

# 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/](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	
<b>% bees leaving voluntarily</b>						
Intercept	-14.87	9.43	-35.35	2.07	0.0446	*
Treatment: Ringers	0.66	0.97	-1.39	2.43	0.2321	
Treatment: Heat-treated LPS	1.30	0.61	0.13	2.53	0.0153	*
Treatment: LPS	1.68	0.60	0.53	2.90	0.0020	**
hive1	-1.51	2.62	-6.60	3.58	0.2808	
hive2	3.13	1.48	0.84	6.62	0.0012	**
hive3	-1.52	1.60	-4.78	1.56	0.1718	
Observation duration (minutes)	0.09	0.09	-0.07	0.28	0.1477	
<b>% bees forced out</b>						
Intercept	-7.40	6.71	-20.82	5.74	0.1341	
Treatment: Ringers	0.55	0.45	-0.34	1.44	0.1143	
Treatment: Heat-treated LPS	1.30	0.41	0.52	2.10	0.0004	***
Treatment: LPS	0.97	0.42	0.16	1.80	0.0113	*
hive1	-0.39	2.52	-5.31	4.67	0.4367	
hive2	-0.12	0.65	-1.39	1.16	0.4306	
hive3	-0.76	1.52	-3.83	2.20	0.3094	
Observation duration (minutes)	0.04	0.07	-0.10	0.18	0.2885	

**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	
<b>% bees staying inside</b>							
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	
<b>% bees leaving voluntarily</b>							
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	
<b>% bees forced out</b>							
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 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	
<b>% bees leaving voluntarily</b>						
Intercept	-6.37	6.67	-19.69	6.68	0.1683	
Treatment: LPS	0.38	0.44	-0.48	1.25	0.1974	
hive1	0.11	1.52	-2.87	3.08	0.4657	
hive2	-0.18	0.68	-1.51	1.16	0.3902	
hive3	0.08	2.53	-4.84	5.11	0.4913	
Observation duration (minutes)	0.03	0.07	-0.10	0.16	0.3366	
<b>% bees forced out</b>						
Intercept	-5.18	6.71	-18.32	7.89	0.2217	
Treatment: LPS	1.10	0.43	0.29	1.99	0.0039	**
hive1	-0.03	1.54	-3.06	2.97	0.4900	
hive2	-0.85	0.71	-2.27	0.49	0.1120	
hive3	0.05	2.55	-4.89	5.09	0.4928	
Observation duration (minutes)	0.01	0.07	-0.12	0.15	0.4140	

**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 control, 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	
<b>% bees staying inside</b>						
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	**
<b>% bees leaving voluntarily</b>						
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	
<b>% bees forced out</b>						
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	0.0000	***
Treatment: LPS	-0.37	0.20	-0.76	0.02	0.0328	*
hive1	-0.20	0.17	-0.54	0.14	0.1300	
hive2	0.14	0.16	-0.16	0.46	0.1800	
hive3	-0.23	0.18	-0.58	0.12	0.1021	

**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. 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.

Metric	Estimate	Est.Error	Lower 95% CI	Upper 95% CI	PP	
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	*