# Crowd Behavior

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## Behavioral Process

- Behavioral process for most actions can be Broken down into:
  - Stimulus
  - Mental Process
  - Reaction

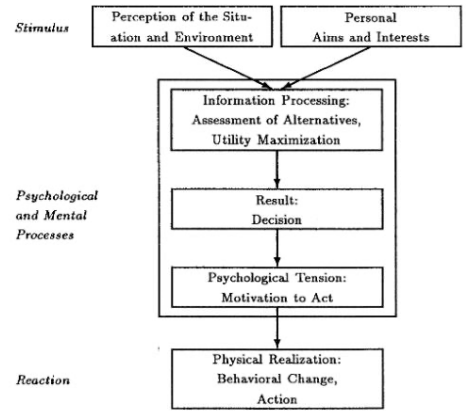



FIG. 1. Schematic representation of processes leading to behavioral changes.

## Social Force

- Provides an explanation for the simple behaviors and complex results in groups of people
- It is a quantity that describes the concrete motivation of an individual, including those in crowds.
- In pedestrian situations, social force is responsible for generating movement towards a goal in individuals.

## Social Force Model

- Sum of increases and decreases in an individual's motivation
  - Acceleration to desired velocity
  - Desired distance from walls and other pedestrians
  - Attractiveness of different goals.

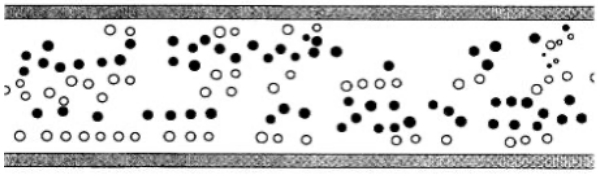
$$\vec{F}_\alpha(t) := \vec{F}_\alpha^{\,0}(\vec{v}_\alpha, v_\alpha^0 \vec{e}_\alpha) + \sum_\beta \vec{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_\beta) + \sum_B \vec{F}_{\alpha B}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_B^{\,\alpha}) + \sum_i \vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_i, t)\,.$$

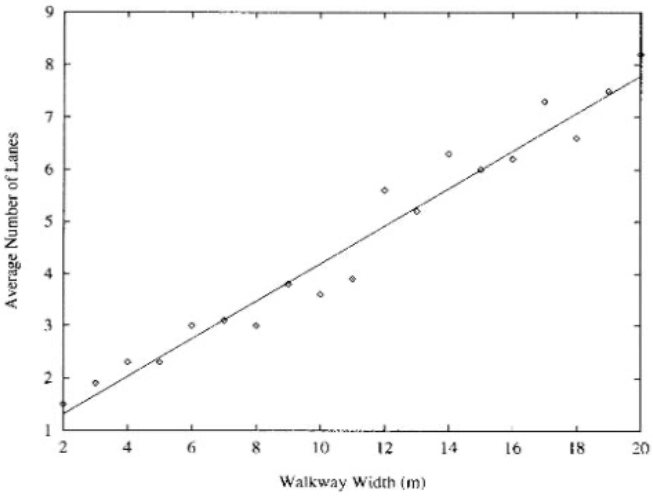
- Results in equation for social force over time

$$\frac{d\vec{w}_\alpha}{dt} := \vec{F}_\alpha(t) + \text{fluctuations.}$$

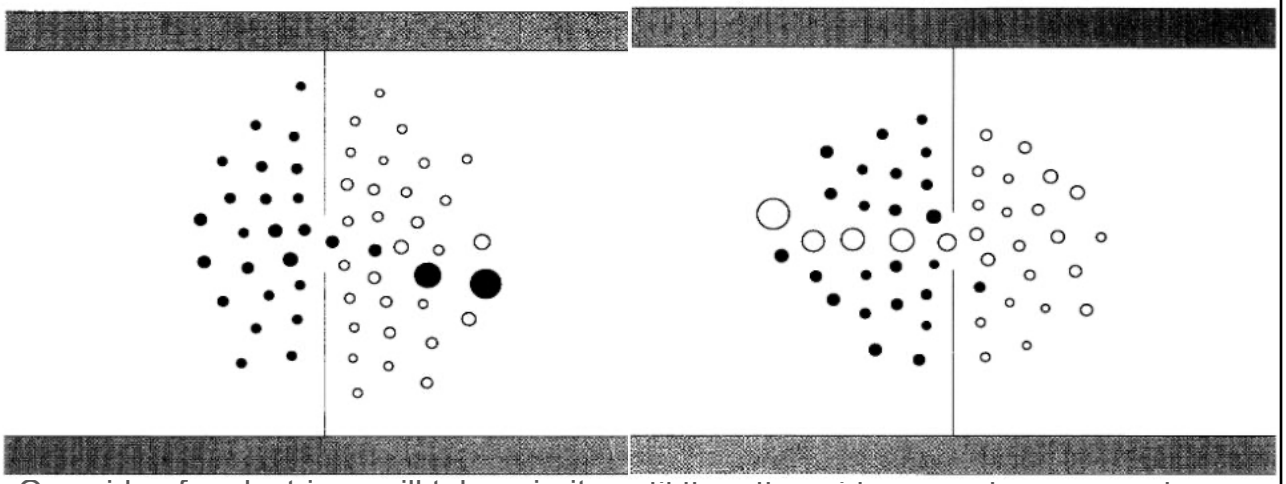
## Social Force Simulated

- Result of simulating pedestrians on a 10m wide pathway
- 10m averages 4-5 lines, similar to a real pathway
- Lanes form due to pedestrian interaction



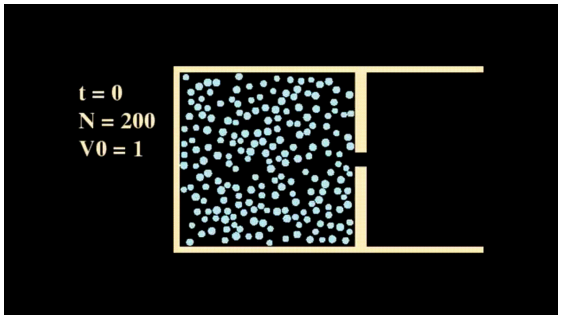



## Simulated Doorway

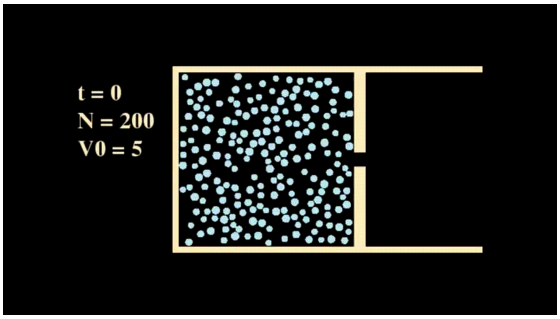


One side of pedestrians will take priority until the other side grows large enough

## Panicking Behavior uses the same force model but with higher desired velocity

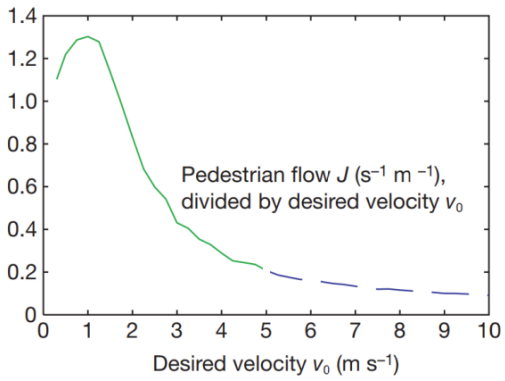


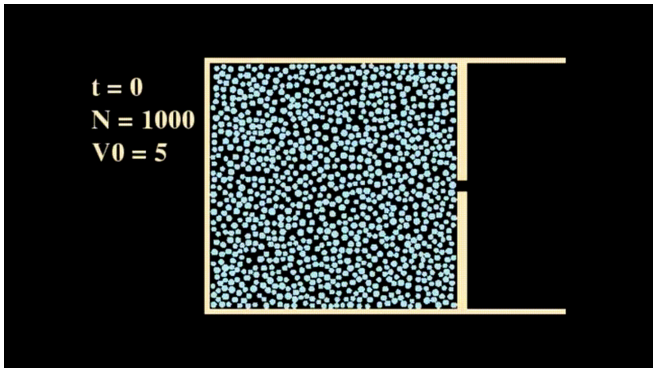

Normal crowd exiting speed




Increased panic exiting speed

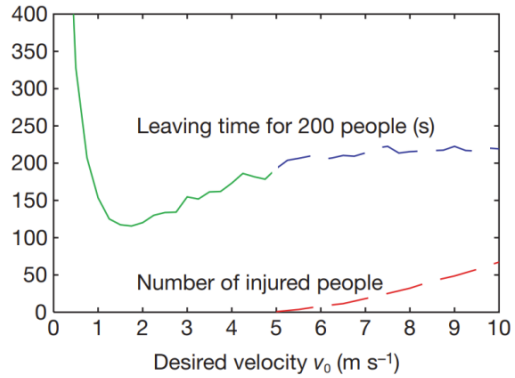
## Panicked escapes are less efficient than calm exits

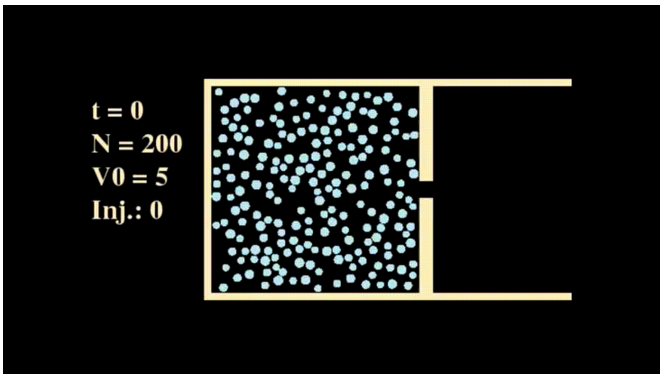



Panicked exit with large crowd

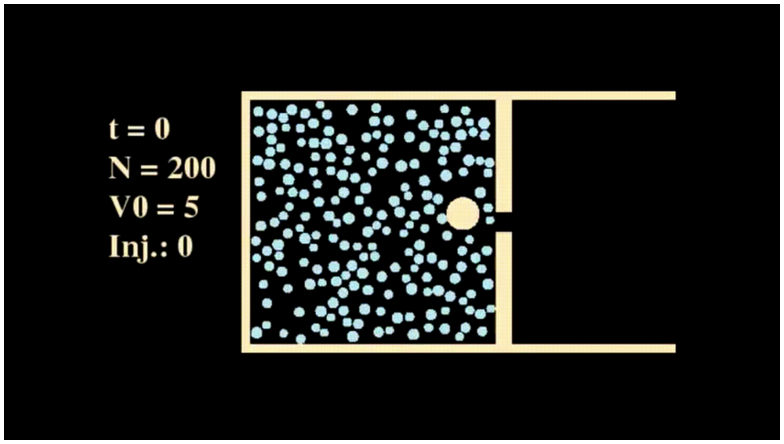
## Panicked behavior increases forces and pressure in the crowd which can cause injuries



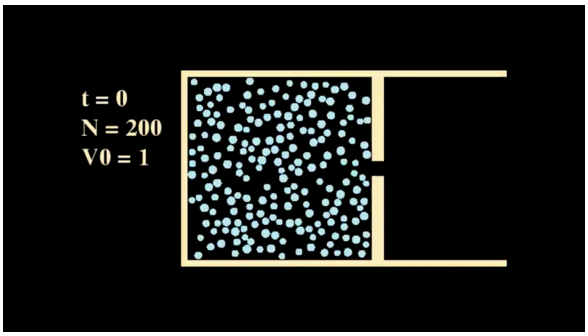

Panicked exit with injuries shown

## Columns placed asymmetrically in front of the exit reduces the buildup of pressure

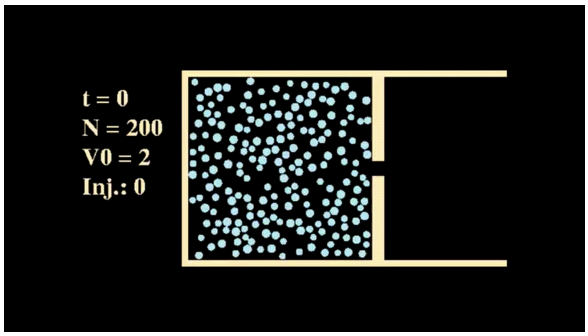



Panicked exit with column in front of door

## Panic slows traffic which lowers people's chances of survival in events like fires

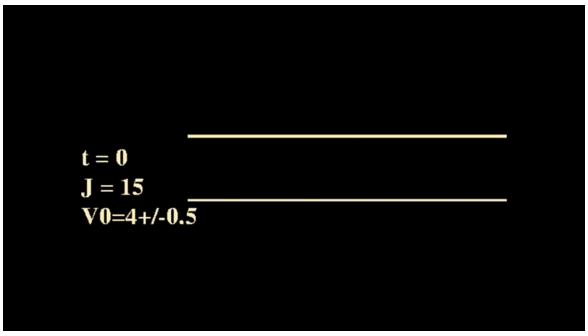



Normal Crowd Exiting Speed

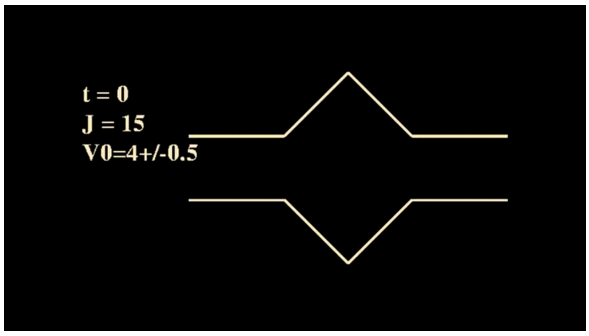



Panicked Fire Escape

## Wider escape paths can help increase escape efficiency

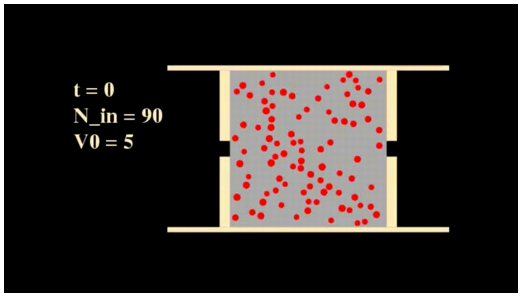



Wider Path

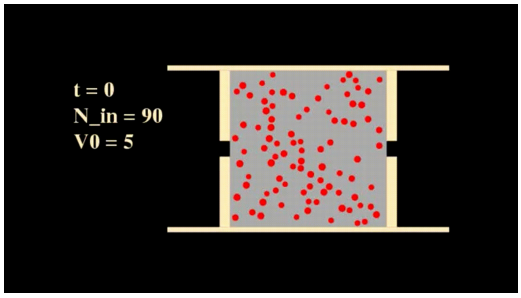



Wider path with opening

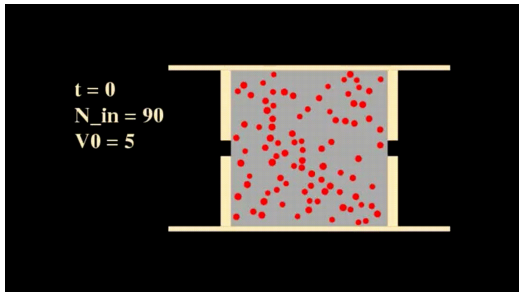
## Individualistic behavior alone isn't always effective




Individualistic

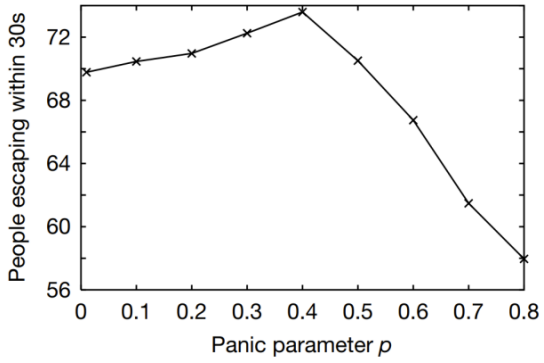


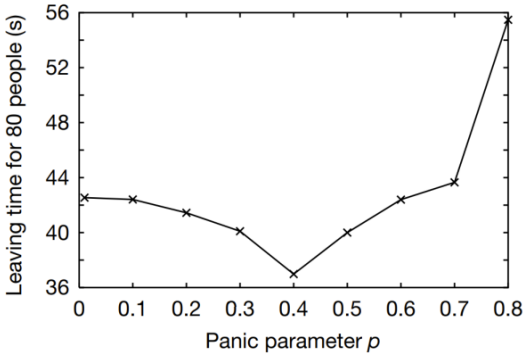

Herding




Both

## Some herding behavior allows for faster learning




Higher *p* leads to more crowd behavior

Questions?