

## Supplementary Information for

Multimodal cue integration in the dung beetle compass

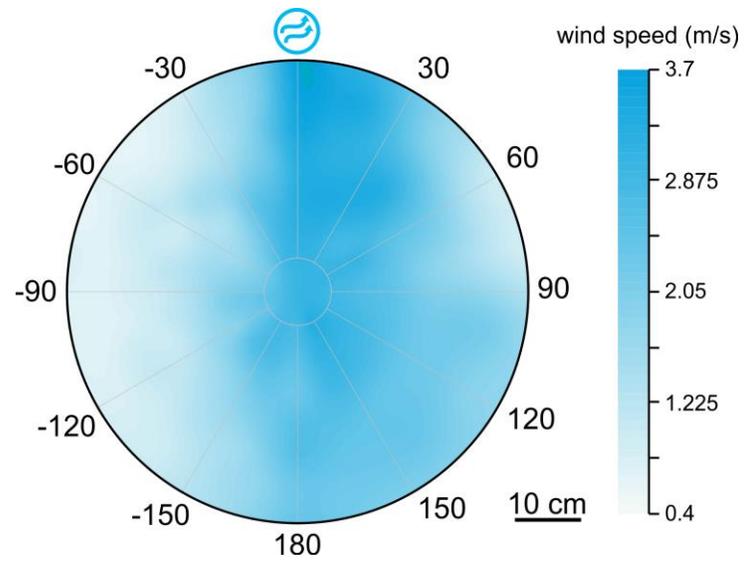
Marie Dacke, Adrian T.A. Bell, James J. Foster, Emily J. Baird, Martin F. Strube-Bloss,  
Marcus J. Byrne, Basil el Jundi

Basil el Jundi

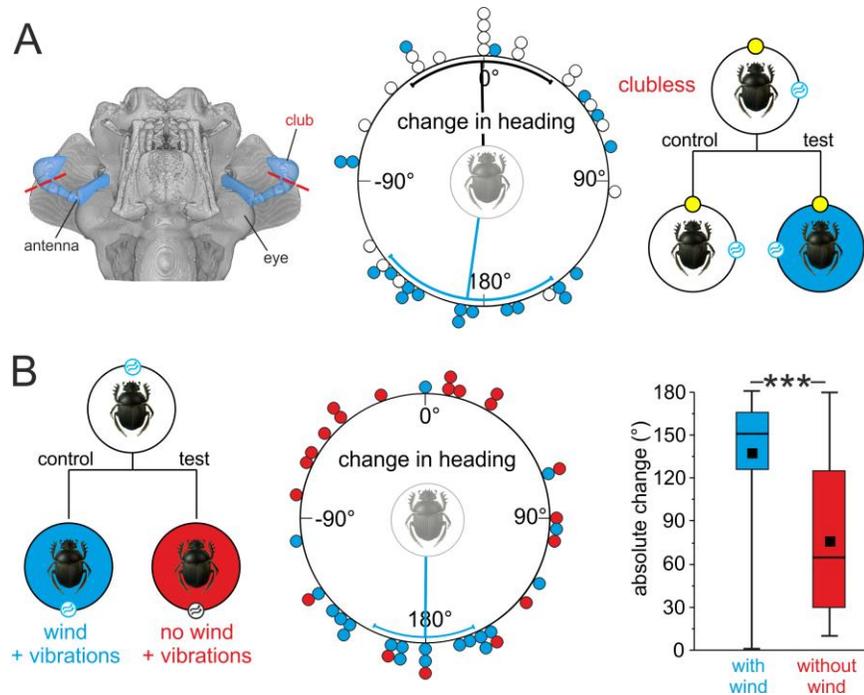
Email: [basil.el-jundi@uni-wuerzburg.de](mailto:basil.el-jundi@uni-wuerzburg.de)

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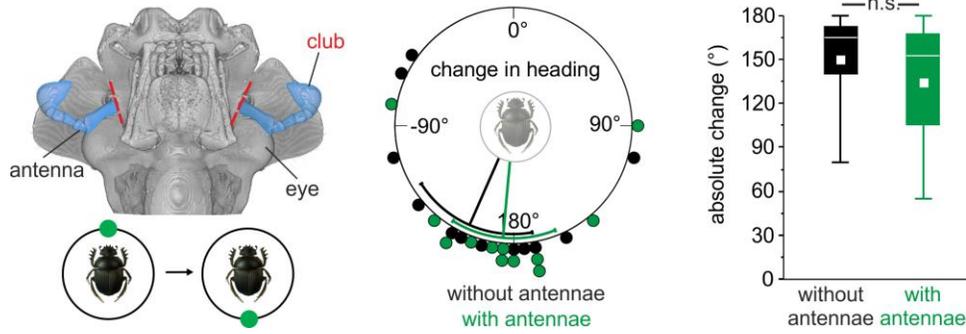
Figs. S1 to S3



**Fig. S1.** The wind speeds of the artificial wind stimulus measured across the field arena. Wind speed measured at the arena's center was 3 m/s. The circle with blue arrows indicates the position of the wind stimulus.



**Fig. S2.** Control experiments to study if olfactory cues (**A**) or vibrations (**B**) could play a role in the observed orientation behavior. (**A**) To test if olfactory cues play a role, we repeated the experiments shown in Fig. 2B (sun and wind stimuli in conflict during the second roll at high solar elevation) but this time, the part of the antennae that carries the olfactory receptor neurons, the club, was ablated. Even without the club, the beetles followed the wind stimulus (*blue circles*), suggesting that they use wind cues to maintain their heading. Beetles with intact clubs were tested in parallel (*open circles*). Mean directions are shown as lines, CIs are shown as sectors. (**B**) To test if beetles can use vibrations produced by the fan to orient by, we blocked the air-flow coming from one fan during the second roll. In the control condition (*blue circles*), the wind was not blocked. If the fan did not produce any wind during the second roll (but did vibrate), the beetles were not able to follow the 180° turn of the fan vibrations (*red circles*). \*\*\* =  $p < 0.001$ .



**Fig. S3.** Control experiments to study if dung beetles without antennae are still able to orient to a 180° change of the ersatz sun position. Beetles without (and with) complete antennae (the same beetles as shown in Fig. 3B) are able to follow a 180° switch of an ersatz sun stimulus (elevation: 20°). *Left plot:* in beetles with /without antennae the changes in heading were significantly clustered around 180° (with antennae, *green circles*,  $p < 0.001$ ; without antennae, *black circles*,  $p = 0.002$ , *V* test). Lines show the mean directions and the sectors indicate the CIs. *Right plot:* the absolute changes in heading (same beetles as shown in the *Left plot*) did not differ significantly ( $p = 0.393$ , Watson Williams F test). The white squares indicate the average and white horizontal lines the median absolute change. The boxes show the interquartile range and whiskers extend to the 5<sup>th</sup> and 95<sup>th</sup> percentile. n.s. =  $p > 0.05$ .