# A Bifurcation in Visually-Guided Behavior when Following a Crowd

William H. Warren, Trenton D. Wirth & Brian Free

Models of human 'flocking' show that collective motion emerges when each individual takes a weighted average of neighbor velocities (Rio, Dachner & Warren, *PRSB,* 2018). But when a crowd splits into two groups heading in different directions, what does an individual do? Wirth & Warren (FAMS, 2021) found robust averaging up to a heading difference of 40° between groups. Here we explore a larger range of heading differences (0˚-120˚) and observe a sudden transition from averaging to following one group. Participants (N=6) were instructed to "walk with" a virtual crowd while wearing a wireless head-mounted display (101˚H x 105˚V, 90 Hz). After 2-3s, 50% of the crowd turned left and 50% turned an equal angle to the right; the heading difference between groups was manipulated (0˚, 20˚, 30˚, 40˚, … 90°, 120°). Group members were randomly interspersed and formed two continuously crossing flows. The participant's walking trajectory was recorded, and final heading during the last 2s of each trial was measured. Participants walked in the mean direction of the crowd until 60˚, where a bifurcation occurred. Probability density functions fit to the data switched from unimodal ($\Delta BIC_{UB}$=8.23 at 50˚) to bimodal ($\Delta BIC_{BU}$=2.37 at 60˚; $\Delta BIC_{BU}$=21.69 at 70˚), with the two modes close to the heading directions of the two groups. We simulated the data by modifying Rio, et al.'s (2018) model so an individual is attracted to neighbor headings between ±30˚ rather than ±90˚. A similar bifurcation has been reported in diverging fish schools (Couzin, et al., 2005). These bifurcations in behavior are suggestive of phase transitions observed in systems of coupled oscillators (Kelso, 1995; Mirollo & Strogatz, 1990; Nabet, Leonard, Couzin & Simon, 2009). We next plan to test for hysteresis around the transition point, a signature of nonlinear phase transitions.

Funding: NIH R01EY029745, NSF BCS-1849446