Online Supplementary Material

Social immunity and chemical communication in the honeybee: immune-challenged bees enter enforced or self-imposed exile, by Tarli Conroy and Luke Holman.

The figures and tables in this document, along with the with the R code used to generate them, can also be viewed online at https://lukeholman.github.io/social_immunity/

Table S1: Table summarising the posterior estimates of each fixed effect in the best-fitting model of Experiment 1. This was a multinomial model with three possible outcomes (stay inside, leave voluntarily, be forced out), and so there are two parameter estimates for the intercept and for each predictor in the model. 'Treatment' is a fixed factor with four levels, and the effects shown here are expressed relative to the 'Intact control' group. 'Hive' was also a fixed factor with four levels; unlike for treatment, we modelled hive using deviation coding, such that the intercept term represents the mean across all hives (in the intact control treatment), and the three hive terms represent the deviation from this mean for three of the four hives. Lastly, observation duration was a continuous predictor expressed to the nearest minute. The p column gives the posterior probability that the true effect size is opposite in sign to what is reported in the Estimate column, similarly to a p-value.

Parameter	Estimate	Est. Error	Lower 95% CI	Upper 95% CI	PP	
% bees leaving voluntarily						
Intercept	-14.87	9.43	-35.35	2.07	0.04	*
Treatment: Ringers	0.66	0.97	-1.39	2.43	0.23	
Treatment: Heat-treated LPS	1.30	0.61	0.13	2.53	0.02	*
Treatment: LPS	1.68	0.60	0.53	2.90	0.00	**
hive1	-1.51	2.62	-6.60	3.58	0.28	
hive2	3.13	1.48	0.84	6.62	0.00	**
hive3	-1.52	1.60	-4.78	1.56	0.17	
Observation duration (minutes)	0.09	0.09	-0.07	0.28	0.15	
% bees forced out						
Intercept	-7.40	6.71	-20.82	5.74	0.13	
Treatment: Ringers	0.55	0.45	-0.34	1.44	0.11	
Treatment: Heat-treated LPS	1.30	0.41	0.52	2.10	0.00	***
Treatment: LPS	0.97	0.42	0.16	1.80	0.01	*
hive1	-0.39	2.52	-5.31	4.67	0.44	
hive2	-0.12	0.65	-1.39	1.16	0.43	
hive3	-0.76	1.52	-3.83	2.20	0.31	
Observation duration (minutes)	0.04	0.07	-0.10	0.18	0.29	

Table S2: This table gives statistics associated with each of the contrasts plotted in Figure 1B. Each pair of rows gives the absolute effect size (i.e. the difference in % bees) and standardised effect size (as log odds ratio; LOR) for the focal treatment, relative to the treatment shown in parentheses, for one of the three possible outcomes (stayed inside, left voluntarily, or forced out). A LOR of $|log(x)|$ indicates that the outcome is x times more frequent in one treatment compared to the other, e.g. $log(2) = 0.69$ and $log(0.5) = -0.69$ correspond to a two-fold difference in frequency. The PP column gives the posterior probability that the true effect size has the same sign as is shown in the Estimate column; this metric has a similar interpretation to a one-tailed p value in frequentist statistics.

Comparison	Metric	Estimate	Est.Error	Lower 95% CI	Upper 95% CI	PP
% bees staying inside						
LPS (Heat-treated LPS)	Difference in % bees staying inside	0.98	8.09	-17.01	17.18	
	Log odds ratio	0.05	0.43	-0.90	0.85	0.4255
LPS (Ringers)	Difference in % bees staying inside	-9.54	9.87	-33.80	5.35	
	Log odds ratio	-0.62	0.54	-1.82	0.33	0.1047
LPS (Intact control)	Difference in % bees staying inside	-17.27	10.86	-42.03	-1.89	
	Log odds ratio	-1.23	0.46	-2.21	-0.38	0.0021
Heat-treated LPS (Ringers)	Difference in % bees staying inside	-10.52	9.66	-31.87	5.76	
	Log odds ratio	-0.68	0.51	-1.69	0.37	0.0840
Heat-treated LPS (Intact control)	Difference in % bees staying inside	-18.25	10.72	-40.41	-2.13	
	Log odds ratio	-1.29	0.40	-2.09	-0.49	0.0021
Ringers (Intact control)	Difference in % bees staying inside	-7.73	8.93	-29.75	4.96	
	Log odds ratio	-0.61	0.54	-1.70	0.44	0.1158
% bees leaving voluntarily						
LPS (Heat-treated LPS)	Difference in % bees leaving voluntarily	3.64	6.63	-5.35	22.30	
	Log odds ratio	0.46	0.53	-0.56	1.52	0.1919
LPS (Ringers)	Difference in % bees leaving voluntarily	6.27	10.01	-5.24	35.00	
	Log odds ratio	0.95	0.90	-0.64	2.82	0.1396
LPS (Intact control)	Difference in % bees leaving voluntarily	9.51	11.02	0.13	40.61	
	Log odds ratio	1.53	0.63	0.28	2.77	0.0091
Heat-treated LPS (Ringers)	Difference in % bees leaving voluntarily	2.64	8.40	-11.88	25.56	
	Log odds ratio	0.49	0.94	-1.20	2.46	0.3086
Heat-treated LPS (Intact control)	Difference in % bees leaving voluntarily	5.87	8.33	-0.48	30.99	
	Log odds ratio	1.07	0.66	-0.25	2.38	0.0546
Ringers (Intact control)	Difference in % bees leaving voluntarily	3.23	7.79	-6.36	26.72	
	Log odds ratio	0.58	0.98	-1.47	2.37	0.2559
% bees forced out						
LPS (Heat-treated LPS)	Difference in % bees forced out	-4.62	6.30	-20.93	4.80	
	Log odds ratio	-0.39	0.39	-1.19	0.36	0.1601
LPS (Ringers)	Difference in % bees forced out	3.27	6.31	-7.38	19.17	
	Log odds ratio	0.30	0.46	-0.64	1.18	0.2446
LPS (Intact control)	Difference in % bees forced out	7.76	8.27	-0.83	28.69	
	Log odds ratio	0.80	0.48	-0.21	1.71	0.0535
Heat-treated LPS (Ringers)	Difference in % bees forced out	7.88	7.87	-1.34	27.16	
	Log odds ratio	0.69	0.44	-0.18	1.53	0.0556
Heat-treated LPS (Intact control)	Difference in % bees forced out	12.38	10.49	0.32	36.95	
	Log odds ratio	1.18	0.44	0.29	2.03	0.0078
Ringers (Intact control)	Difference in % bees forced out	3.23	7.79	-6.36	26.72	
	Log odds ratio	0.58	0.98	-1.47	2.37	0.2559

Table S3: Table summarising the posterior estimates of each fixed effect in the best-fitting model of Experiment 2. This was a multinomial model with three possible outcomes (stay inside, leave voluntarily, be forced out), and so there are two parameter estimates for the intercept and for each predictor in the model. 'Treatment' is a fixed factor with two levels, and the effect of LPS shown here is expressed relative to the 'Ringers' treatment. 'Hive' was a fixed factor with four levels; unlike for treatment, we modelled hive using deviation coding, such that the intercept term represents the mean across all hives (in the Ringers treatment), and the three hive terms represent the deviation from this mean for three of the four hives. Lastly, observation duration was a continuous predictor expressed to the nearest minute. The p column gives the posterior probability that the true effect size is opposite in sign to what is reported in the Estimate column, similarly to a p-value.

Parameter	Estimate	Est. Error	Lower 95% CI	Upper 95% CI	PP	
% bees leaving voluntarily						
Intercept	-6.37	6.67	-19.69	6.68	0.17	
Treatment: LPS	0.38	0.44	-0.48	1.25	0.20	
hive1	0.11	1.52	-2.87	3.08	0.47	
hive2	-0.18	0.68	-1.51	1.16	0.39	
hive3	0.08	2.53	-4.84	5.11	0.49	
Observation duration (minutes)	0.03	0.07	-0.10	0.16	0.34	
% bees forced out						
Intercept	-5.18	6.71	-18.32	7.89	0.22	
Treatment: LPS	1.10	0.43	0.29	1.99	0.00	**
hive1	-0.03	1.54	-3.06	2.97	0.49	
hive2	-0.85	0.71	-2.27	0.49	0.11	
hive3	0.05	2.55	-4.89	5.09	0.49	
Observation duration (minutes)	0.01	0.07	-0.12	0.15	0.41	

Table S4: This table gives statistics associated with each of the contrasts plotted in Figure 2B. Each pair of rows gives the absolute (i.e. the difference in % bees) and standardised effect size (as log odds ratio; LOR) for the LPS treatment, relative to the Ringers treatment, for one of the three possible outcomes (stayed inside, left voluntarily, or forced out). A LOR of $|log(x)|$ indicates that the outcome is x times more frequent in one treatment compared to the other, e.g. $log(2) = 0.69$ indicates a two-fold difference in frequency. The PP column gives the posterior probability that the true effect size has the same sign as is shown in the Estimate column; this metric has a similar interpretation to a one-tailed p value in frequentist statistics.

Metric	Estimate	Est.Error	Lower 95% CI	Upper 95% CI	PP	
% bees staying inside						
Absolute difference in % bees staying inside	-11.95	4.94	-22.21	-2.75		
Log odds ratio	-0.84	0.33	-1.52	-0.20	0.0048	**
% bees leaving voluntarily						
Absolute difference in % bees leaving voluntarily	1.34	2.62	-3.72	7.09		
Log odds ratio	0.24	0.44	-0.62	1.11	0.2881	
% bees forced out						
Absolute difference in % bees forced out	10.61	4.63	2.54	20.46		
Log odds ratio	1.08	0.43	0.27	1.97	0.0047	**

Table S5: Table summarising the posterior estimates of each fixed effect in the best-fitting model of Experiment 3 that contained the treatment effect. This was a binomial model where the response variable was 0 for observations in which bees were not in close contact, and 1 when they were. 'Treatment' is a fixed factor with two levels, and the effect of LPS shown here is expressed relative to the 'Ringers' treatment. 'Hive' was a fixed factor with four levels; unlike for treatment, we modelled hive using deviation coding, such that the intercept term represents the mean across all hives (in the Ringers treatment), and the three hive terms represent the deviation from this mean for three of the four hives. The model also included one random effect, 'pair ID', which grouped observations made on each pair of bees, preventing pseudoreplication. The PP column gives the posterior probability that the true effect size is opposite in sign to what is reported in the Estimate column, similarly to a p-value.

Parameter	Estimate	Est. Error	Lower 95% CI	Upper 95% CI	PP	
Intercept	1.68	0.14	1.40	1.96	0.00	***
Treatment: LPS	-0.37	0.20	-0.76	0.02	0.03	*
hive1	-0.20	0.17	-0.54	0.14	0.13	
hive2	0.14	0.16	-0.16	0.46	0.18	
hive3	-0.23	0.18	-0.58	0.12	0.10	

Table S6: Pairs in which one bee had received LPS were observed in close contact less frequently than pairs in which one bee had received Ringers solution.

Metric	Estimate	Est.Error	Lower 95% CI	Upper 95% CI	p	
Absolute difference in % time in close contact	5.54	3.01	-0.33	11.50		
Log odds ratio	-0.37	0.20	-0.76	0.02	0.0328	*