Collective Motion in Human Crowds: Tests of the Weighted-Averaging Model

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Abstract

What local interactions between pedestrians give rise to collective motion in crowds? Rio, Dachner & Warren (PRSB 2018) developed an experiment-driven model in which each individual aligns their heading direction (and speed) with a weighted average of their neighbors' heading (or speed), and the weight decays exponentially with distance. The model makes two assumptions: (1) a pedestrian's response is based on the average of neighbors within the neighborhood, and (2) walking speed and heading direction are controlled independently. We tested these assumptions in two experiments. On each trial, the participant 'walked with' a virtual crowd viewed in an HMD, and the walking direction or speed of 12 virtual neighbors was perturbed. Experiment 1 tested the averaging assumption by manipulating the distribution of headings (or speeds) in the virtual crowd. To dissociate the mean from the mode (4 neighbors with same motion), we varied the skewness of the distribution (normal, positive skew, negative skew). As the model predicts, we found no significant differences between heading distributions (BF_{01}=8.46). In contrast, there was an effect of speed distribution ($p<.001$; $BF_{10} = 42.15$): final speed was faster when modal neighbors slowed down (negative skew). Surprisingly, the model yielded similar results, as it passed slower neighbors. Experiment 2 tested the assumption of independent control. We perturbed the heading, speed, or both, of a subset of neighbors and looked for crosstalk. Heading perturbations influenced participant speed, as pedestrians slow down slightly to turn ($p<0.05$) (Hicheur, et al. 2005). The combination of heading and speed perturbations also influenced participant heading: participants turned more when neighbors turned and slowed down ($p<0.05$). The model showed a similar response, because slower neighbors drift closer and thus exert greater influence. The results confirm both assumptions of averaging and independent control, and reveal how heading and speed are coupled through the world.

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