Simulating and quantifying the influence of covert and explicit leaders on human crowd motion

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Abstract We previously reported an experiment in which covert or explicit leaders (confederates) were placed in a group of walking pedestrians in order to test leader influence on human crowd motion [1]. Here we simulate the participant trajectories with variants of an empirical pedestrian model, treating the covert leaders' motion as input, and test model agreement with the experimental data. We are currently using reconstructed influence networks [2] to modify the model weights in order to simulate the influence of explicit leaders. The results help us to understand how leader influence propagates via local interactions in real human crowds.

Keywords Pedestrian dynamics, Leadership, Modelling, Experiment, Influence networks

Motivation

Collective motion of human crowds is thought to be a self-organizing phenomenon that emerges from local interactions between neighboring individuals. Some positions in a crowd are more influential than others, resulting in the emergence of strong leaders [2]. We recently conducted an experiment in which confederates were strategically placed in these positions to test their influence on crowd motion [1]. The results showed that both covert and explicit leaders can steer a crowd, but explicit leaders are significantly more influential and can also split a crowd. Reconstruction of the influence networks revealed that explicit leaders change the network topology.

In the present study, we simulate the data with an empirical model of human locomotion, the SCruM (Self-organized Collective Motion) model. First, using the motions of covert confederates as input, we simulate the participant trajectories with visual and 'omniscient' versions of the model, to investigate the local coupling between neighbors that accounts for the experimental data. Second, we use the reconstructed network topology [2] to modify the local weights in the model, to estimate the influence of explicit leaders. The results help us to understand how leader influence propagates through a crowd based on local interactions.

Methods

Experiment

In each session, a group of pedestrians (N=16 to 22) was instructed to walk across a field together. Four confederates, whose presence was either unknown ("covert") or visually specified by pennants ("explicit"), simultaneously turned about 25°mid-way through the trial. We varied the turn direction of each confederate, creating three trial conditions: "control" (no turns), "steer" (all confederates turn left or right), or "split" (2 confederates turn left and 2 turn right). Data were recorded by a camera drone (50 Hz). Head positions were extracted by a data processing pipeline using multiple-object tracking frameworks.

Pedestrian Models

The SCruM model controls the heading direction and speed of an agent based on input from its environment. We evaluate two variants of the model: (i) Omnisicient SCruM, based on neighbor velocities without occlusion [3] and (ii) Visual SCruM, based on visual variables (optical expansion, angular velocity, and eccentricity of neighbors) with visual occlusion [4].

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Two model components are used here: the goal component orients the agent's heading toward a distant goal, while the alignment component attracts the agent toward the mean heading and speed of its neighbors. In the simulations, the trajectories of the confederates are taken from the human data, while the movements of participants are simulated, with initial conditions taken from their data.

Analyses

Figure 1 presents the probability density distributions of the change in heading direction for participants on each trial, with covert confederates. We statistically compared the distributions for the simulated data (B and C) with the human data (A).

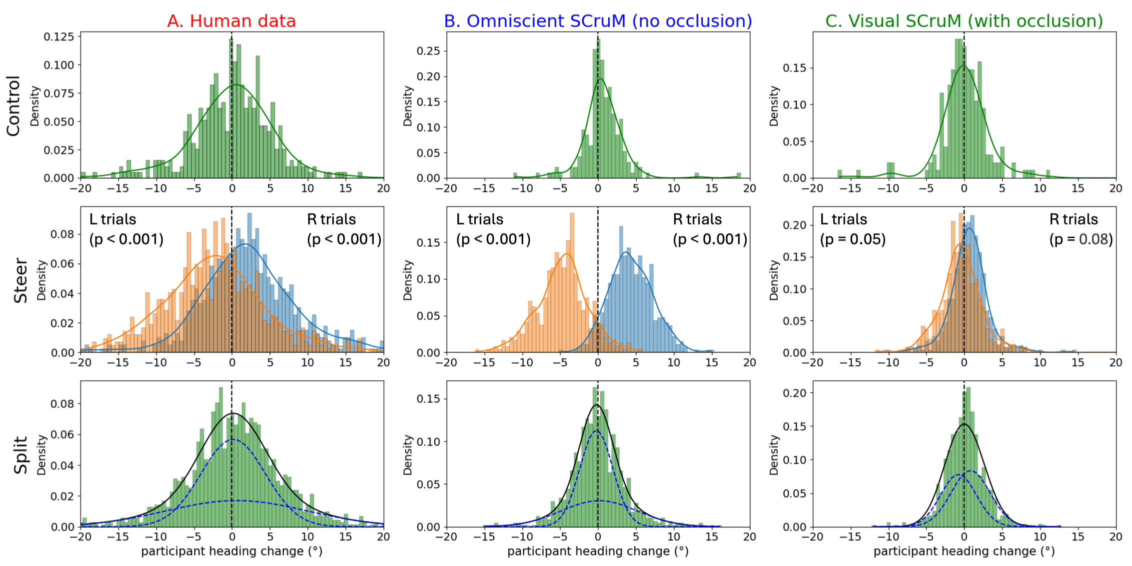

Figure 1: Probability density distributions of heading change by participants on each trial when covert confederates are present. From the top, rows represent control, steer (left-turning in orange, right-turning in blue), and split trials. **A.** Experimental data of participants. **B,C.** Simulated data of non-confederate agents using the SCruM model, without (B) or with (C) occlusion.

In the Control condition, neither omniscient SCruM ($p = 0.16$) or visual SCruM ($p = 0.94$) was significantly different from the human data, although Kolmogorov-Smirnov (KS) tests indicated significant distributional differences (both $p < 0.001$). In the Steer condition, for both left and right turns, omniscient SCruM turned significantly more than humans ($p < 0.001$), whereas visual SCruM turned significantly less than humans ($p < 0.001$), although the left/right difference was still significant; both models exhibited distributional differences from the human data (KS, $p < 0.001$). In the Split condition, omniscient SCruM was marginally different from the human mean ($p = 0.05$), whereas visual SCruM was not significantly different ($p = 0.23$), although both exhibited distributional differences (KS, $p < 0.001$).

In sum, human crowds are surprisingly resistant to Splitting, consistent with both models, due to averaging the influence of neighbors. In the Steer condition, the omniscient model over-steered whereas the visual model was somewhat closer to human behavior. To model the influence of explicit leaders, we are currently modifying the local weights in the alignment component based on the topology of the reconstructed networks [2]. The results will help us to understand how leader influence propagates via local interactions in real human crowds.

Bibliography

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