Supplementary Table

Emergence of collective changes in travel direction of starling flocks from individual birds' fluctuations

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Event number	Event label	N	Φ	$\mathbf{I}_1 \cdot \mathbf{G}$ at t_1	$\mathbf{I}_3 \cdot \mathbf{G}$ at t_1	$\mathbf{V}_1 \cdot \mathbf{G}$ at t_1	$\mathbf{I}_3 \cdot \mathbf{V}_1$ at t_1	$\mathbf{I}_3 \cdot \mathbf{V}_2$ at t_2	$\mathbf{I}_3 \cdot \frac{\mathbf{d}_0}{\|\mathbf{d}_0\|}$ at t_1	$\mathbf{V}_1 \cdot \frac{\mathbf{d}_0}{\|\mathbf{d}_0\|}$ at t_1	$\mathbf{V}_2 \cdot \frac{\mathbf{d}_0}{\|\mathbf{d}_0\|}$
E1	20110208_ACQ3	176	0.806	0.95	0.15	0.47	0.14	0.93	0.97	0.08	-0.91
E2	20111124_ACQ1	125	0.959	0.97	0.15	0.01	0.65	0.99	0.97	0.81	-0.78
E3	20111125_ACQ1	50	0.866	0.86	0.42	0.26	0.41	0.88	0.91	0.05	-0.82
E4	20111214_ACQ4_F1	154	0.940	0.69	0.72	0.03	0.12	0.63	0.97	0.10	-0.83
E5	20111215_ACQ1	384	0.801	0.97	0.16	0.13	0.24	0.92	0.98	0.05	-0.94
E6	20111125_ACQ2	502	0.841	0.98	0.16	0.35	0.38	0.89	1.00	0.43	0.74
E7	20110217_ACQ2	404	0.854	0.91	0.32	0.39	0.34	0.96	0.78	0.83	-0.89
E8	20111220_ACQ2	197	0.907	0.98	0.03	0.94	0.30	0.90	0.56	0.20	-0.53
E9	20111201_ACQ3_F1	133	0.793	0.76	0.46	0.04	0.21	0.99	0.89	0.21	0.78
E10	20110211_ACQ1	595	0.757	0.94	0.10	0.34	0.03	0.36	0.91	0.37	-0.96
E11	20111214_ACQ4_F2_T1	139	0.890	0.35	0.87	0.67	0.92	0.56	0.84	0.74	0.08
E12	20111214_ACQ4_F2_T2	139	0.808	0.66	0.74	0.11	0.58	0.79	0.89	0.15	0.39

TABLE S1. **Global quantitative properties of the turning events.** We analyzed twelve turning events, of which two (E11 and E12) are performed by the same flock one after the other (therefore marked T1 and T2 in the event label). N is the number of birds in the flock. The polarization is defined as $\Phi = \|(1/N)\sum_i \mathbf{v}_i/\|\mathbf{v}_i\|\|$. In the remaining columns we report absolute values of the scalar products between yaw $\mathbf{I}_1$ (the axis relative to the shortest dimension of the flock), the longest elongation axis $\mathbf{I}_3$, and gravity $\mathbf{G}$, with the direction of motion before and after the turn given by velocity vectors $\mathbf{V}_1$ and $\mathbf{V}_2$ at times t_1 and t_2, respectively. The scalar products are calculated using the values of appropriate quantities at times t_1 of the start of the turn, or t_2 at the end of the turn, as indicated. Note that the vectors $\mathbf{I}_1$, $\mathbf{I}_3$, and $\mathbf{G}$ are unitary by definition, while for the direction of motion we used normalized velocity vectors $\mathbf{n}_1 \equiv \mathbf{n}(t_1) = \mathbf{V}(t_1)/\|\mathbf{V}(t_1)\|$ and $\mathbf{n}(t_2) = \mathbf{V}(t_2)/\|\mathbf{V}(t_2)\|$, which are for clarity called $\mathbf{V}_1$ and $\mathbf{V}_2$ in the column titles. Finally, in order to quantify the location of the origin of the turn, we use a mean relative position of the 10 top-ranked birds with respect to the barycenter of the flock, $\mathbf{d}_0$, as defined in the main text. We calculate absolute scalar products of the normalized vector $\mathbf{d}_0/\|\mathbf{d}_0\|$ with the unitary vector $\mathbf{I}_3$ of the longest elongation axes at t_1, as well as with the direction of motion at the start of the turn $\mathbf{n}_1$. In the last column, we report the scalar product between $\mathbf{d}_0/\|\mathbf{d}_0\|$ and the new direction of motion after the turn, given by the unitary velocity vector $\mathbf{n}(t_2) = \mathbf{V}(t_2)/\|\mathbf{V}(t_2)\|$ (called $\mathbf{V}_2$ for simplicity). Note that absolute values of all scalar products are reported, except for the last one whose negative values signify that the top-ranked birds initiated the turn in the direction towards the flock's barycenter (towards inside of the flock and not outside).

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