Supporting Information

Cheeseman et al. 10.1073/pnas.1408039111

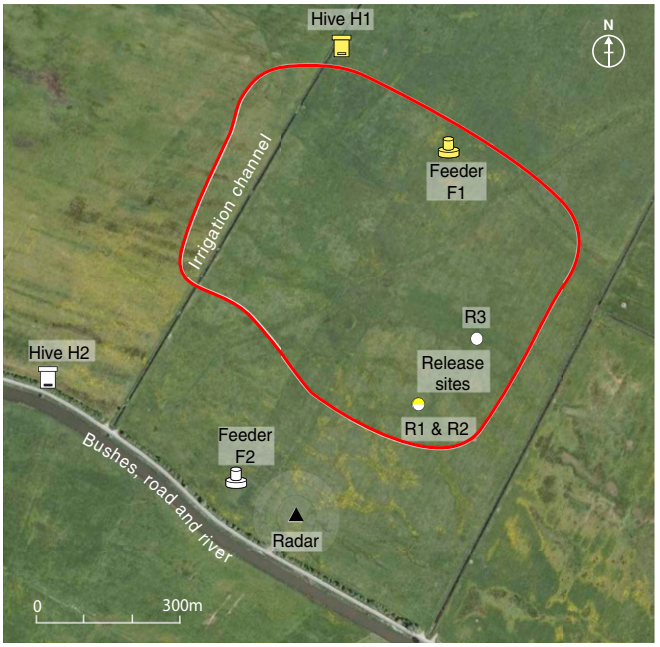

Fig. S1. Map of the study area showing the limits of the influence of the skyline. Inside the red boundary, no skyline cues are greater than 2° above the horizon. Release site R1 was selected for the first experiment to keep flights of control bees and time-shifted bees within this area, preventing their referring to the structure of the skyline.

Fig. S2. Two views from release site R1: (*A*) toward north; (*B*) toward south.

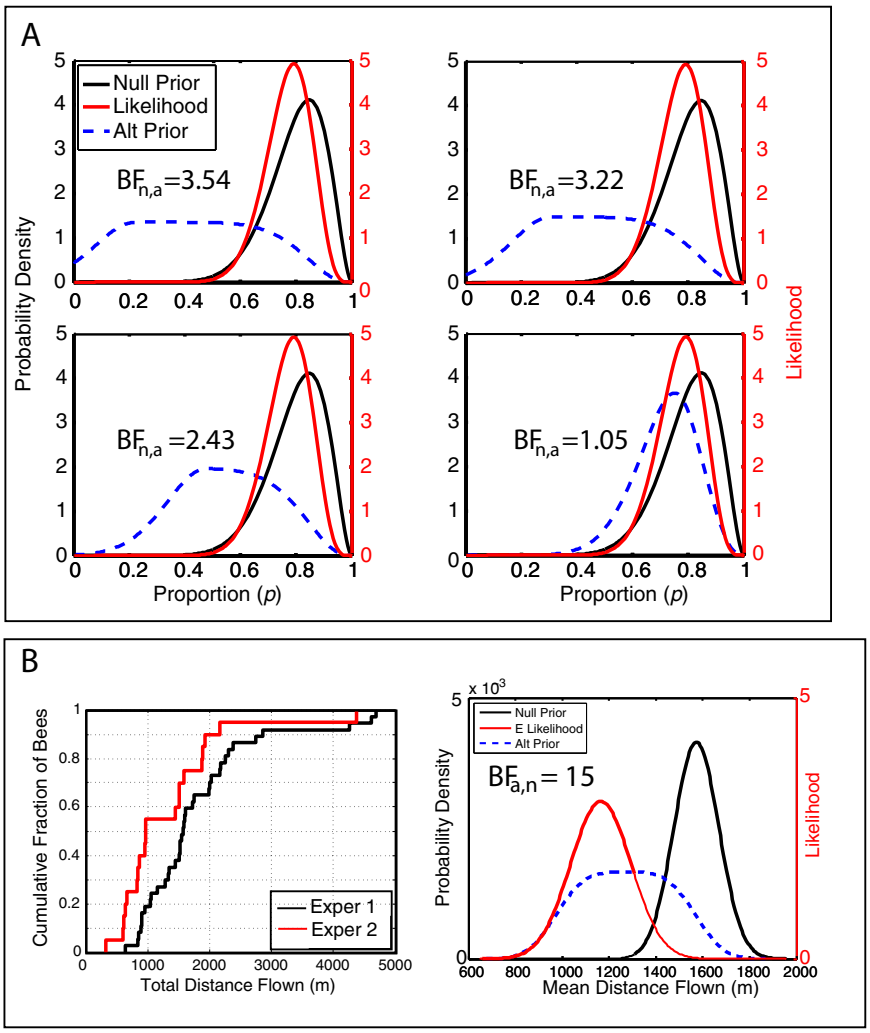

Fig. S3. (*A*) Graphic illustration of the computation of Bayes Factors for the null hypothesis showing that there is no difference between the proportions of bees returning to the hive in the control and clock-shifted groups. The null hypothesis (no difference in the proportions) is represented by the black probability distribution, which is the same from panel to panel. This distribution is the normalized likelihood function, given the control data. The alternative hypotheses, which suggest that there is a range of possible differences, are represented by the dashed blue probability distributions, which vary from panel to panel. The prior probability distributions, representing the competing hypotheses (Null and Alt Prior) are plotted against the left Probability Density axis. The red curve, which is the same from panel to panel, is the likelihood function given the clock-shifted data. It is plotted against the right axis (Likelihood). The two posterior likelihood functions for a given panel are the products of the likelihood function with each of the competing probability distributions. The marginal likelihoods of the competing hypotheses are the integrals of the posterior likelihood functions. The Bayes Factors ($BF_{n,a}$) are the ratios of the two marginal likelihoods. (The subscript "n,a" indicates that the marginal posterior likelihood of the null is the numerator and the marginal posterior likelihood of the alternative the denominator.) The probability distribution that puts more prior probability under the likelihood function has the greater marginal likelihood; hence, the Bayes Factor favors that that hypothesis (that prior). It is generally graphically obvious which prior puts more probability under the likelihood function. In this sequence, we see that no matter how limited the range of the alternative to the null is taken to be (no matter how narrow the dashed blue distribution), the black distribution puts more probability under the likelihood function (the red curve); hence, the Bayes Factor always favors the null. Of course, the extent to which it favors the null gets smaller as the alternative to the null becomes less and less distinguishable from the null. (*B*) The cumulative distributions of total distances flown by the bees in Exps. 1 and 2. The values >3,000 m appear to be outliers and were removed from the data before computing the Bayes Factor for the effect of the manipulation that distinguished Exp. 2 from Exp. 1. One sees that the distribution of distances flown in Exp. 2 (red plot) lies substantially to the left of the distribution of distances flown in Exp. 1 (black plot); that is, the bees in Exp. 2 did not fly as far in the course of getting home, even though they were released farther from the hive than were the bees in Exp. 1. (*Right*) Graphic illustration of the computation of the Bayes Factor. Because the alternative hypothesis (some effect, dashed blue distribution, plotted against left axis) places much more probability mass under the likelihood function (red curve, plotted against right axis) than does the null hypothesis (black distribution, plotted against the left axis), the Bayes Factor ($BF_{a,n}$) strongly favors the hypothesis that the manipulation did affect the distance flown.

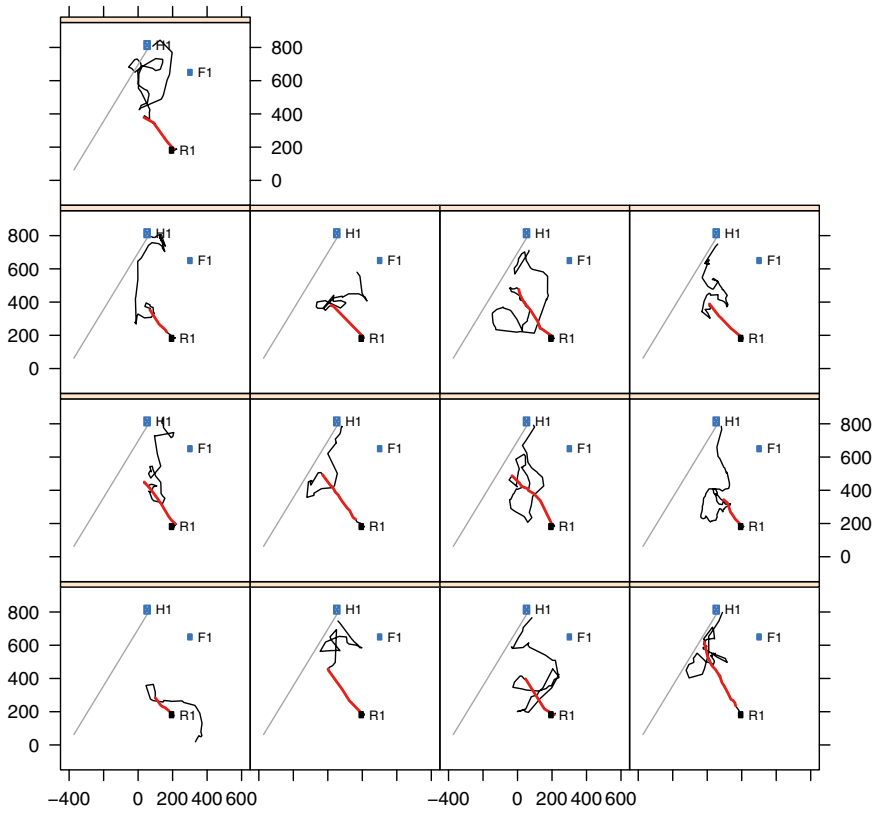

Fig. S4. Individual flight paths of the control bees in Exp. 1. The red line indicates the initial vector flight component. The gray diagonal line represents the western irrigation channel. The hive, feeder, and release sites are labeled H1, F1, and R1, respectively.

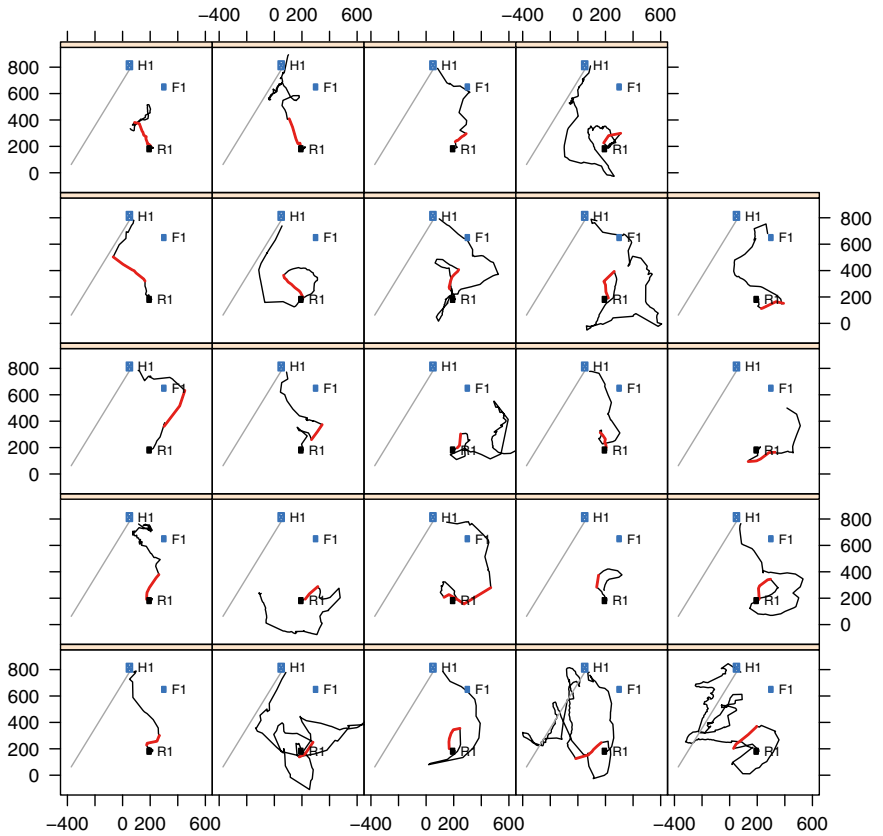

Fig. S5. Individual flight paths of the time-shifted bees in Exp. 1. See caption to Fig. S1 for key.

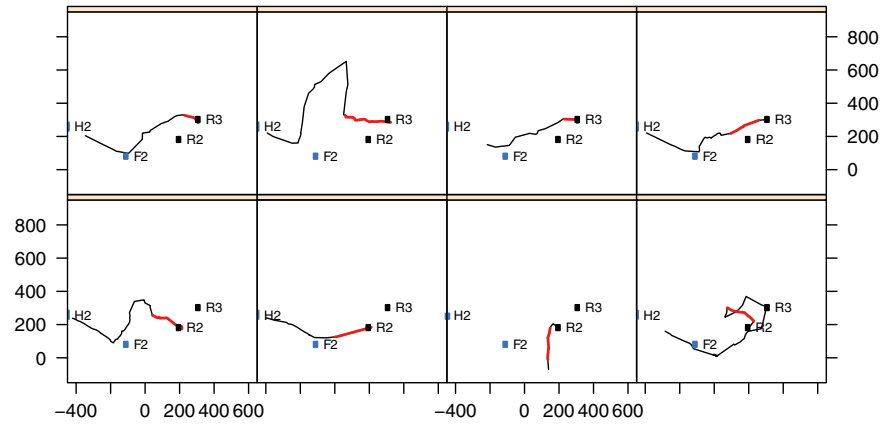

Fig. S6. Individual flight paths of the control bees in Exp. 2. The red line indicates the initial vector flight component. The hive, feeder, and release sites are labeled H2, F2, R2, and R3, respectively.

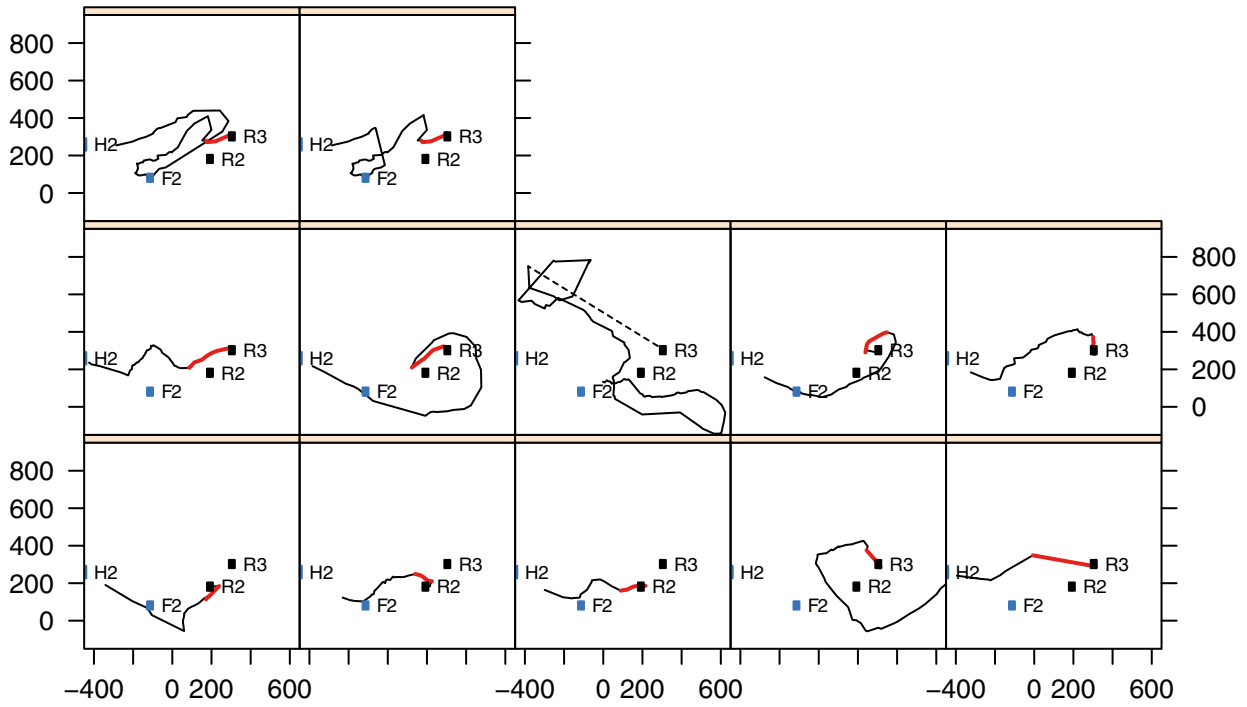

Fig. S7. Individual flight paths of the time-shifted bees in Exp. 2. In one animal (center row, center columns) the dashed line indicates missing data interpolated from the release site. For this animal, no vector flight was defined. The hive, feeder, and release sites (1 and 2) are labeled H2, F2, and R2, respectively.

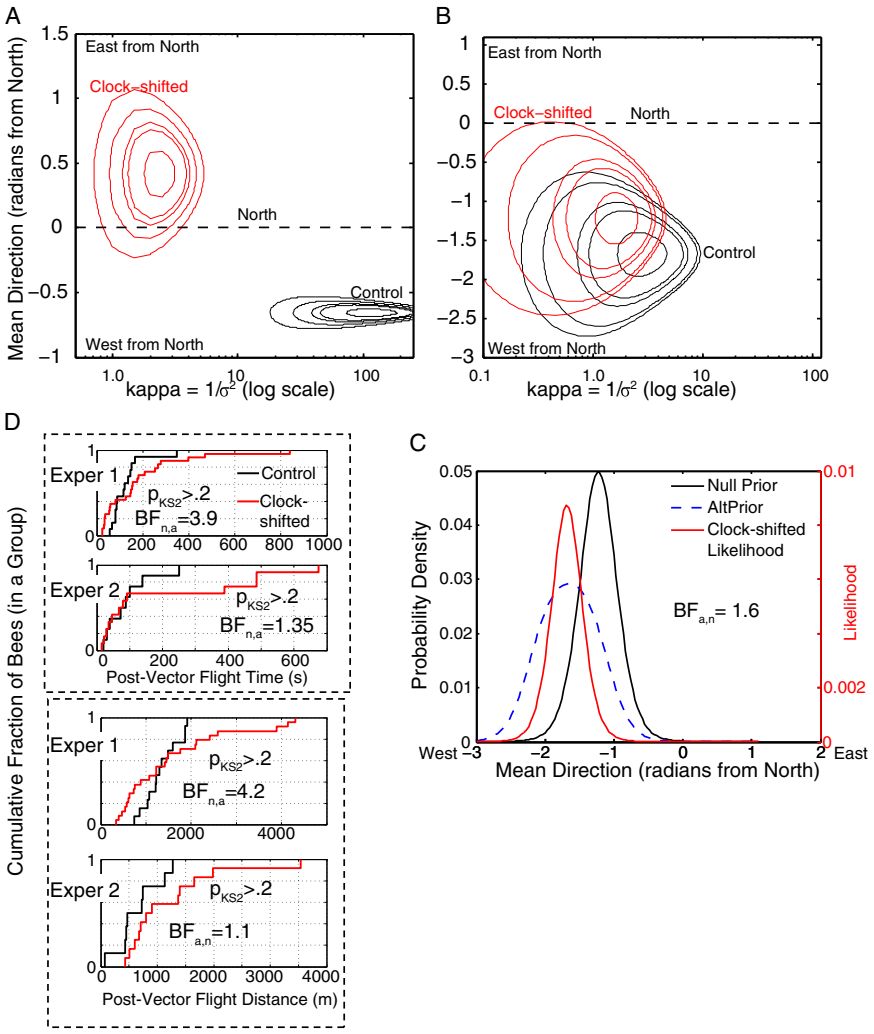

Fig. S8. (*A*) Contour plots of the directional likelihood functions for the control and clock-shifted bees in Exp. 1. The outer contours are for a likelihood 1/1,000th of the maximum likelihood. Because the likelihood functions do not overlap (either in their means or in their precisions (κ), either an null-hypothesis significance test or a Bayes Factor will show overwhelming support for the existence of an experiment effect. (*B*) The directional likelihood functions in Exp. 2. These overlap strongly. (*C*) Computation of the Bayes Factor for difference in the mean directions in Exp. 2. The Null Prior (black distribution, plotted against left axis, Probability Density) is the normalized marginal likelihood function for the mean direction of the control bees (partial integral of the black likelihood function in *B*). The red function is the (unnormalized) marginal likelihood function for mean direction of the clock-shifted bees (the partial integral of the red likelihood function in *B*). It is plotted against the right axis (Likelihood). The dashed blue prior probability distribution (plotted against the left axis) is for the hypothesis that the directional shift in this experiment is somewhere within the range between 0 (no shift) and the shift observed in Exp. 1. The alternative prior (some shift in direction) puts slightly more probability mass under the likelihood function. However, the BF of 1.6 is far from the 3.0 level generally taken to indicate nonnegligible evidence for an experimental effect. (*D*) Cumulative distributions of postvector flight times (*Upper*) and flight distances (*Lower*) together with Kolmogorov–Smirnov *P* values and Bayes Factors. By either assessment, there are no within-experiment effects on flight time and distance flown: that is, the clock-shifted bees took no longer to get to the hive and flew no further in doing so than did the control bees. There is, however, a highly significant difference in flight distances between the two experiments (see Fig. S3*B*).