escaping under life-and-death conditions and pedestrian simulations, ants do not produce a higher density zone near the exit door. Instead, ants are uniformly distributed over the available space allowing for efficient evacuations. Consequently, the faster-is-slower effect observed in ants (Soria et al., 2012) is clearly of a different nature to that predicted by de social force model. In the case of ants, the minimum evacuation time is correlated with the lower probability of taking backward steps. Thus, as biological model ants have important differences that make their use inadvisable for the design of human facilities.

Velocity is almost independent on density!

Animals passing through bottlenecks

Mice



100000 w=1 20 100000 w = 1 2

PNAS PNAS PNAS

Self-organized queuing and scale-free behavior in real escape panic

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Edited by Kenneth W. Wachter, University of California, Berkeley, CA, and approved August 14, 2003 (received for review April 1, 2003)

Numerical investigations of escape panic of confined pedestrians have revealed interesting dynamical features such as pedestrian arch formation around an exit, disruptive interference, self-organized queuing, and scale-free behavior. However, these predictions have remained unverified because escape panic experiments with real systems are difficult to perform. For mice escaping out of a water pool, we found that for a critical sampling rate the escape behavior exhibits the predicted features even at short observation times. The mice escaped via an exit in bursts of different sizes that obey exponential and (truncated) power-law distributions depending on exit width. Oversampling or undersampling the mouse escape rate prevents the observation of the predicted features. Real systems are normally subject to unavoidable constraints arising from occupancy rate, pedestrian exhaustion, and nonrigidity of pedestrian bodies. The effect of these constraints on the dynamics of real escape panic is also studied.

C

w

waterline

wood

18.5 cm

10.5 cm

34 cm

38.5 cm

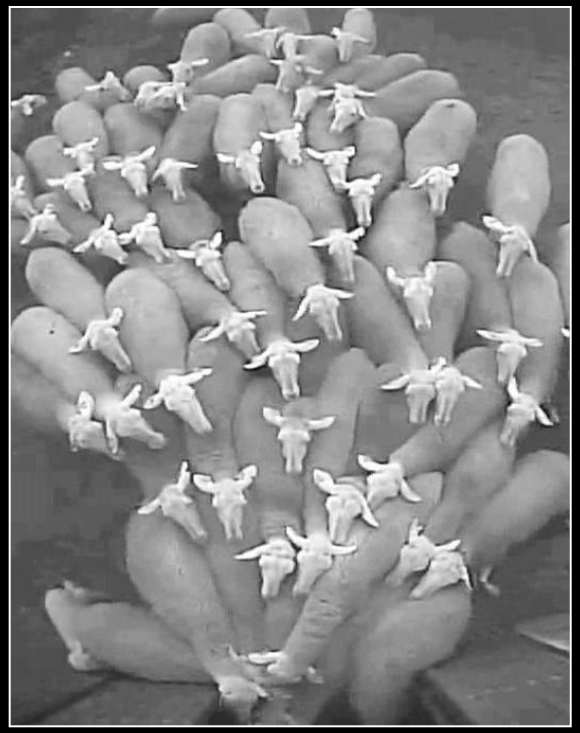
12 cm

91 100

Elapsed time (X 500 milliSec)

Crowding in the outlet is not observed!

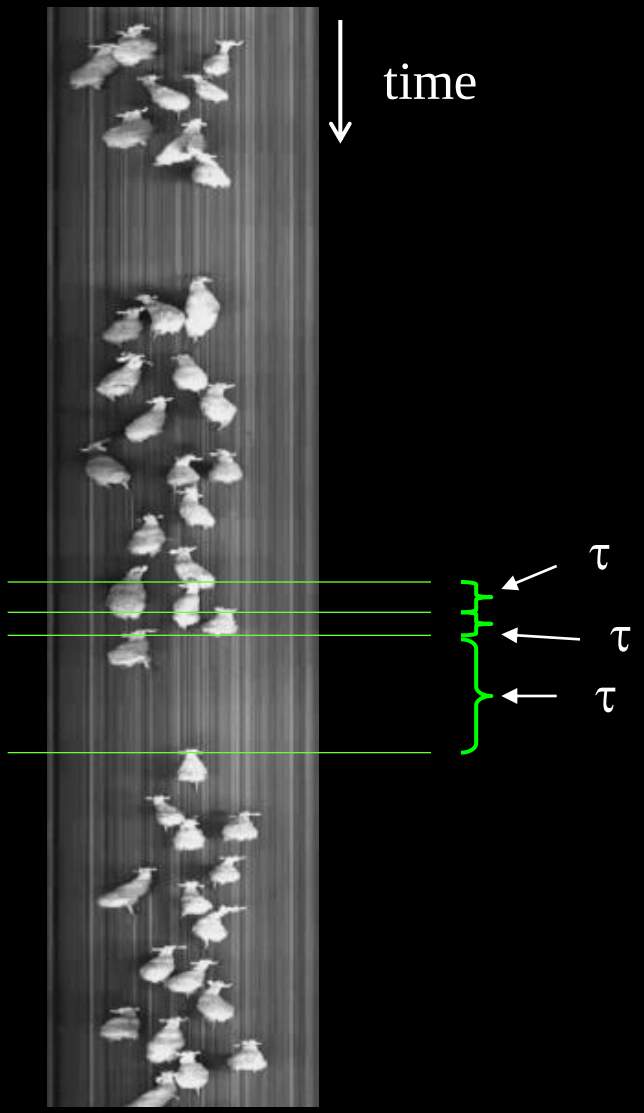
Sheep



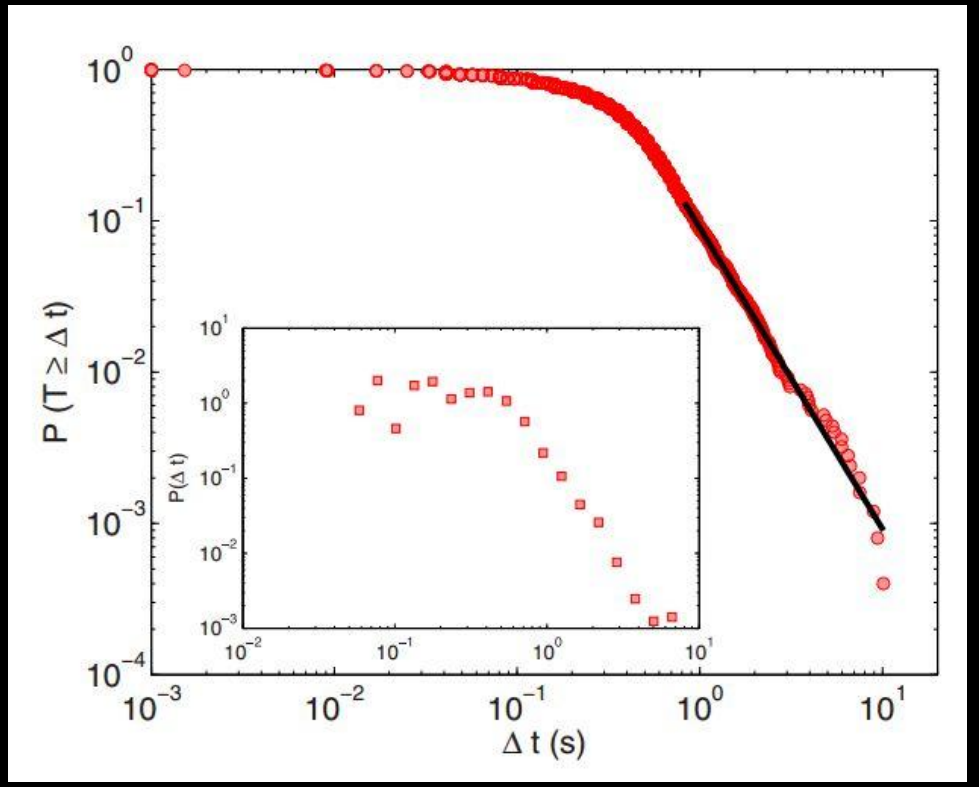
Very competitive (for food)
Gregarious
Size and velocity ~ humans
Easy to find them in barns
Typically in large numbers
All the same size

One test per day (need to be hungry)
Shape
Move along their long axis
Quadruped
Nasty smell

Intermittent flow of sheep

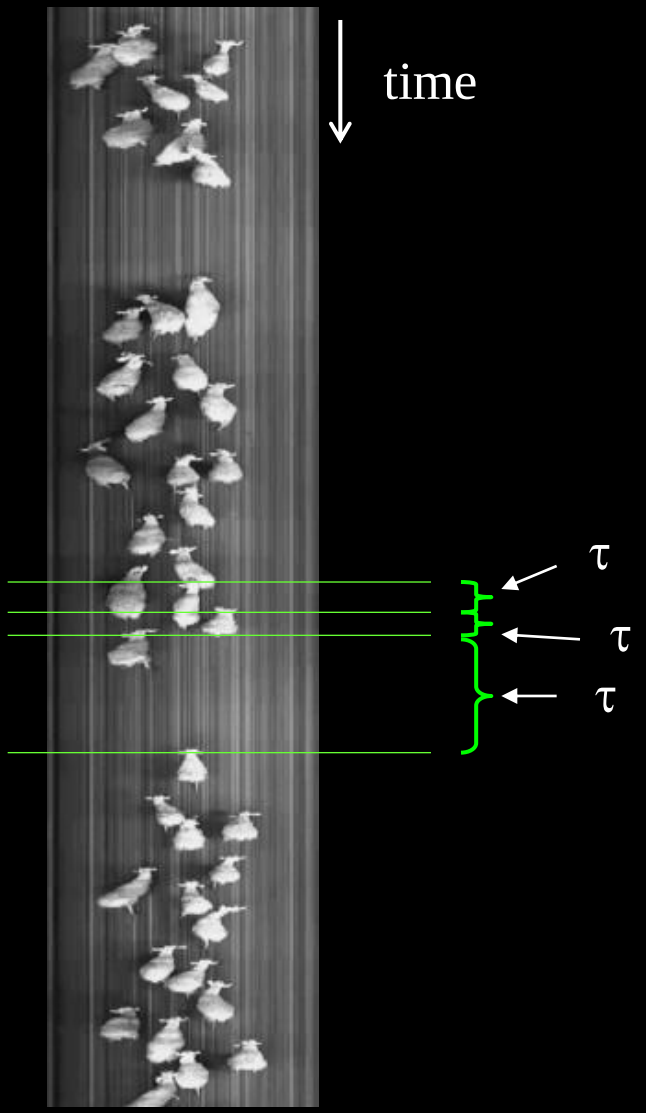


Clogging time: power-law tail

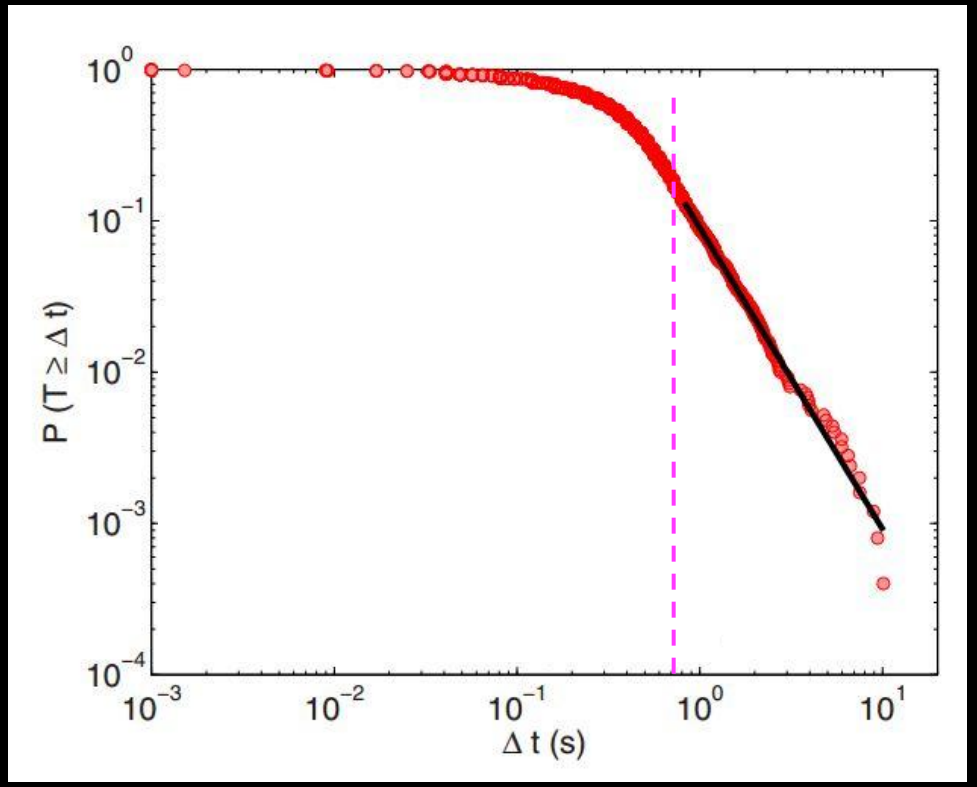


A. Clauset, C. R. Shalizi and M. E. J. Newman,
"Power-Law Distributions in Empirical Data"
SIAM Review **51**, 661-703 (2009)

Intermittent flow of sheep



Clogging time: power-law tail



A. Clauset, C. R. Shalizi and M. E. J. Newman,
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SIAM Review **51**, 661-703 (2009)

exponent α & t_{min}

Intermittent flow of sheep

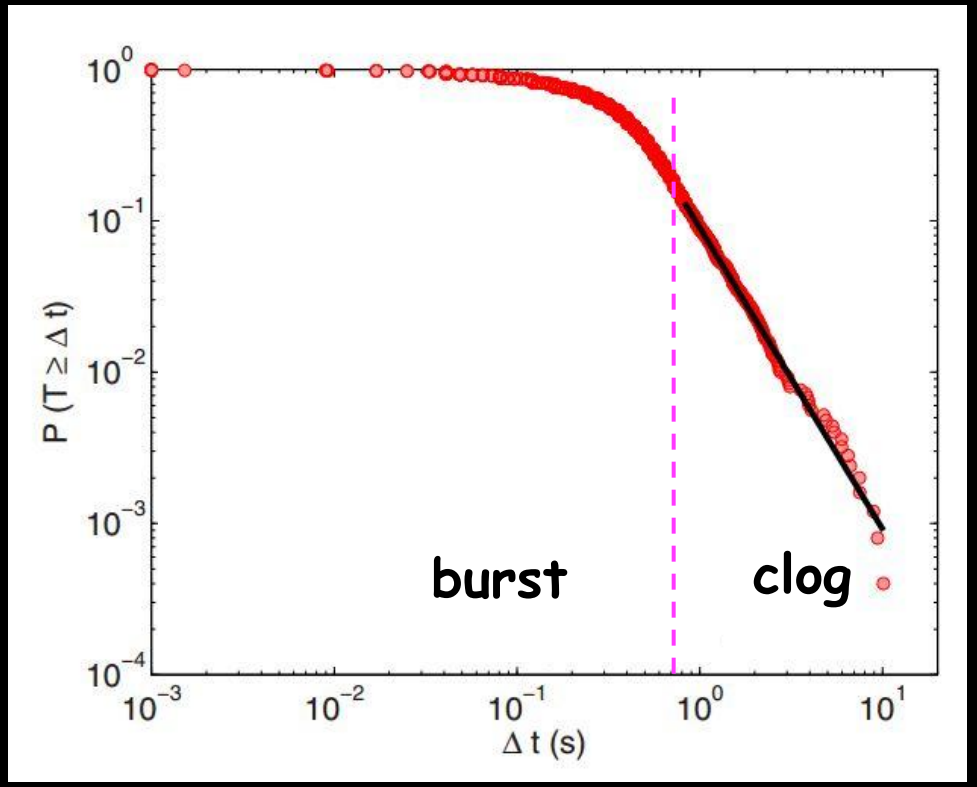
Clog

"Burst"
(burst size s =17)

Clog

"Burst"

Clogging time: power-law tail



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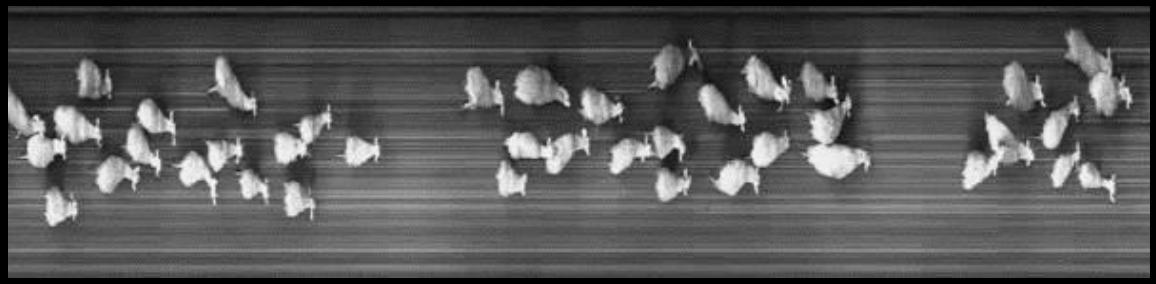
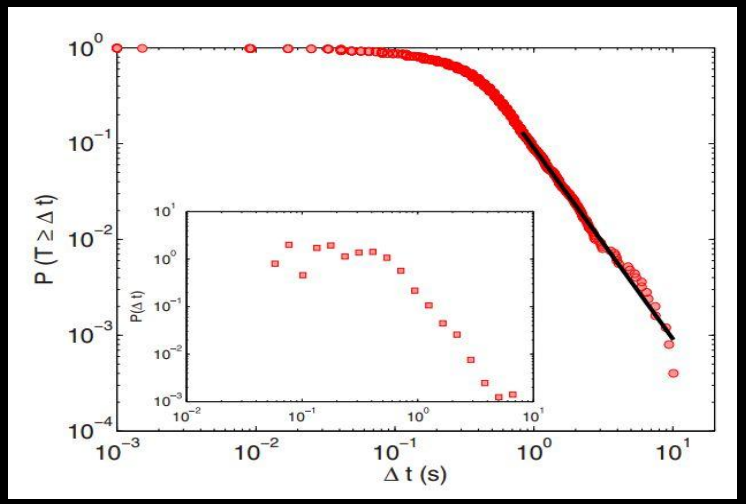
exponent α & t_{min}

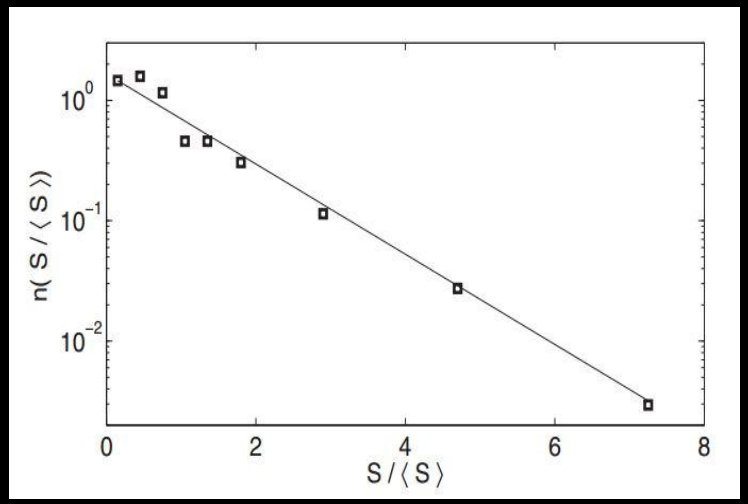
Intermittent flow of sheep



Clogging time: power-law tail



Burst sizes: exponential decay



Take care with averages!

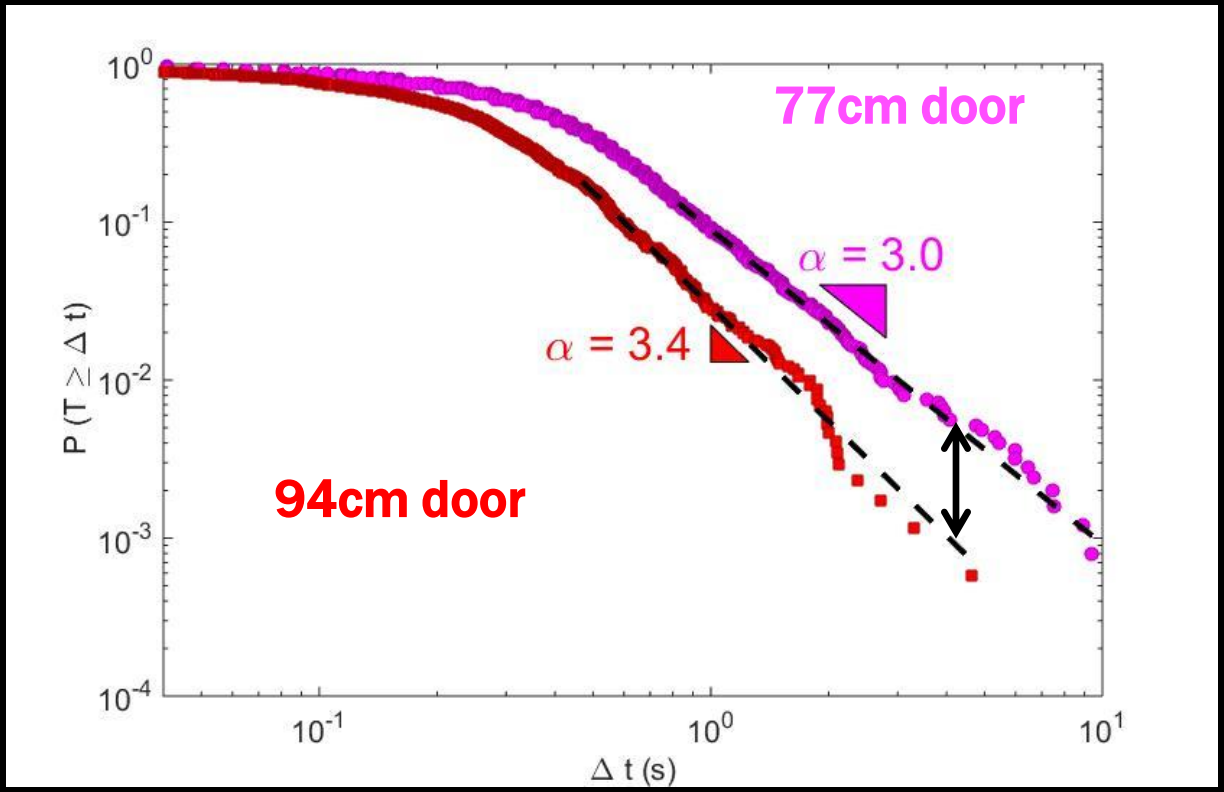
Evacuation time is strongly affected by clogging times!

A. Garcimartín et al. Scientific Reports **4**, 7324 (2014)

Flow of sheep through bottlenecks: door size

‹τ›=0.50

‹τ›=0.30



Affects bursts and clogging dynamics!

PRE 91, 022808 (2015).

Flow of sheep through bottlenecks: obstacle

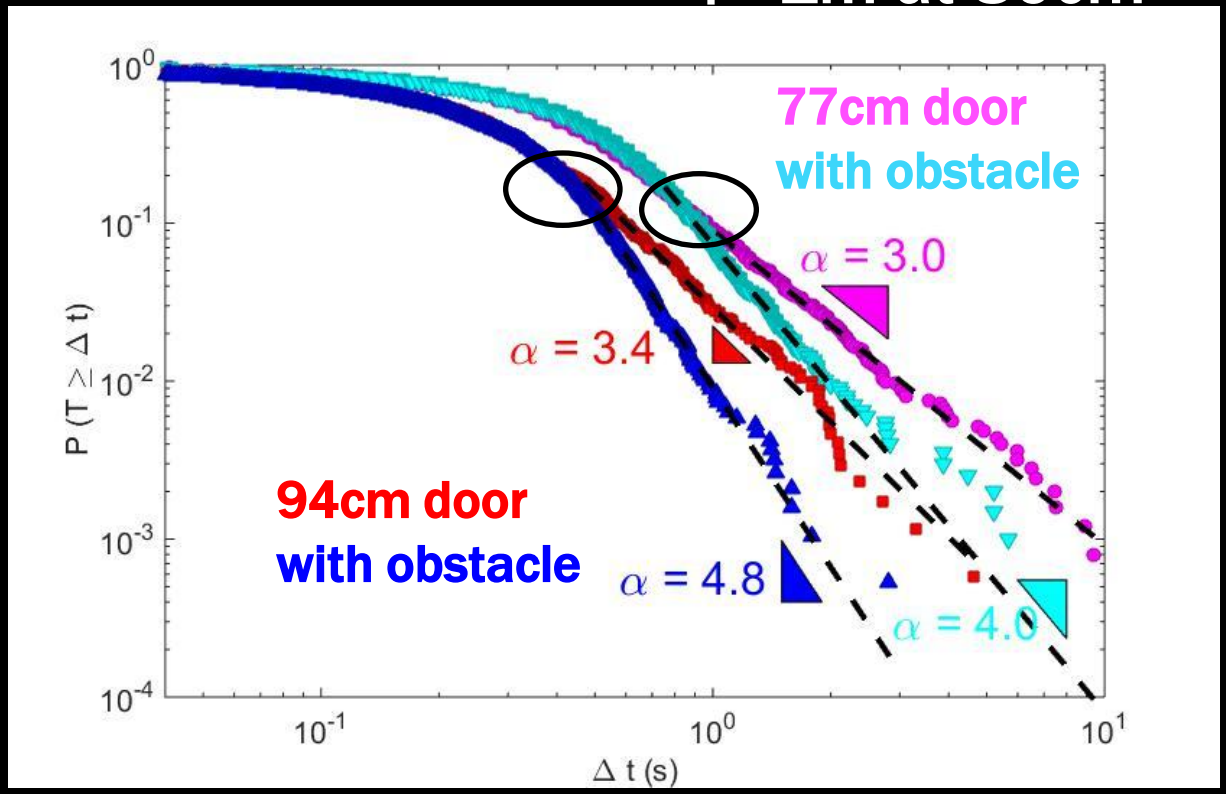
Φ=1m at 80cm

‹τ›=0.50

‹τ›=0.47

‹τ›=0.30

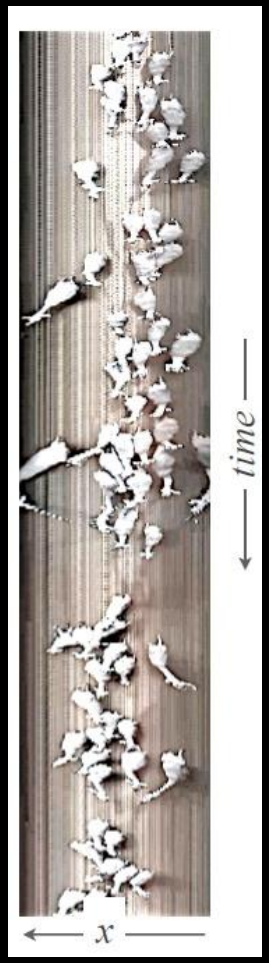
‹τ›=0.27



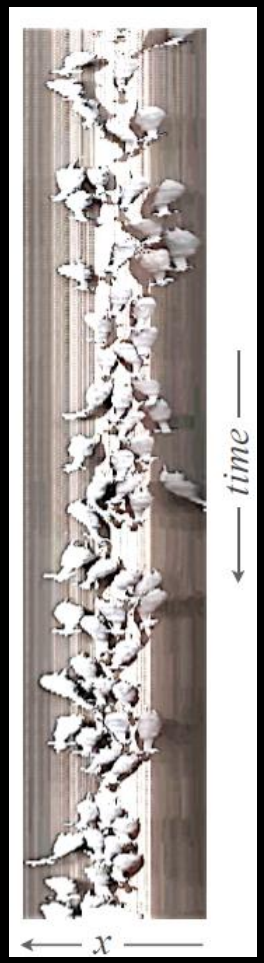
Affects ~~bursts~~ and clogging dynamics!

PRE 91, 022808 (2015).

Flow of sheep through bottlenecks: competitiveness

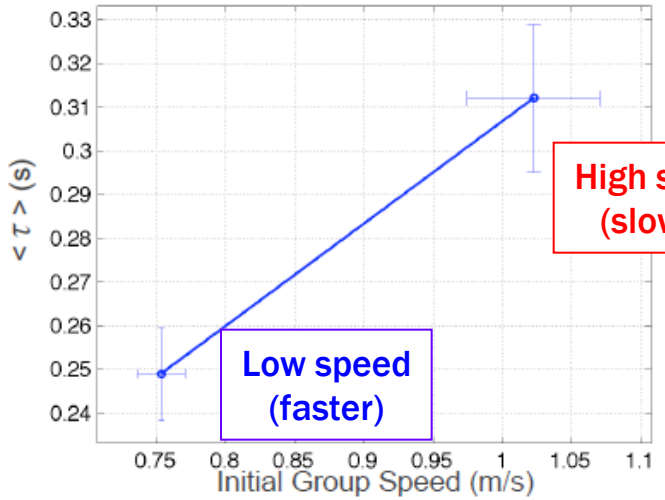


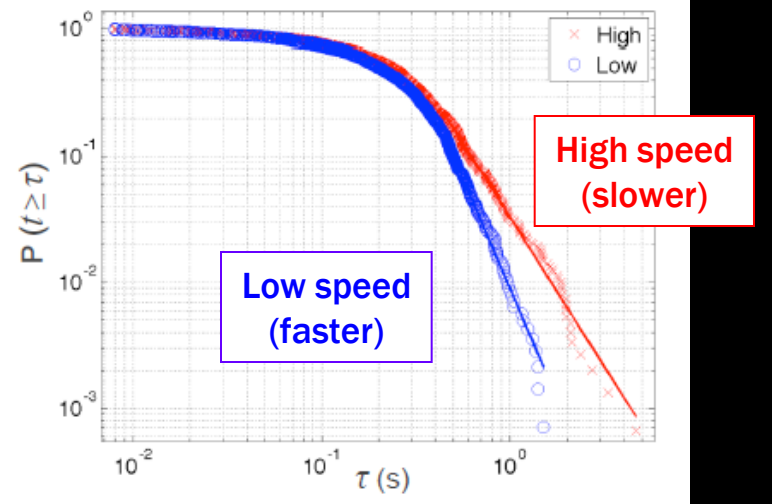
High
(cold days)



Low
(warm days)

Faster is slower





Pedestrian evacuations through bottlenecks

Two days (~ 30 evacuations each)

- First day (to acquire experience)

Transport. Res. Proc. 2, 760 (2014)

- Second day (systematic exp.):

95 volunteers

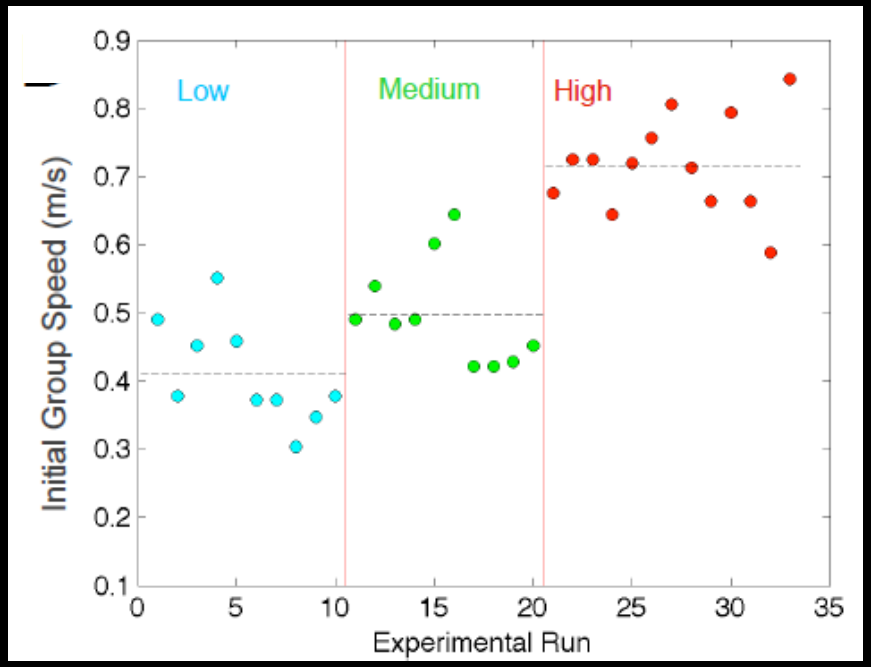
Door size reduced

3 competitiveness degrees (pushing allowed)

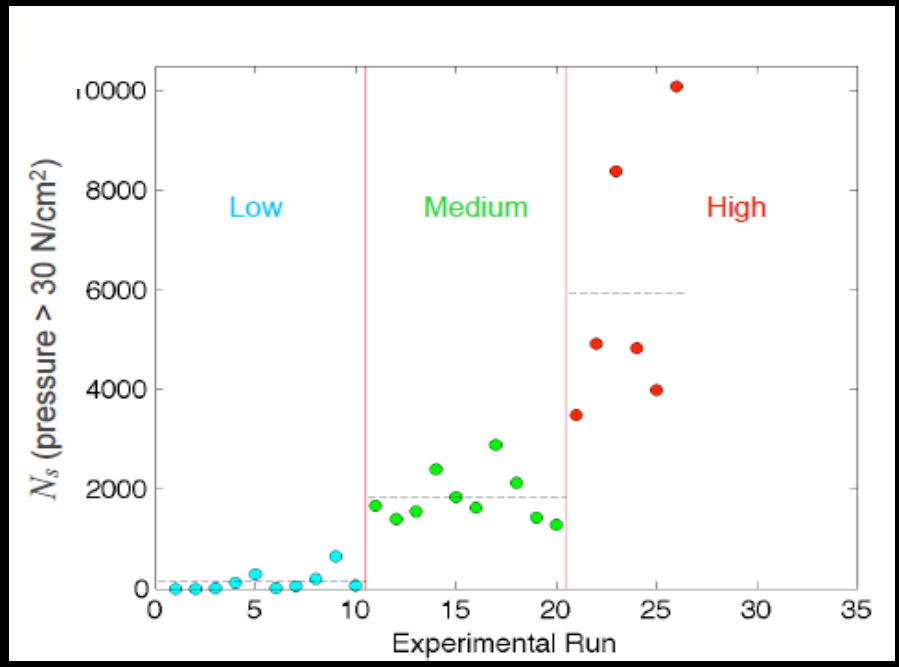
Pressure sensors

Flow of pedestrians: competitiveness quantification

Initial group speed

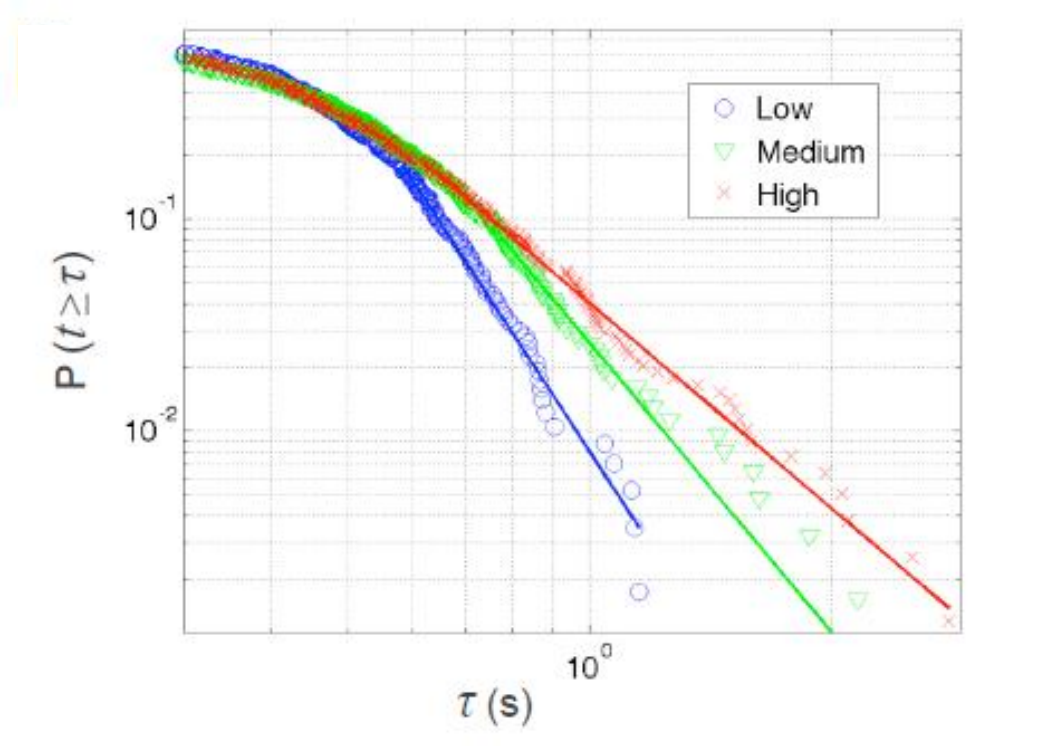


Pressure

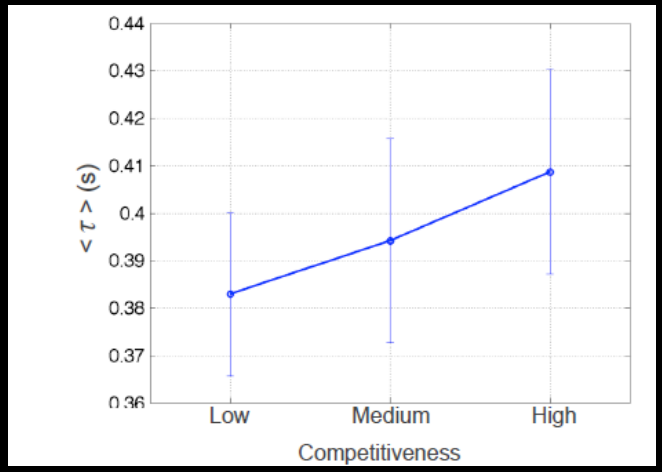


Intermittent flow of pedestrians: competitiveness

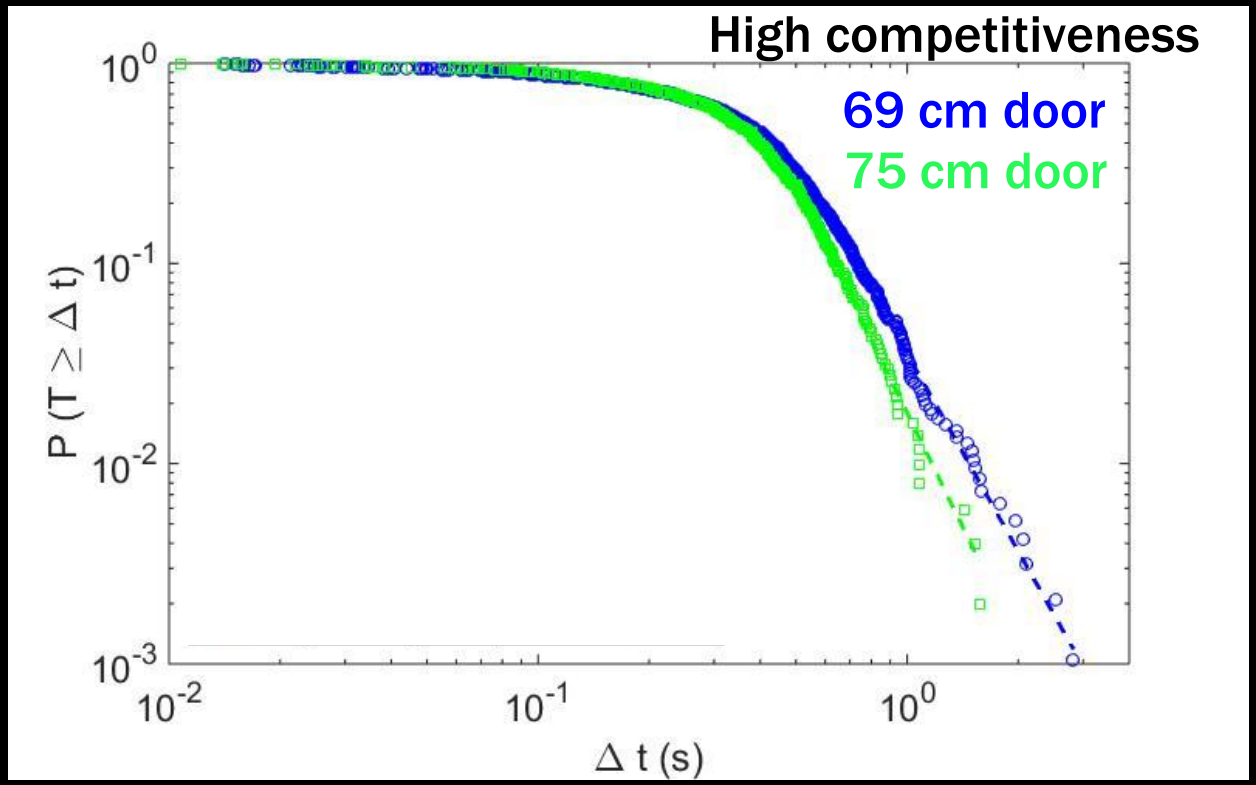
Low **Medium** **High**



Faster is slower

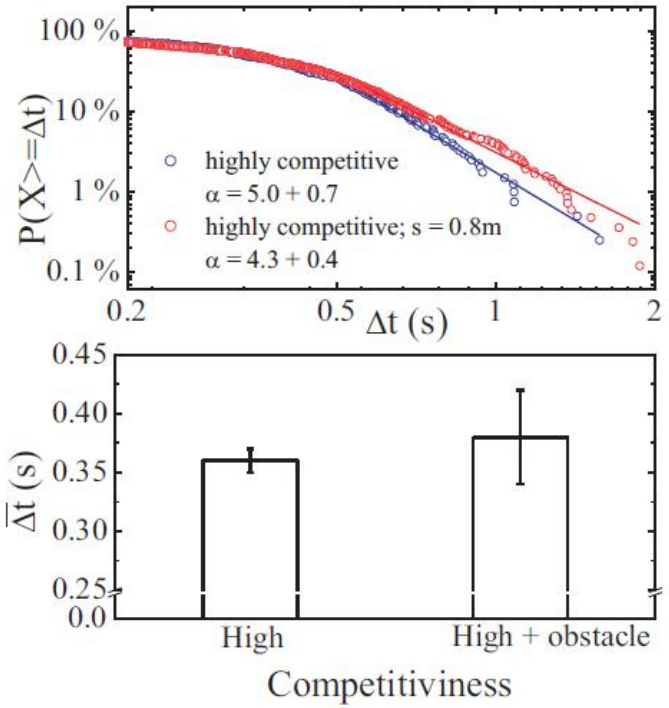


Intermittent flow of pedestrians: door size



Intermittent flow of pedestrians: obstacle

(1 m diameter, at 0.8 m in front of the door)



Too far? **Too small?** **Not enough statistics?**

400 Kg is too light? It slightly moved backwards! (also tested with sheep)

Might it induce an alteration in the students behavior?

Summarizing

Both, sheep and pedestrians reveal an intermittent flow: alternation of flowing and clogging processes.

The flowing intervals (bursts/avalanches) display exponential distributions whereas the arrest ones follow power law decays

Enlarging door size increases flow rate & prevents flow interruptions

Reducing competitiveness prevents flow interruptions

“Light” obstacles move backwards!

So…

Up to this stage of the research sheep have revealed as a good model to mimic a scenario where pedestrians behave in a very competitive manner

Tracking of individuals would possibly reveal disagreements associated to shape differences and biped/quadruped locomotion behavior

Thank you!

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FIS2011-26675
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Experimental procedure

Collaboration with veterinarians of UNIZAR
Daily, sheep are taken out of the yard
Food is placed inside it
When the yard is opened again, all the sheep crowd together in front of the door

Sheep width ~ 35 cm (soft)
Around 100 sheep (replaced afer 30-40 days)
Different door sizes / obstacles

Two cameras (one outside and one inside the barn) register the entrances





Pedestrian evacuations through bottlenecks