Model Predictions vs. Experimental Data

The Influence of Social Groups on Evacuation Scenarios

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Overview

- Introduction
- Social groups in pedestrian dynamics
- Floor Field model and model predictions
- Experimental study and experimental results
- Comparison
- Conclusion

Introduction

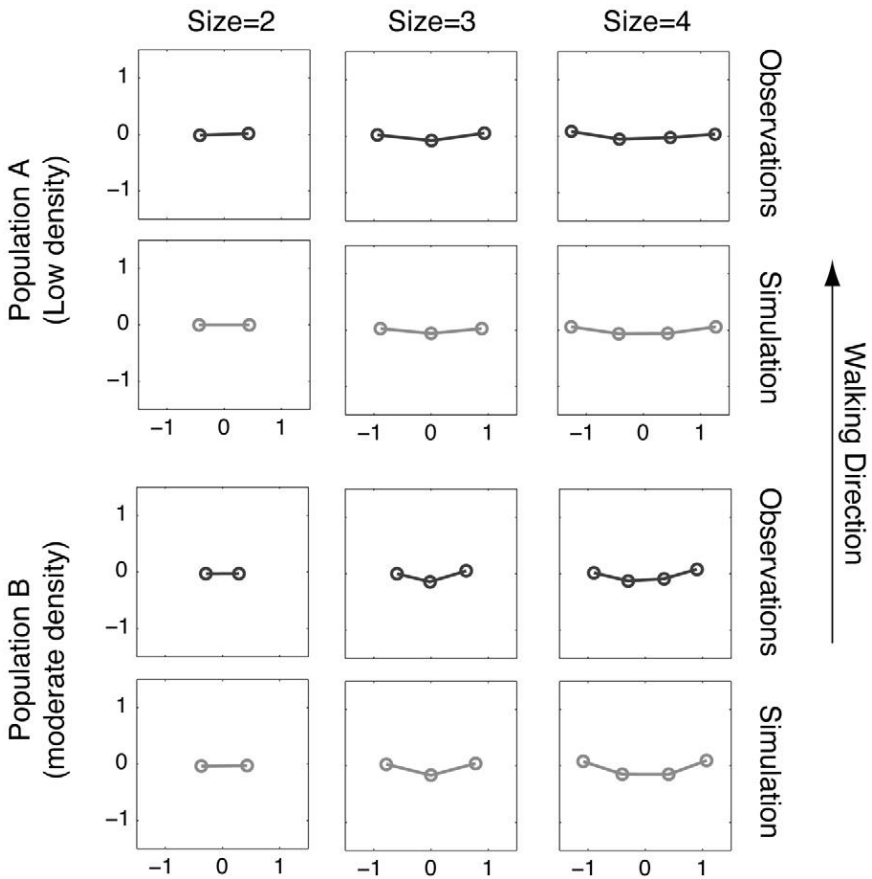
- Social groups: pedestrians that stand or walk together due to social relationships

- Modelling and simulation approaches
  - Dynamic Group Floor Field (DGFF) model
- Experimental data
  - Study on evacuations of pupils including social groups

- Comparison: choice of modelling parameters

Social Groups in Pedestrian Crowds

- Groups dominate in pedestrian crowds
  - Frequency decreases with increasing group size
- They show different walking patterns
  - Abreast
  - “V”- / “U”-shape
  - Splitting up



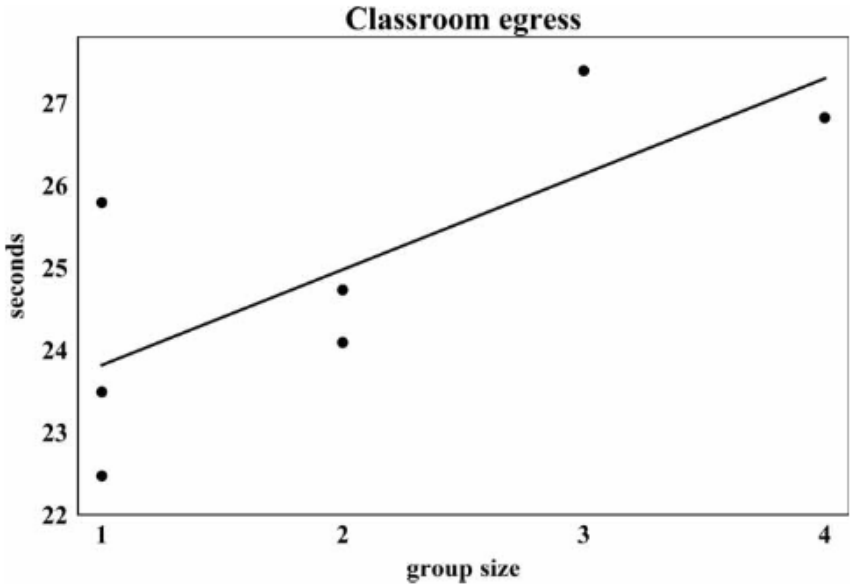
Moussaïd et al., 2010, *PloS ONE* 5.10047

Social Groups in Pedestrian Crowds

- Groups influence the velocity of movement
  - Gait velocity decreases in the presence of social groups
  - Social groups often move slower than individuals
  - Average velocity decreases with increasing group size
  - Impact may depend on external conditions, e.g. density or geometry of environment

Social Groups in Evacuations

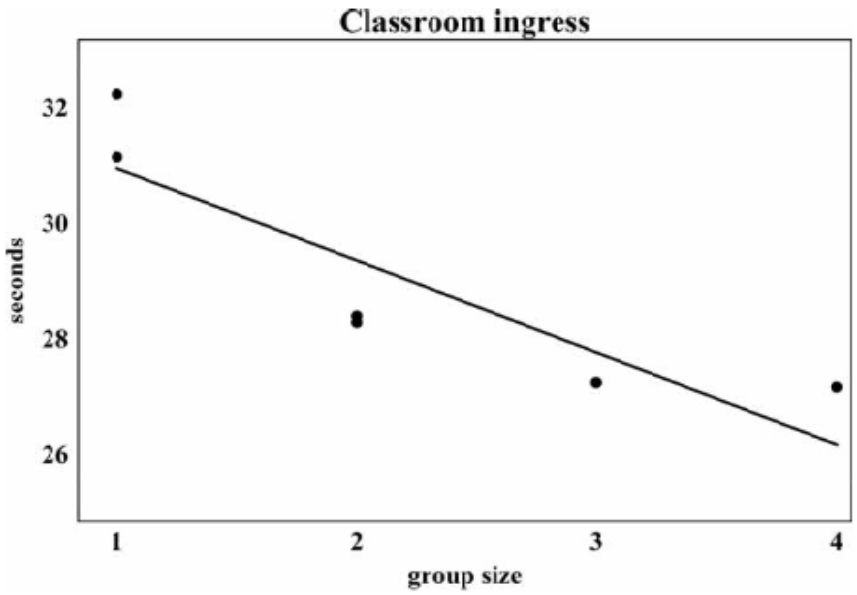
- Groups as “moving obstacles” (Reuter et al., 2014)
- Groups evacuate slower due to larger pre-movement time and time to reach the target (Bode et al., 2015)
- Higher egress time of groups due to waiting of group members in front of the door (Köster et al., 2011)



Köster et al., 2011, Contemp Soc Science 6:3, p. 397 - 414

Social Groups in Evacuations

- Effect depends on order of experiments / only weak effect (Bode, 2016)
- Evacuation of pairs faster than individual evacuation (Guo et al., 2015)
- Lower ingress time of groups due to ordering effect caused by groups (Köster et al., 2011)



Köster et al., 2011, Contemp Soc Science 6:3, p. 397 - 414

Modelling Social Groups

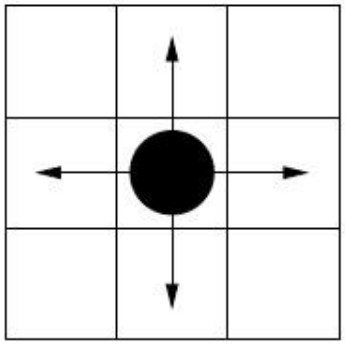
- Extensions of various models to include social groups
  - Social force models, cellular automaton models, agent-based models, …
  - Discomfort potential, communication parameter, …

- Many observations can be reproduced, e.g. walking pattern, impact on velocity, evacuation times …

- Concept of leadership

Floor Field Model

- Cellular automaton model
  - Discrete time, space and velocity
  - Rule-based
  - Transition probabilities to adjacent cells
  - Exclusion principle: each cell is empty or occupied by one particle
  - Parallel or sequential update
  - Deterministic or stochastic



0	$p_{-1,0}$	0
$p_{0,-1}$	$p_{0,0}$	$p_{0,1}$
0	$p_{1,0}$	0

Kirchner and Schadschneider, 2001, Phys A 312, p. 260 - 276

Floor Field Model

- Floor Field: particles follow (virtual) trace created by other pedestrians

- Static Floor Field
  - Knowledge about environment
  - Constant in time
  - Coupling constant k_S

- Dynamic Floor Field
  - Interaction and herding
  - Dropped markers diffuse and decay
  - Coupling constant k_D

$$p_{ij} = N e^{k_D D_{ij}} \mathrm{e}^{k_S S_{ij}} \left(1 - \eta_{ij}\right) \xi_{ij}$$

Kirchner and Schadschneider, 2001,
Phys A 312, p. 260 - 276

Floor Field Model with Social Groups

- Asymmetric pair-coupling
  - Leader and follower with different dynamic and static floor fields
  - Coupling may be advantageous if the leaders have a better orientation
  - Followers may lose contact with their leaders
- Moving Target Floor Field
  - Floor Field associated to the leader depends on distance
- Asymmetric fixed-bonded leader-follower FF model

Floor Field Model with Social Groups

- Social groups: sub-crowds with common behaviour
  - Try to maintain proximity between group members
  - Different species of particles for different groups

- Dynamic Group Floor Field (DGFF)
  - Group interaction is mediated by group-specific dynamic floor field
  - Particles can only detect trace of own group members

Floor Field Model with Large Social Groups

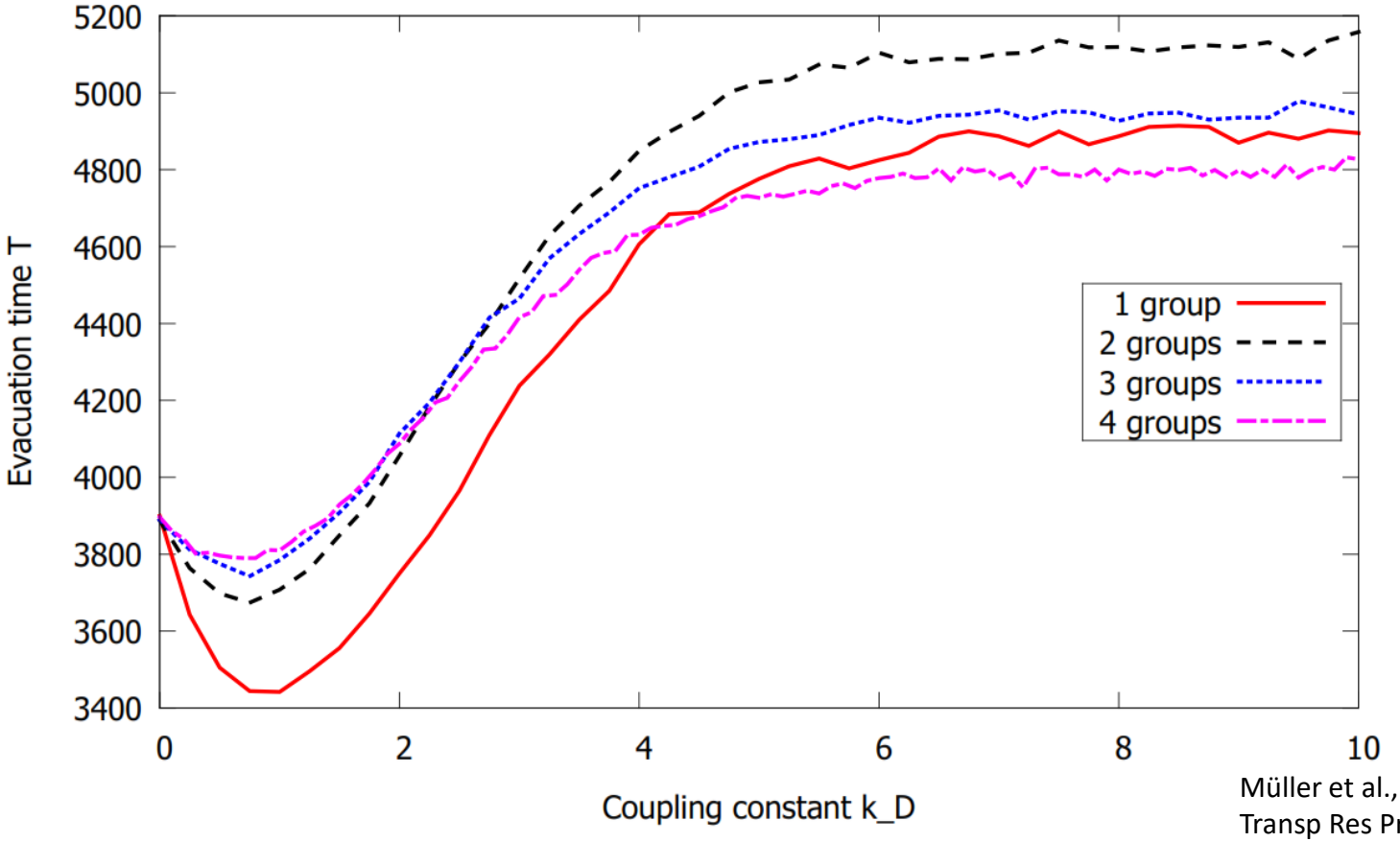
- Symmetric interaction: each particle increases DGFF
  - DGFF obeys diffusion and decay

- Evacuation simulation
  - Square room with single exit
  - Density $\rho = 0.3 \triangleq 1116$ pedestrians
  - Crowd is separated in up to four social groups
  - Evacuation times are measured when 95 % of all pedestrians have left the room and are averaged over 100 runs

Model Predictions for Large Groups

Cooperative regime

Disordered regime



Müller et al., 2014,
Transp Res Proc 2, p 168-176

- Impact of social groups depends on the coupling strength

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Experimental Study

- Joint study of Forschungszentrum Jülich, University of Wuppertal and University of Cologne

- Investigation of the impact of inhomogeneities on pedestrian dynamics
  - Fundamental diagrams of inhomogeneous crowds
  - Influence of social groups on evacuation scenarios

- Pupils of two schools in Wuppertal, Germany

Experimental Study

- Evacuation runs with different configurations
  - Group composition: children, youths, mixtures
  - Group size: individuals, pairs, large groups (4, 6, 8 persons)
  - Group interaction:
    - Bond between group members: loose or fixed
    - Hierarchy: treated equally or leader-follower relationship

Experimental Study

- Evacuation runs with different configurations
  - Group composition: children, **youths**, mixtures
  - Group size: **individuals**, **pairs**, **large groups** (4, 6, 8 persons)
  - Group interaction:
    - Bond between group members: **loose** or fixed
    - Hierarchy: **treated equally** or leader-follower relationship
    - Additional: explicit **cooperative behaviour**

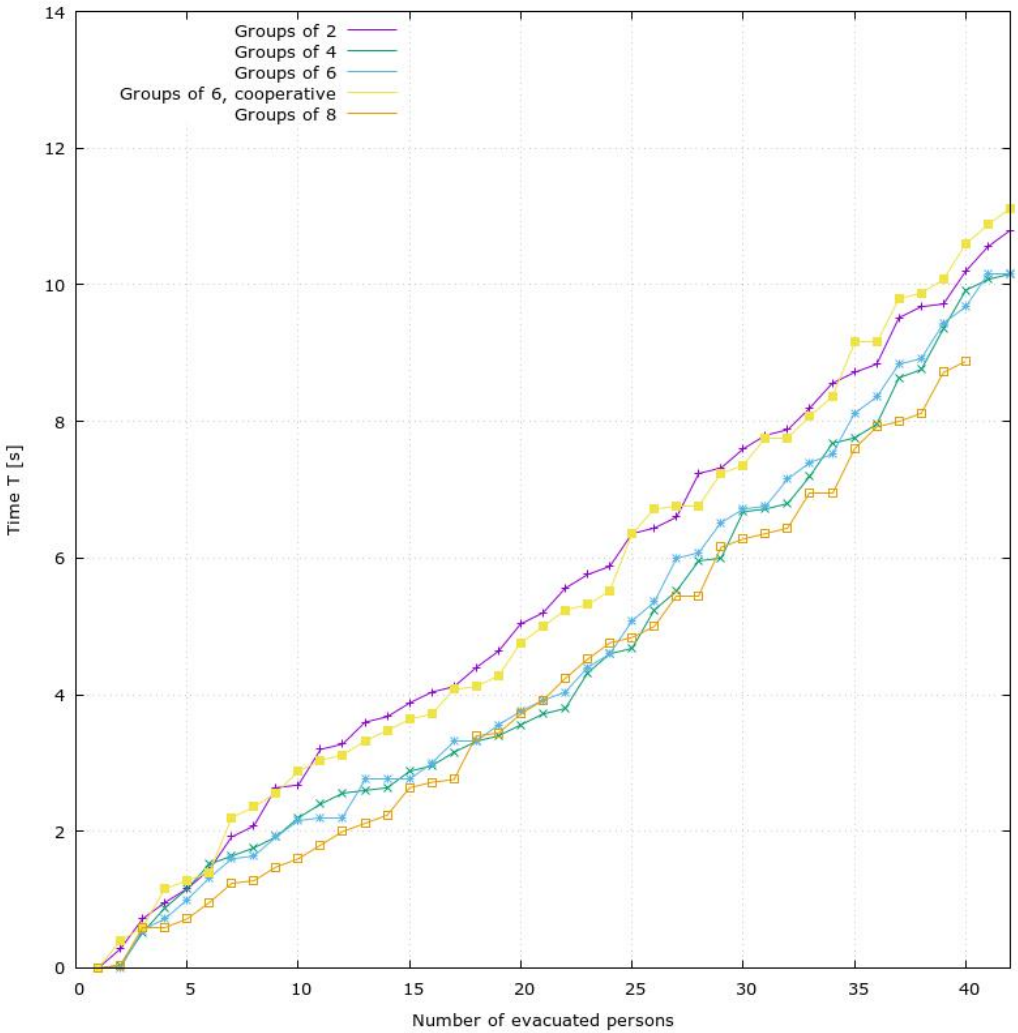
Experimental Set-up

Screenshot from video recordings, FZ Jülich

- Square room with entrance, exit door and starting area
- Camera system on the ceiling
- Coloured caps: body heights
- Video processing: PeTrack

M. Boltes, FZ Jülich

Experimental Results



- Presence of groups has an advantageous impact

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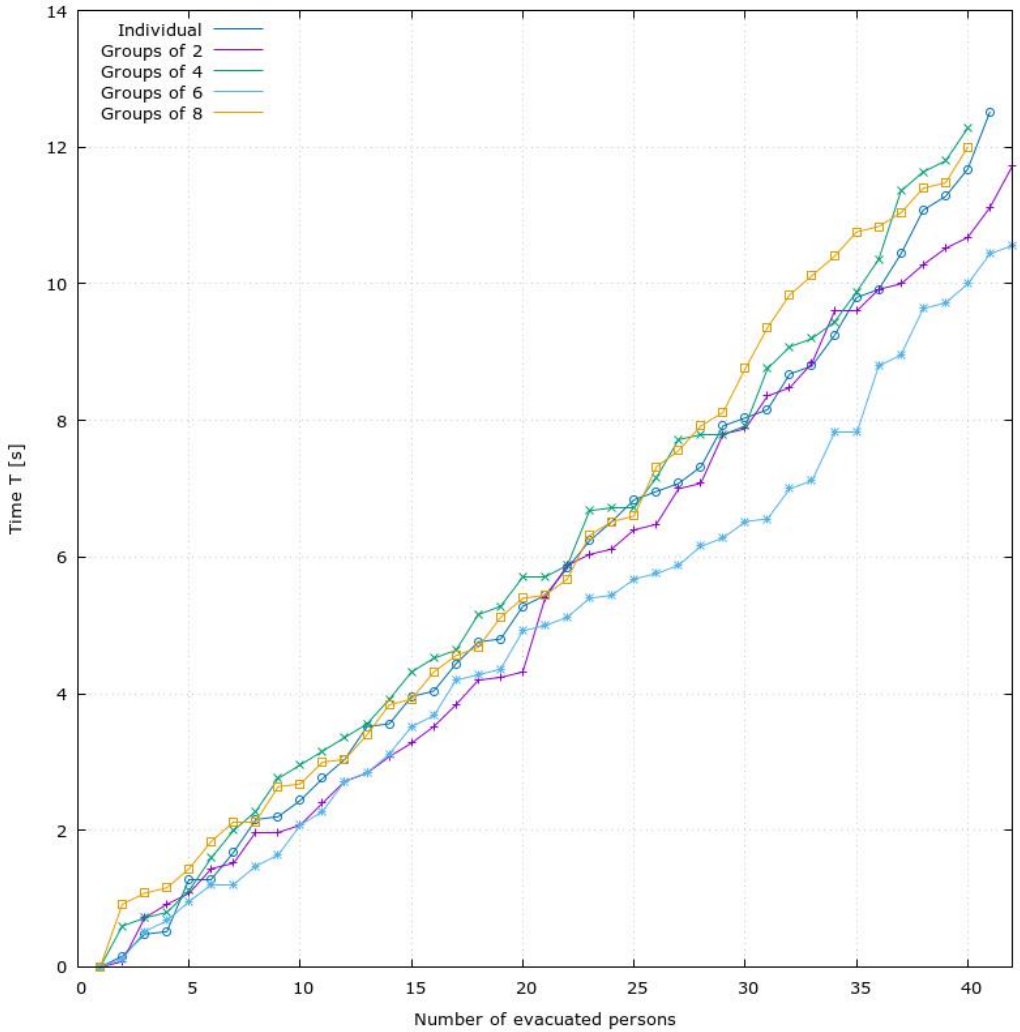
Experimental Results



- No distinct impact of groups

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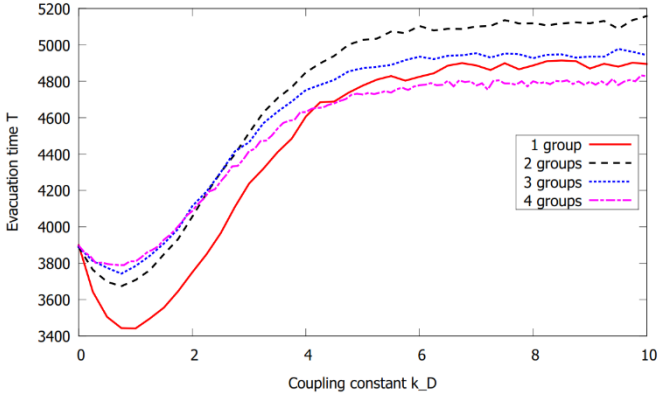
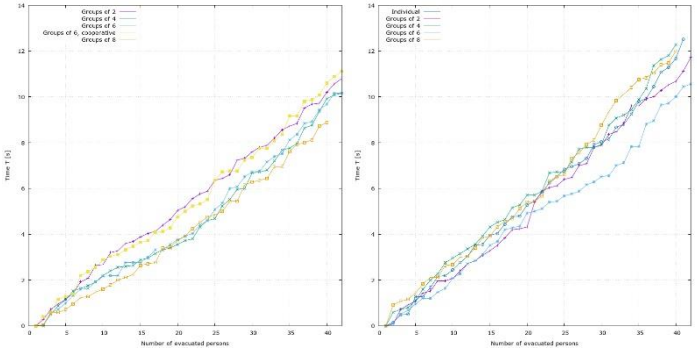
Comparison

- Cooperative regime: groups advantageous
- Disordered regime: groups disadvantageous



- 1st school: positive impact of groups
- 2nd school: no significant impact of groups



Comparison

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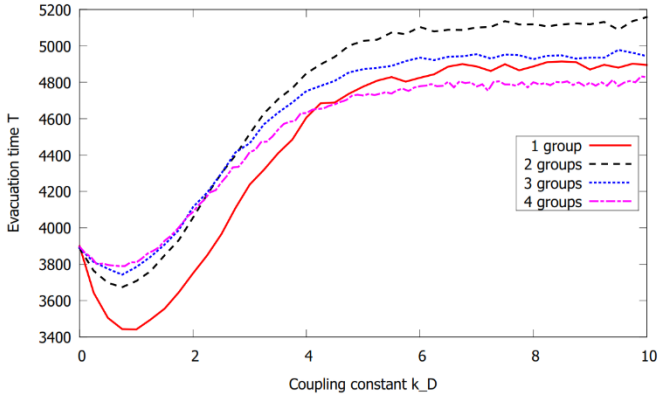
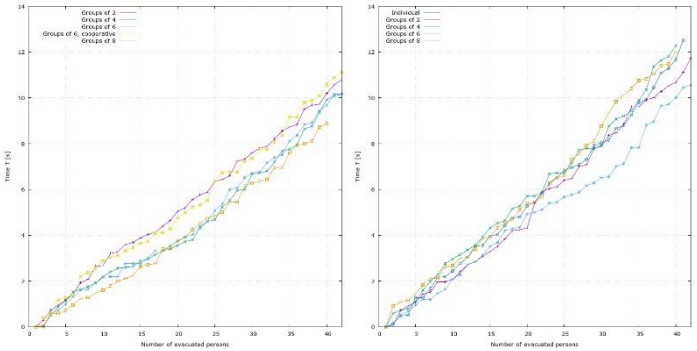


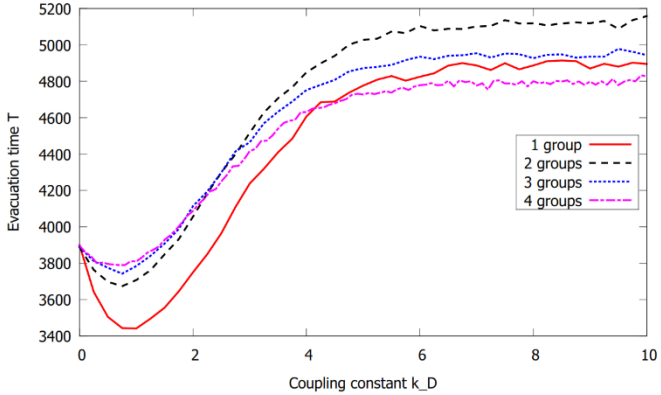
Coupling constant near the transition between the regimes

- 1st school: positive impact of groups
- 2nd school: no significant impact of groups

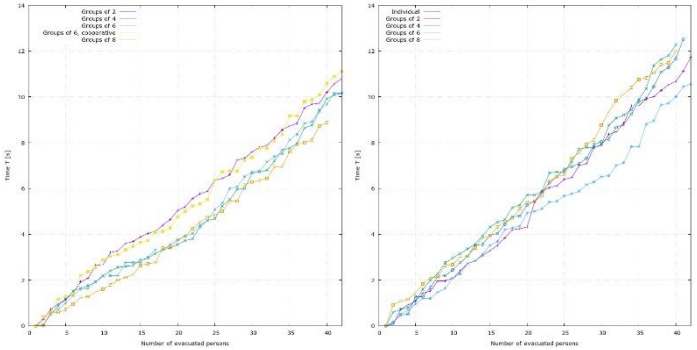


Comparison

- An increased coupling constant k_D leads to higher evacuation times



- Cooperative behaviour has a higher evacuation time than normal behaviour



Comparison

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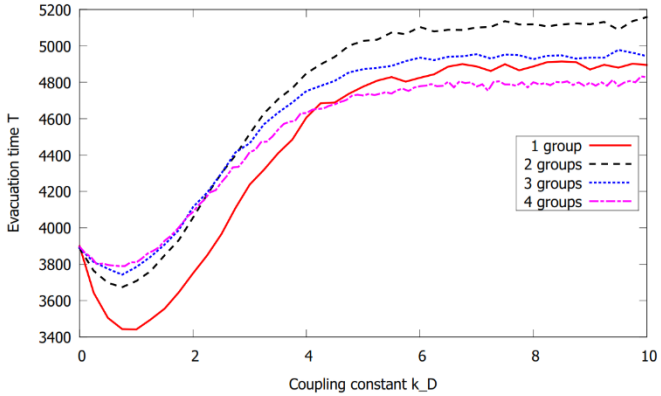
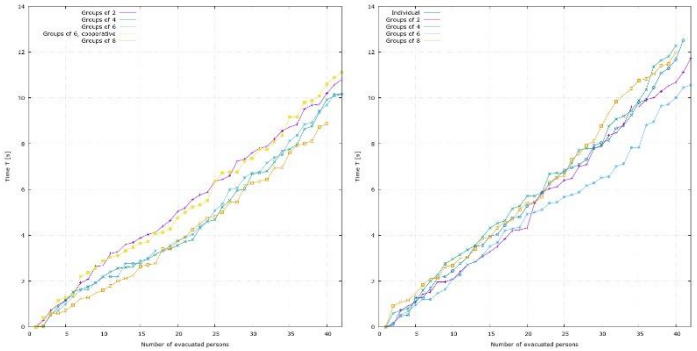


Cooperative behaviour can be described by high coupling constants k_D

- Cooperative behaviour has a higher evacuation time than normal behaviour



Conclusion

- Social groups are a non-neglectable part of pedestrian crowds
  - Dominate in pedestrian crowds
  - Influence the dynamics of the crowd
  - Few, contradictory experimental results on the impact of groups on evacuation scenarios

- Rely on modelling and simulation results

Conclusion

- Dynamic Group Floor Field (DGFF) model
  - Impact of social groups depends on coupling strength
- Experimental study with pupils
  - Advantageous influence of social groups is not significant
- Positive impact for moderate, negative impact for high coupling
  - Coupling constant for grouping near transition
  - High coupling constant for cooperative behaviour

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