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

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Flow through bottlenecks

Traffic

Blood vessels

Grains

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

Julich group PED2011

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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

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

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    \end{itemize}
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\textbf{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 unavoidable for the design of human facilities.

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Velocity is almost independent on density!
Animals passing through bottlenecks

Mice

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

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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.

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

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Intermittent flow of sheep

Clogging time: power-law tail

Intermittent flow of sheep

Clogging time: power-law tail


exponent $\alpha$ & $t_{\text{min}}$
Intermittent flow of sheep


exponent $\alpha$ & $t_{\text{min}}$
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

\[ \langle \tau \rangle = 0.50 \]
\[ \langle \tau \rangle = 0.30 \]

Affects bursts and clogging dynamics!

Flow of sheep through bottlenecks: obstacle

\[ \Phi = 1 \text{m at 80cm} \]

\[ \langle \tau \rangle = 0.50 \]
\[ \langle \tau \rangle = 0.47 \]
\[ \langle \tau \rangle = 0.30 \]
\[ \langle \tau \rangle = 0.27 \]

Affects bursts and clogging dynamics!

Flow of sheep through bottlenecks: competitiveness

High (cold days) Faster is slower

Low (warm days)

Faster is slower

High speed (faster)

Low speed (slower)

High speed (slower)

Low speed (faster)

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Pedestrian evacuations through bottlenecks

Two days (~ 30 evacuations each)
- First day (to acquire experience)
- 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

Experimental Run

Initial Group Speed (m/s)

Low Medium High

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Experimental Run

N_s (pressure > 30 N/cm²)

Low Medium High

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Intermittent flow of pedestrians: **competitiveness**

- **Low**
- **Medium**
- **High**

Faster is slower
Intermittent flow of pedestrians: door size

High competitiveness

69 cm door
75 cm door
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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Mutua Montañesa
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 \(\sim 35\,\text{cm}\) (soft)
Around 100 sheep (replaced after 30-40 days)
Different door sizes / obstacles

Two cameras (one outside and one inside the barn) register the entrances
Pedestrian evacuations through bottlenecks

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