Accelerated landings in stingless bees are triggered by visual threshold cues
Supplementary Material

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Text S1: Calculation of the angular size and rate of expansion of the target during landing:

Consider a landing *Scaptotrigona depilis* with the spatial coordinates x-y-z flying at a linear speed V and at a distance D from the centre of the artificial target of diameter S. We wish to determine the angular size of the target θ^T and the angular rate of expansion $d\theta^T/dt$.

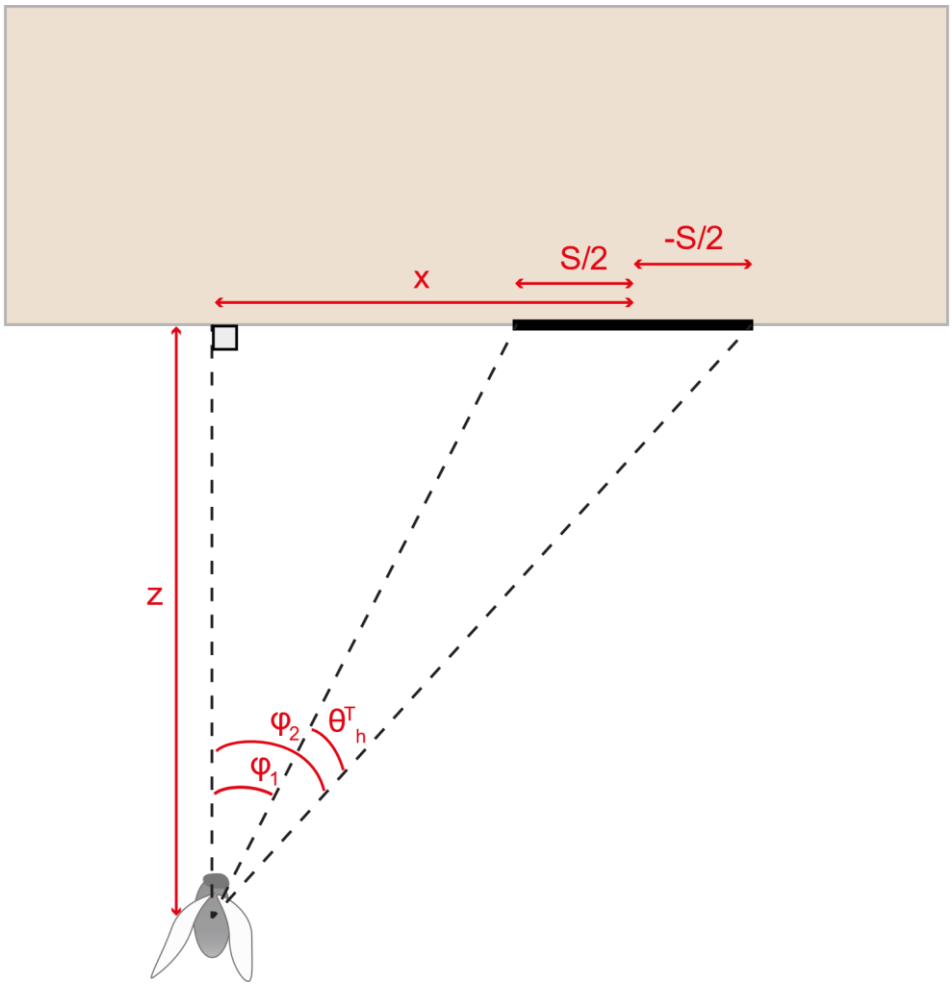


Figure S1: Framework for the calculation of the horizontal component of the angular size of the target θ^T_h. The landing bee has the spatial coordinates x-y-z and the linear speed V. The beige rectangle represents the hive box. The black bar is the target of diameter S.

1) Calculation of the angular size θ^T

Given θ^T_h the horizontal component of θ^T. As schematised in Figure S1:

$\theta^T_h = \varphi_2 - \varphi_1$

Therefore, by using the inverse tangent function - Arctan:

$$\theta^T_h = \text{Arctan}\left(\frac{x + \frac{S}{2}}{z}\right) - \text{Arctan}\left(\frac{x - \frac{S}{2}}{z}\right)$$

As θ^T_h is in the range [-90, 90] deg, we can use the formula Arctan(a) – Arctan(b) = Arctan $\left(\frac{a-b}{1+ab}\right)$:

$$\theta^{T}{}_{h} = \text{Arctan}\ \frac{\frac{x+\frac{S}{2}}{z} - \frac{x-\frac{S}{2}}{z}}{\left(1+\left(\frac{x+\frac{S}{2}}{z}\right)\left(\frac{x-\frac{S}{2}}{z}\right)\right)}$$

Therefore:

$$\theta^{T}{}_{h} = \text{Arctan}\ \frac{\frac{S}{z}}{\left(1+\frac{x^2-\frac{S^2}{4}}{z^2}\right)}$$

Hence:

$$\theta^{T}{}_{h} = \text{Arctan}\left(\frac{Sz}{z^2+x^2-\frac{S^2}{4}}\right)$$

Given $\theta^{T}{}_{v}$ the vertical component of θ^{T}, θ^{T} is the average of its vertical and horizontal components:

$$\theta^{T} = \frac{\theta^{T}{}_{h} + \theta^{T}{}_{v}}{2}$$

Hence equation 1:

$$\text{Eq1: } \theta^{T} = \frac{1}{2}\text{Arctan}\left(\frac{Sz}{z^2+x^2-\frac{S^2}{4}}\right) + \frac{1}{2}\text{Arctan}\left(\frac{Sz}{z^2+y^2-\frac{S^2}{4}}\right)$$

2) Calculation of the absolute and relative angular speed

We take equation 2 from Baird et al 2015:

$$\text{Eq 2: } \frac{d\theta^{T}}{dt} \approx \frac{V\sin 2\theta^{T}}{2D}$$

Where $d\theta^{T}/dt$ is the rate of expansion of the target. And the rate of expansion relative to θ^{T} is:

$$\frac{d\theta^{T}}{\theta^{T}dt}$$

Text S2: Calculation of predicted values of angular size at landing initiation (LI) and leg extension (LE) in four landing control hypotheses:

(1) Constant angular size hypothesis

at LI and LE, for every bee:

$\theta^{T}_{(1)} = \overline{\theta^{T}}$

Where $\overline{\theta^{T}}$ is the average value of angular size over all the bees.

(2) Constant distance to the target hypothesis

at LI and LE, per definition:

$D^2 = x^2 + y^2 + z^2$

With Eq1, for every bee:

$$\theta^{T}_{(2)} = \frac{1}{2}\mathrm{Arctan}\left(\frac{Sz}{\overline{D}^2 + y^2 - \frac{S^2}{4}}\right) + \frac{1}{2}\mathrm{Arctan}\left(\frac{Sz}{\overline{D}^2 + x^2 - \frac{S^2}{4}}\right)$$

Where $\overline{D}$ is the value of the distance to the target averaged across all flights.

(3) Constant absolute rate of expansion hypothesis

With Eq2, for every bee at LI and LE:

$$\overline{\left(\frac{d\theta^{T}}{dt}\right)} = \frac{V\sin 2\theta^{T}_{(3)}}{D}$$

$$\theta^{T}_{(3)} = \frac{1}{2}\mathrm{Arcsin}\left(\frac{\overline{\left(\frac{d\theta^{T}}{dt}\right)}D}{V}\right)$$

Where $\overline{\left(\frac{d\theta^{T}}{dt}\right)}$ is the value of the rate of expansion averaged across all flights.

(4) Constant relative rate of expansion hypothesis

at LI and LE for every bee:

$$\theta^{T}_{(4)}\overline{\left(\frac{d\theta^{T}}{\theta^{T}dt}\right)} = \frac{V\sin 2\theta^{T}_{(4)}}{D}$$

Where $\overline{\left(\frac{d\theta^{T}}{\theta^{T}dt}\right)}$ is the value of the rate of expansion relative to θ^{T} averaged across all flights.

By isolating $\theta^{T}_{(4)}$:

Eq3: $$\frac{\sin 2\theta^{T}_{(4)}}{2\theta^{T}_{(4)}} = \frac{D\overline{\left(\frac{d\theta^{T}}{\theta^{T}dt}\right)}}{V}$$

Given the Taylor series, for every real number x:

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \cdots$$

Hence

$$\frac{\sin x}{x} = 1 - \frac{x^2}{3!} + \frac{x^4}{5!} + \frac{x^6}{7!} + \cdots$$

To solve equation 3, we look for solutions to the equation:

$$1 - \frac{D\overline{\left(\frac{d\theta^T}{\theta^T dt}\right)}}{V} + \frac{x^2}{3!} + \frac{x^4}{5!} + \frac{x^6}{7!} + \cdots = 0$$

Given $X = x^2$:

$$1 - \frac{D\overline{\left(\frac{d\theta^T}{\theta^T dt}\right)}}{V} + \frac{X}{3!} + \frac{X^2}{5!} \approx 0$$

Given X_1 is the positive solution to this second-degree equation, then the solution to equation 3 is:

$$\theta^T{}_{(4)} = \frac{\sqrt{X_1}}{2}$$

Reference:

Baird E, Boeddeker N, Ibbotson MR, Srinivasan M V. 2013 A universal strategy for visually guided landing. Pnas 110, 18686–18691. doi:10.1073/pnas.1314311110/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1314311110

Supplementary movies:
Merged recordings from the two synchronised cameras of landings separated by condition ($C_{position}$ and C_{size}) and hive. The recordings were compressed and slowed down 4.8 times to reduce file size (original frame rate = 120 frames.s^{-1}). The recordings for $C_{control}$ are available as supplementary material in Tichit et al. 2020.

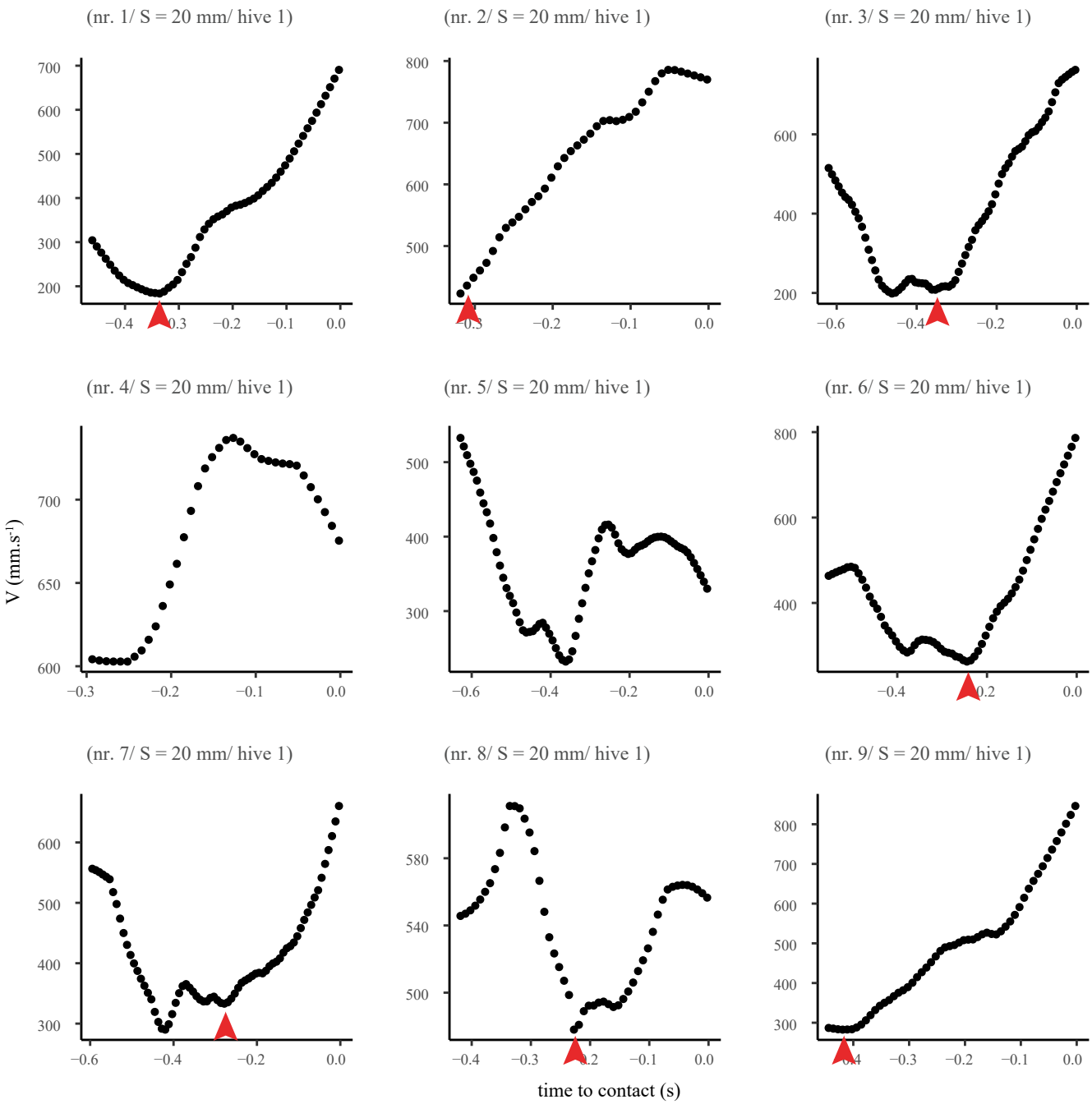
formula	*Sampling distribution (family)*	*Expected values (mu)*	*Variance (V)*	*Random effect of the hive (V)*	*Degree of belief (nu)*	*Residual variance (V)*	*Degree of belief (nu)*	*Number of iterations*	*burnin*	*thin*
1 + S	Gaussian	0 0	10^8 0 0 10^8	1	50	1	0.0002	1 100 000	100 000	100

Table S1:
Parameters of the linear mixed models using Markov Chain Monte Carlo techniques of landing variables with target size (S) as a fixed effect and hive as a random variable. Details on each parameter are provided in the documentation of the MCMCglmm package in R.

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	194	5.3	ns	[-0.88; 12]	0.26	**	[0.079; 0.45]
α	$mm.s^{-2}$	1 + S	495	1425	**	[357; 2372]	0.45	ns	[-27; 30]
θ^{T}_{LE}	deg	1 + S	237	41	**	[17; 64]	0.13	ns	[-0.52; 0.78]
x_{end}	mm	1 + S	224	1.4	ns	[-9.3; 12]	-0.016	ns	[-0.33; 0.29]
y_{end}	mm	1 + S	204	3.0	ns	[-4.5; 11]	0.25	*	[0.017; 0.47]

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	271	9.6	*	[1.1; 18]	0.097	ns	[-0.13; 0.32]
α	$mm.s^{-2}$	1 + S	605	1033	**	[294; 1712]	13	ns	[-5.1; 32]
θ^{T}_{LE}	deg	1 + S	150	31	ns	[-16; 76]	0.35	ns	[-0.64; 1.4]
x_{end}	mm	1 + S	284	-10		[-21; 1.3]	0.31	*	[-0.0041; 0.61]
y_{end}	mm	1 + S	218	-2.6	ns	[-7.2; 2.0]	0.34	***	[0.23; 0.47]

Table S2:
Linear mixed models of landing parameters in C_{size} with MCMC when separated between hive 1 (upper table) and hive 2 (lower table). The significances of the intercepts and slopes are given by the 95% credible interval (CI) and the bayesian p-value (p_{MCMC}). Significance codes: $<10^{-3}$ ***; $<10^{-2}$ **; <0.05 *; >0.05 ns.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(nr. 2/ S = 20 mm/ hive 1)
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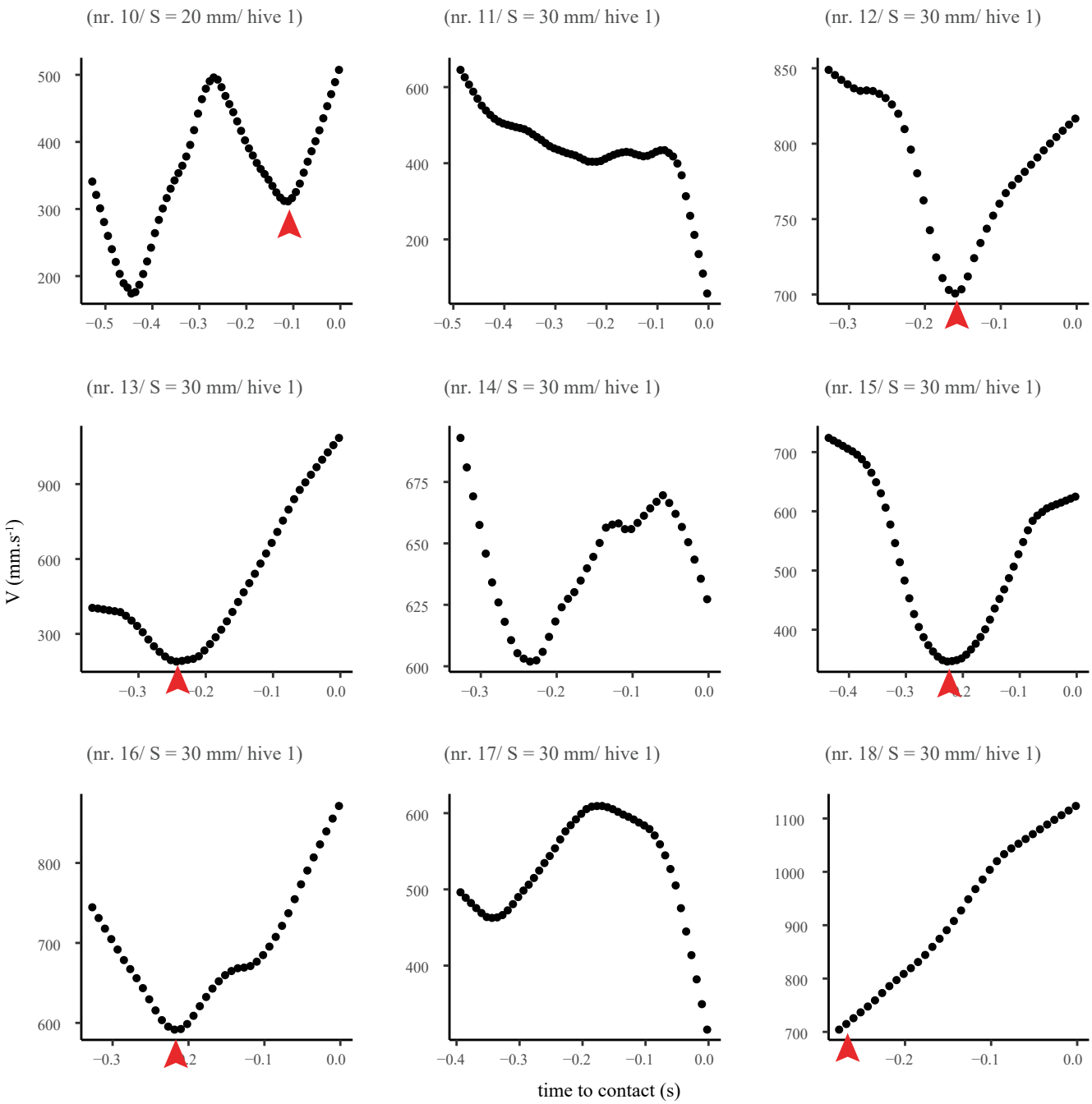
(nr. 4/ S = 20 mm/ hive 1)
(nr. 5/ S = 20 mm/ hive 1)
(nr. 6/ S = 20 mm/ hive 1)
(nr. 7/ S = 20 mm/ hive 1)
(nr. 8/ S = 20 mm/ hive 1)
(nr. 9/ S = 20 mm/ hive 1)
V (mm.s-1)
time to contact (s)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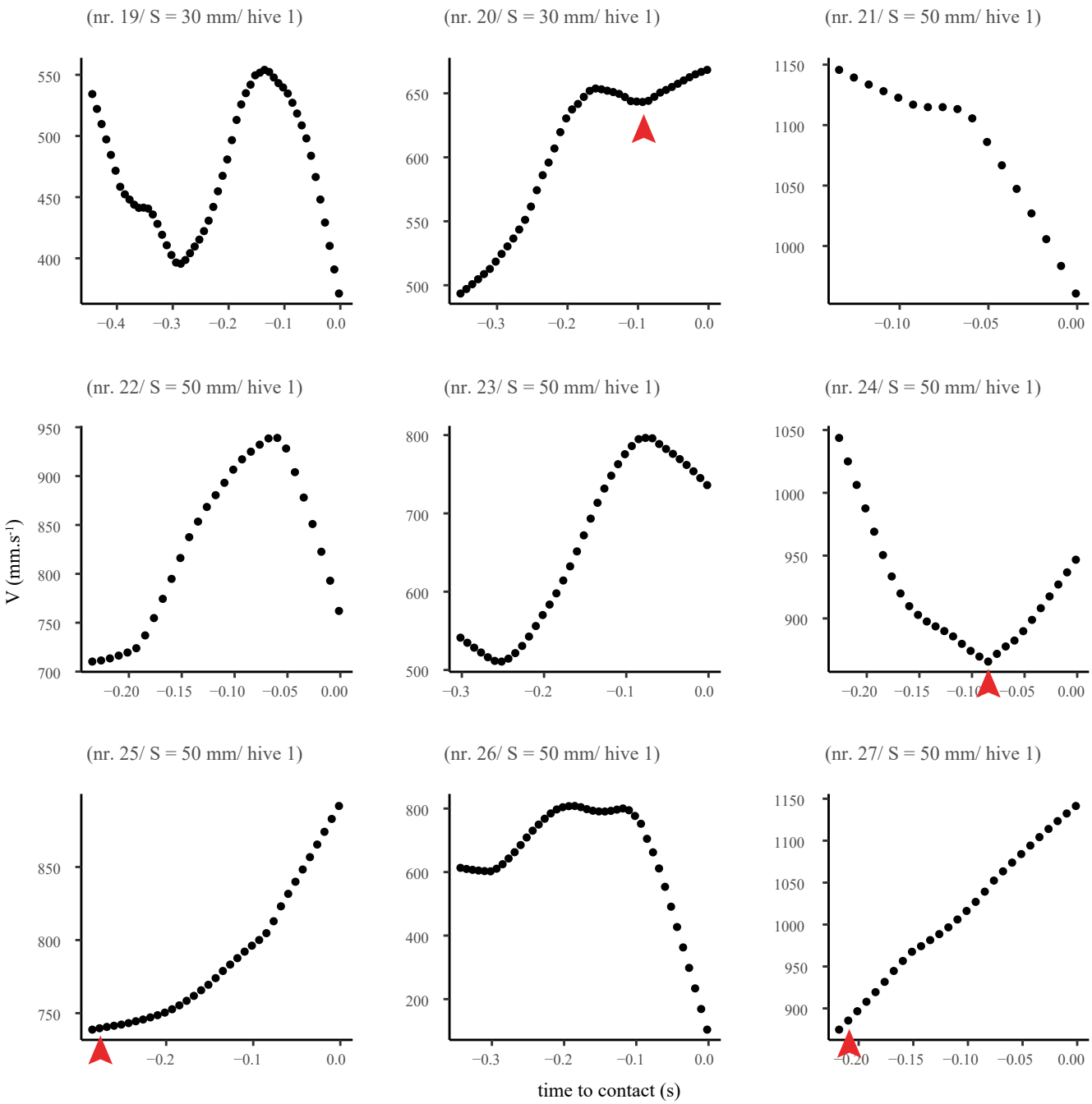
(nr. 14/ S = 30 mm/ hive 1)
(nr. 15/ S = 30 mm/ hive 1)
(nr. 16/ S = 30 mm/ hive 1)
(nr. 17/ S = 30 mm/ hive 1)
(nr. 18/ S = 30 mm/ hive 1)
V (mm.s-1)
time to contact (s)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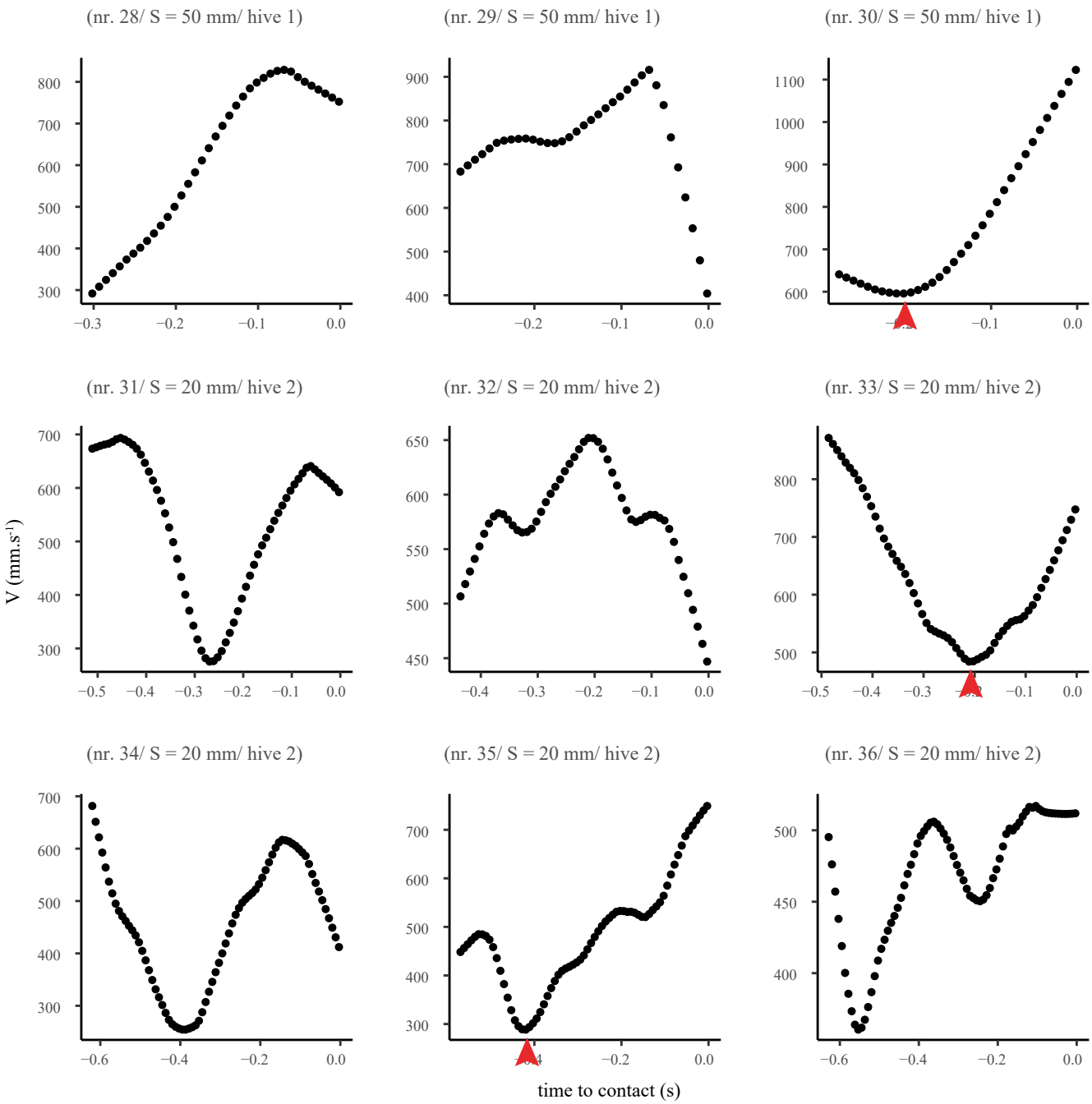
(nr. 23/ S = 50 mm/ hive 1)
(nr. 24/ S = 50 mm/ hive 1)
(nr. 25/ S = 50 mm/ hive 1)
(nr. 26/ S = 50 mm/ hive 1)
(nr. 27/ S = 50 mm/ hive 1)
V (mm.s-1)
time to contact (s)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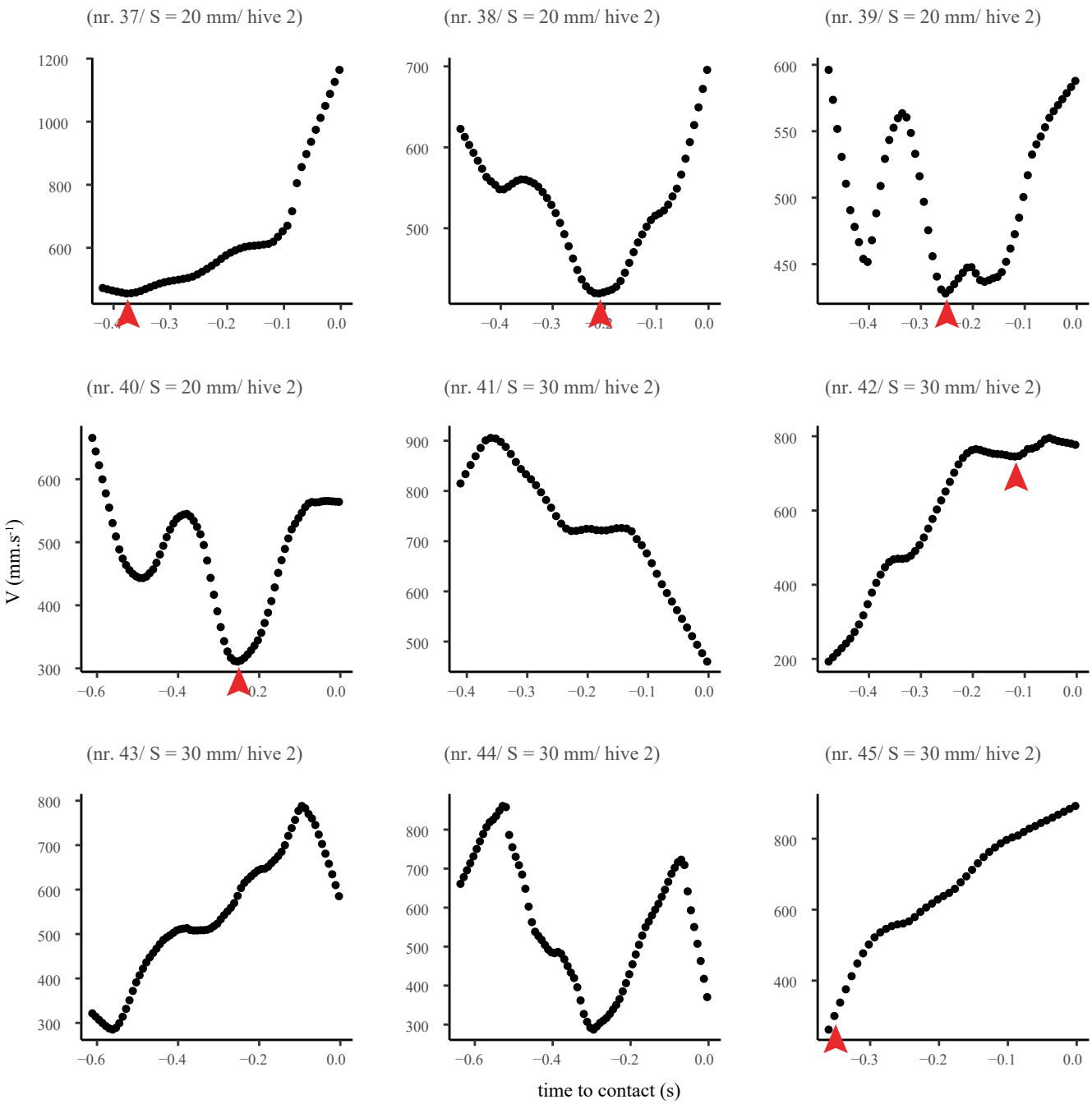
(nr. 32/ S = 20 mm/ hive 2)
(nr. 33/ S = 20 mm/ hive 2)
(nr. 34/ S = 20 mm/ hive 2)
(nr. 35/ S = 20 mm/ hive 2)
(nr. 36/ S = 20 mm/ hive 2)
V (mm.s-1)
time to contact (s)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(nr. 43/ S = 30 mm/ hive 2)
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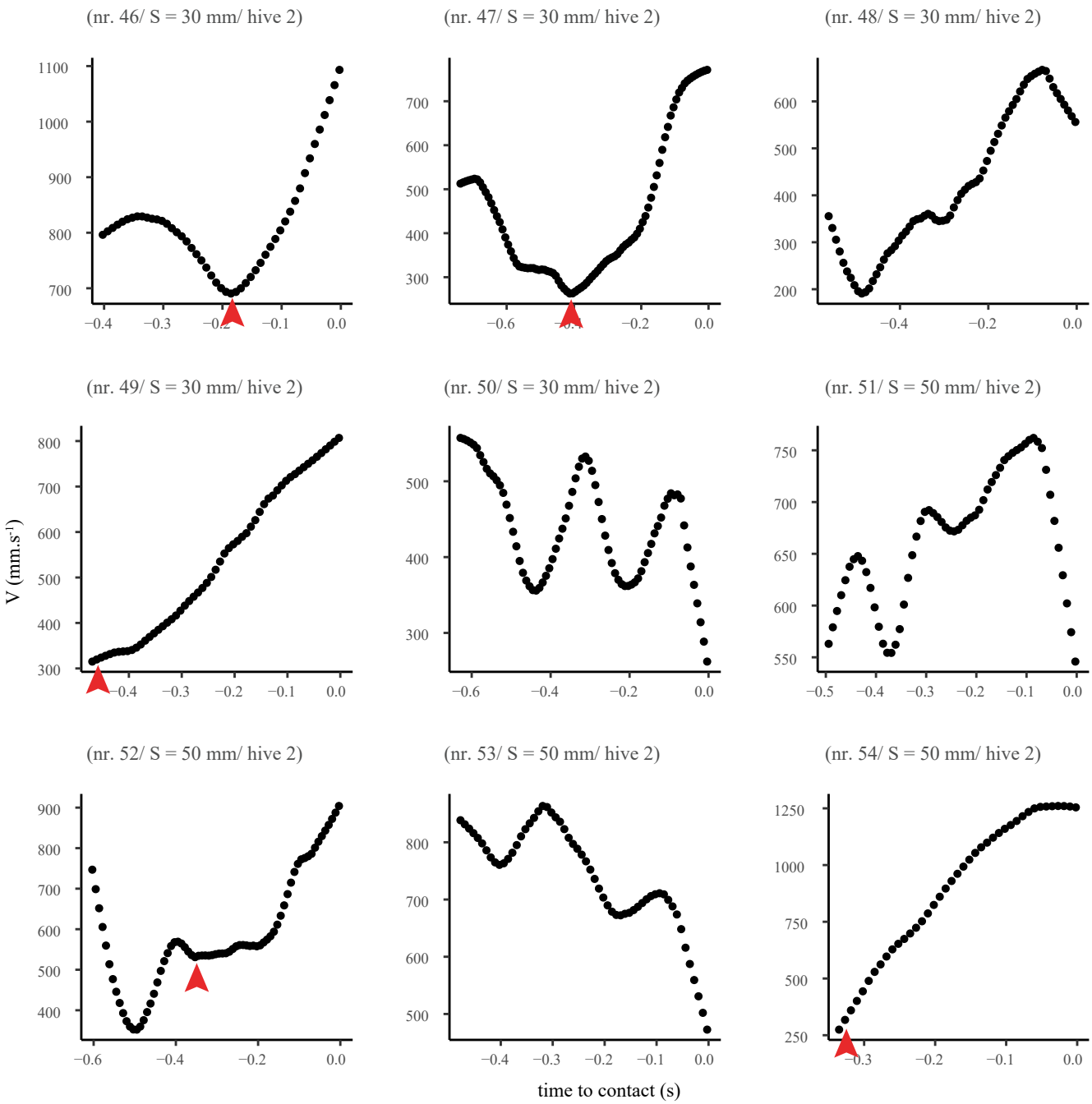
V (mm.s-1)
time to contact (s)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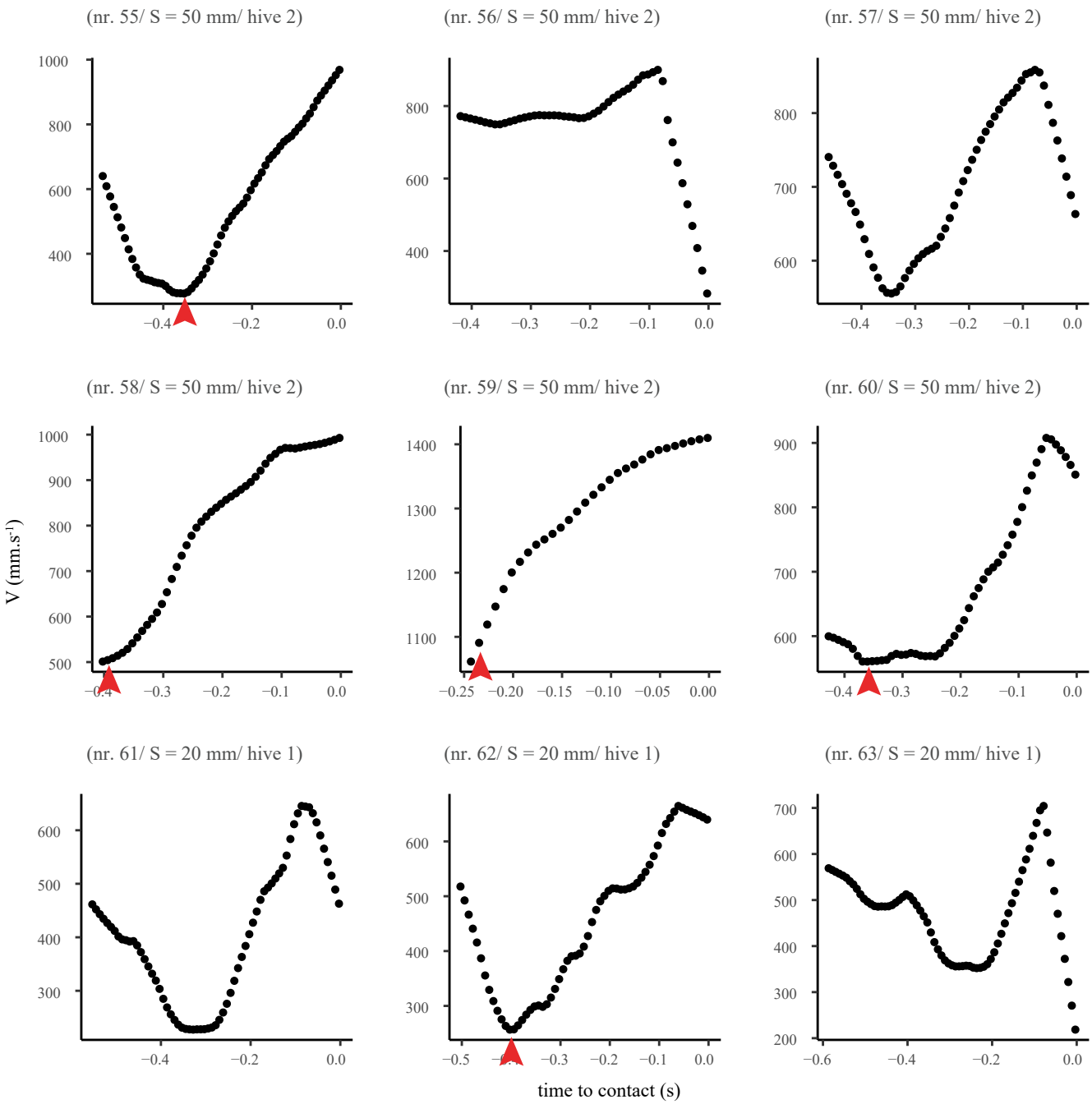
(nr. 50/ S = 30 mm/ hive 2)
(nr. 51/ S = 50 mm/ hive 2)
(nr. 52/ S = 50 mm/ hive 2)
(nr. 53/ S = 50 mm/ hive 2)
(nr. 54/ S = 50 mm/ hive 2)
V (mm.s-1)
time to contact (s)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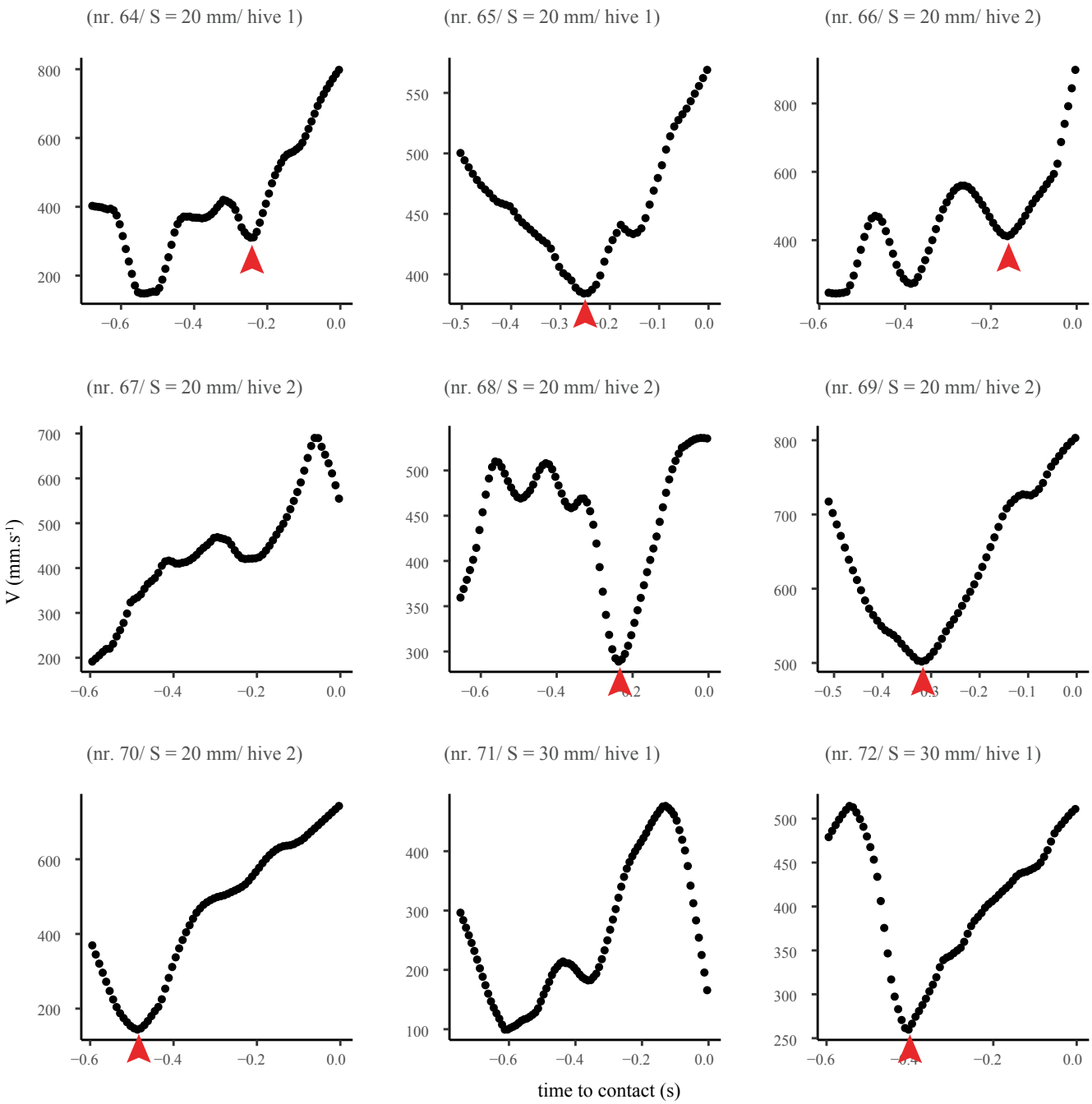
(nr. 59/ S = 50 mm/ hive 2)
(nr. 60/ S = 50 mm/ hive 2)
(nr. 61/ S = 20 mm/ hive 1)
(nr. 62/ S = 20 mm/ hive 1)
(nr. 63/ S = 20 mm/ hive 1)
V (mm.s-1)
time to contact (s)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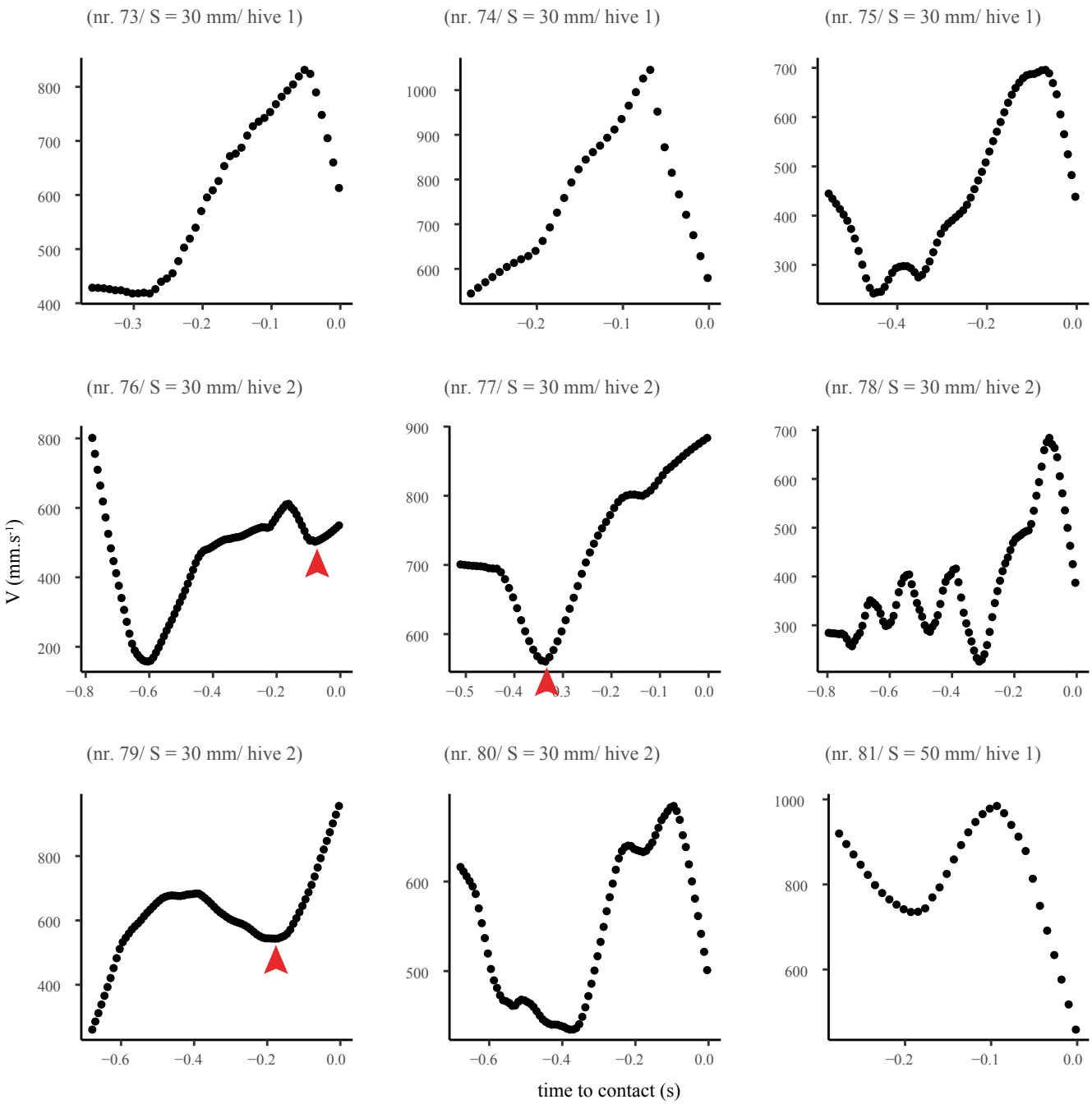
(nr. 67/ S = 20 mm/ hive 2)
(nr. 68/ S = 20 mm/ hive 2)
(nr. 69/ S = 20 mm/ hive 2)
(nr. 70/ S = 20 mm/ hive 2)
(nr. 71/ S = 30 mm/ hive 1)
(nr. 72/ S = 30 mm/ hive 1)
V (mm.s-1)
time to contact (s)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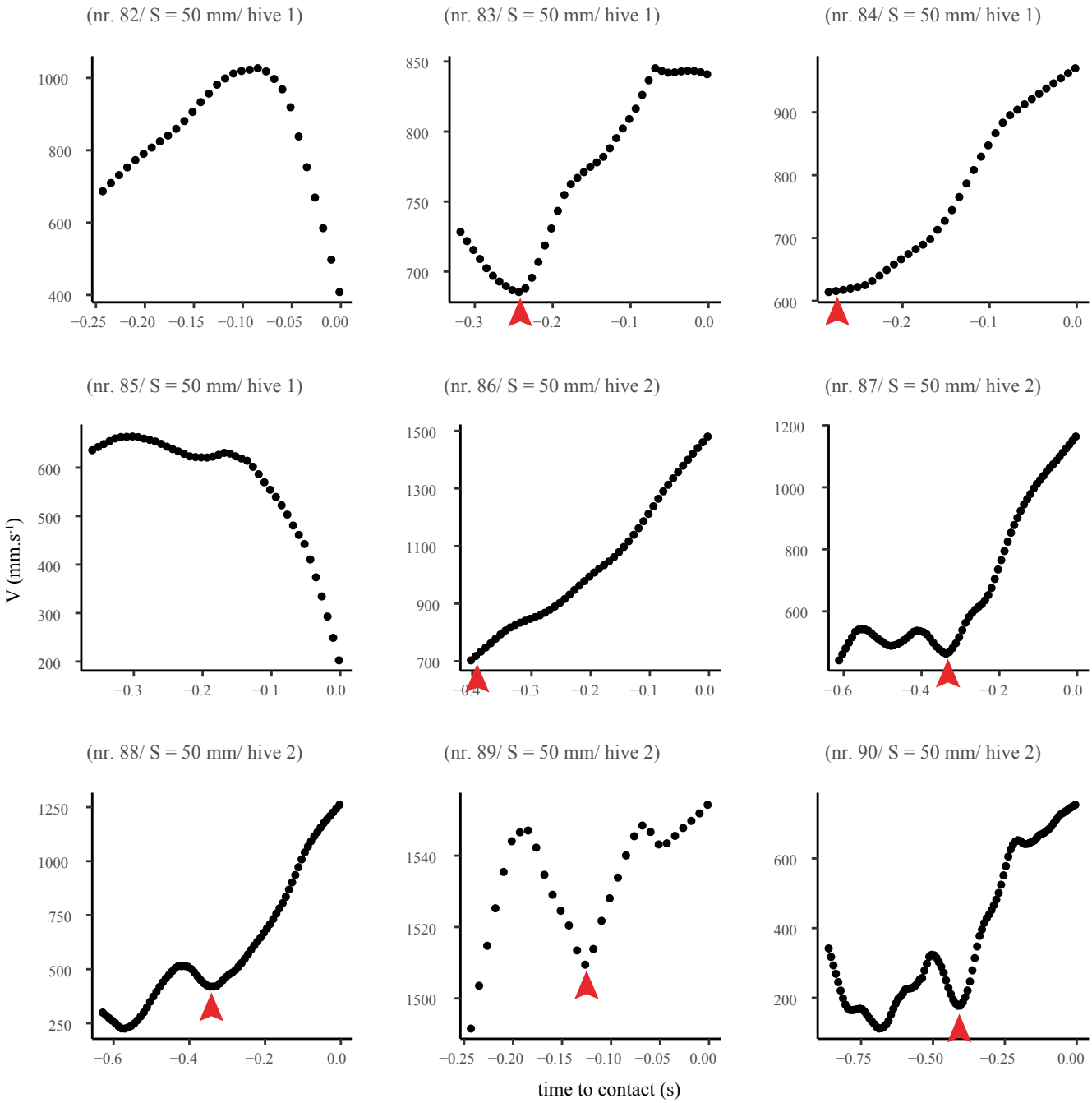
(nr. 77/ S = 30 mm/ hive 2)
(nr. 78/ S = 30 mm/ hive 2)
(nr. 79/ S = 30 mm/ hive 2)
(nr. 80/ S = 30 mm/ hive 2)
(nr. 81/ S = 50 mm/ hive 1)
V (mm.s-1)
time to contact (s)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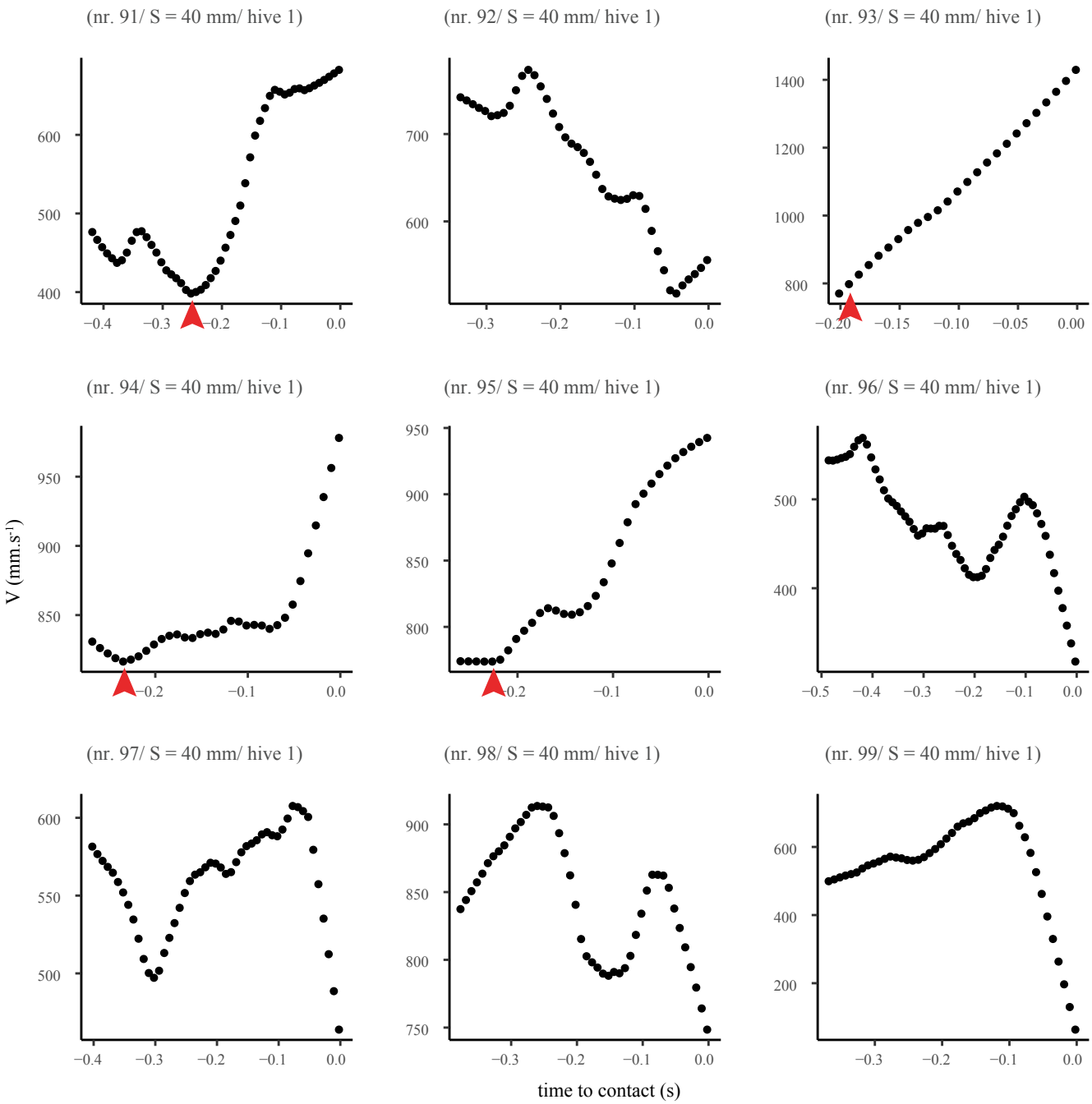
(nr. 86/ S = 50 mm/ hive 2)
(nr. 87/ S = 50 mm/ hive 2)
(nr. 88/ S = 50 mm/ hive 2)
(nr. 89/ S = 50 mm/ hive 2)
(nr. 90/ S = 50 mm/ hive 2)
V (mm.s-1)
time to contact (s)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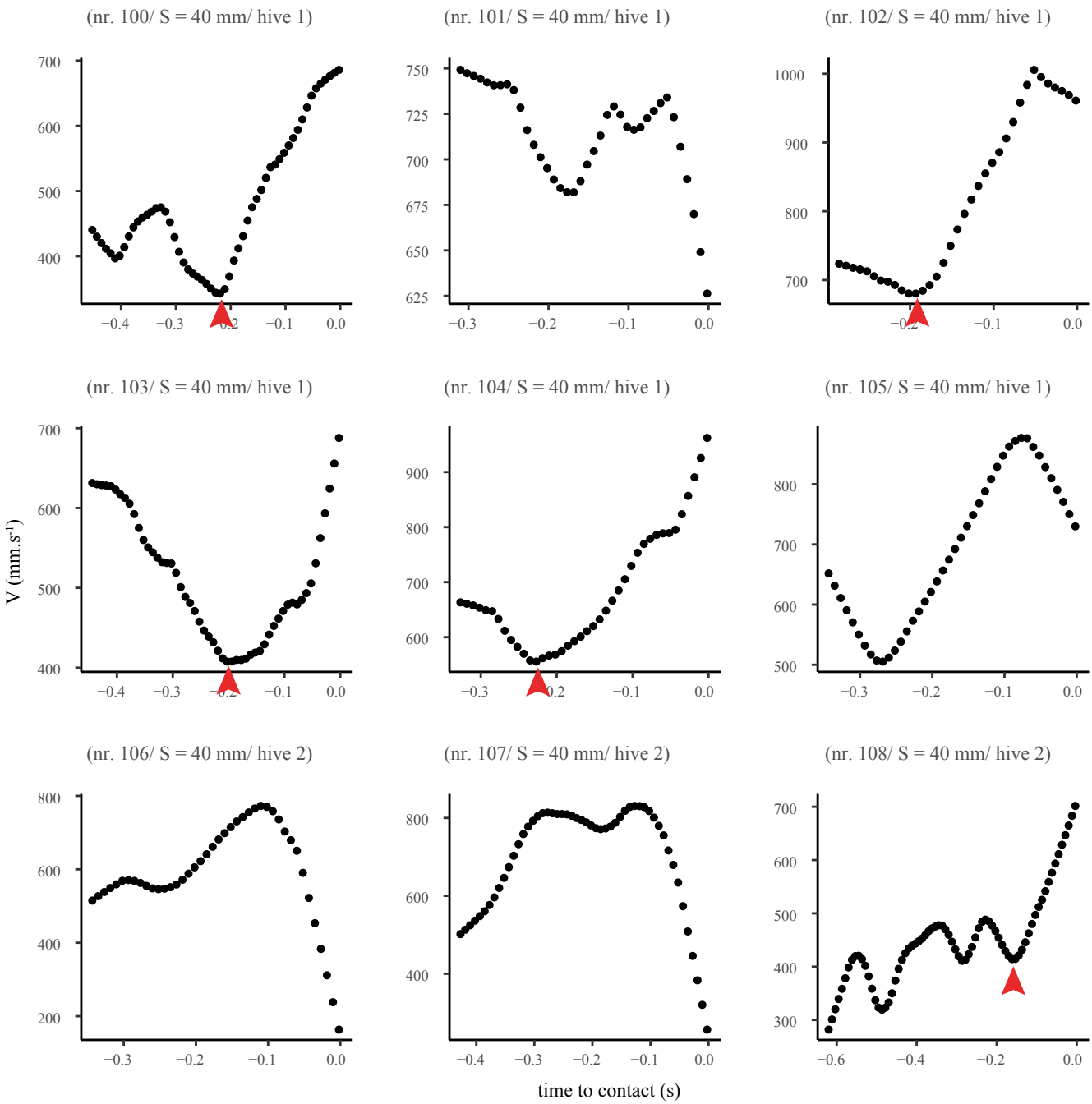
(nr. 92/ S = 40 mm/ hive 1)
(nr. 93/ S = 40 mm/ hive 1)
(nr. 94/ S = 40 mm/ hive 1)
(nr. 95/ S = 40 mm/ hive 1)
(nr. 96/ S = 40 mm/ hive 1)
(nr. 97/ S = 40 mm/ hive 1)
(nr. 98/ S = 40 mm/ hive 1)
(nr. 99/ S = 40 mm/ hive 1)
V (mm.s-1)
time to contact (s)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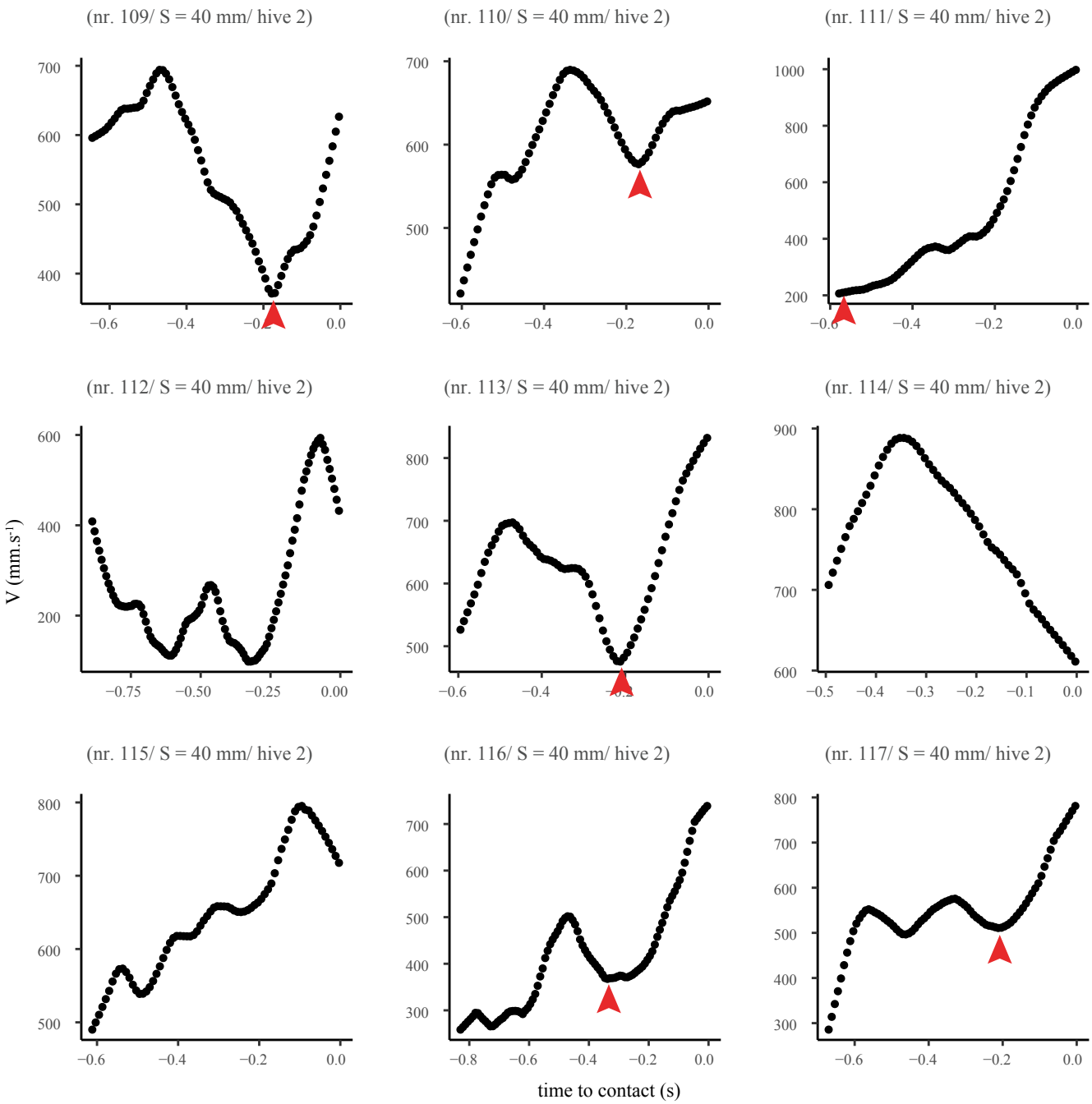
(nr. 103/ S = 40 mm/ hive 1)
(nr. 104/ S = 40 mm/ hive 1)
(nr. 105/ S = 40 mm/ hive 1)
(nr. 106/ S = 40 mm/ hive 2)
(nr. 107/ S = 40 mm/ hive 2)
(nr. 108/ S = 40 mm/ hive 2)
V (mm.s-1)
time to contact (s)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(nr. 113/ S = 40 mm/ hive 2)
(nr. 114/ S = 40 mm/ hive 2)
(nr. 115/ S = 40 mm/ hive 2)
(nr. 116/ S = 40 mm/ hive 2)
(nr. 117/ S = 40 mm/ hive 2)
V (mm.s-1)
time to contact (s)

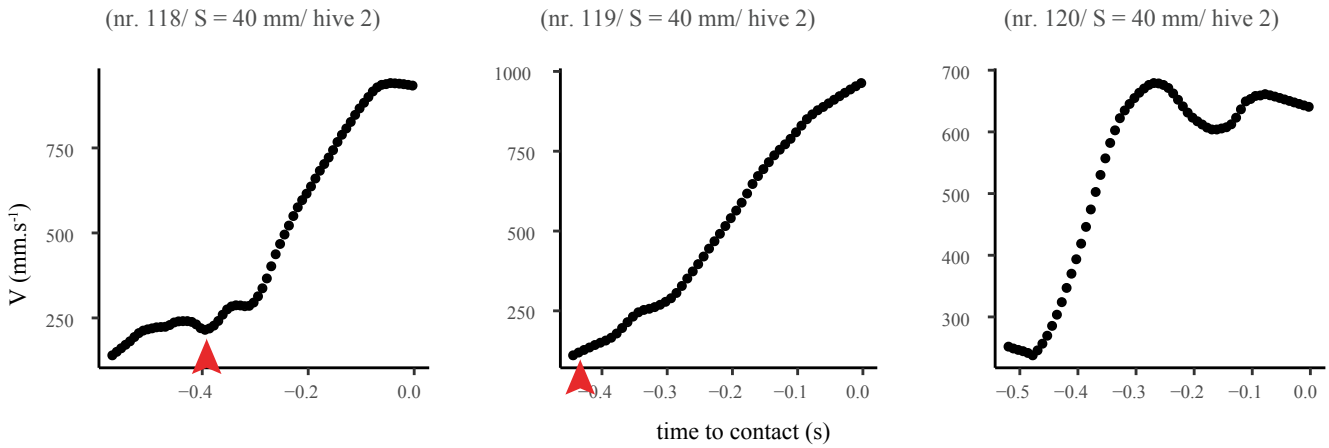
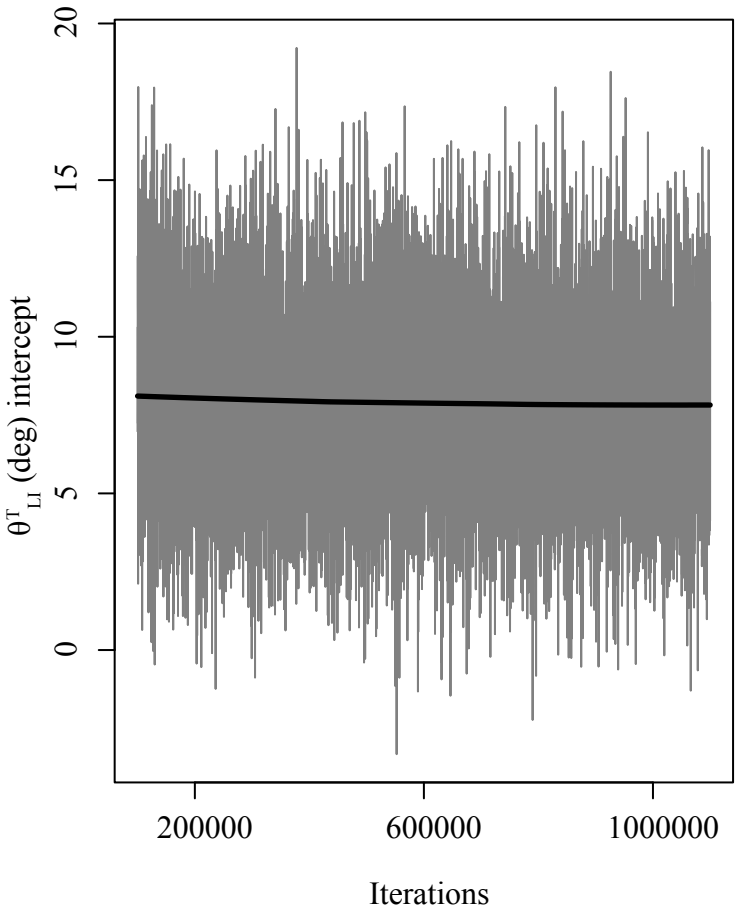
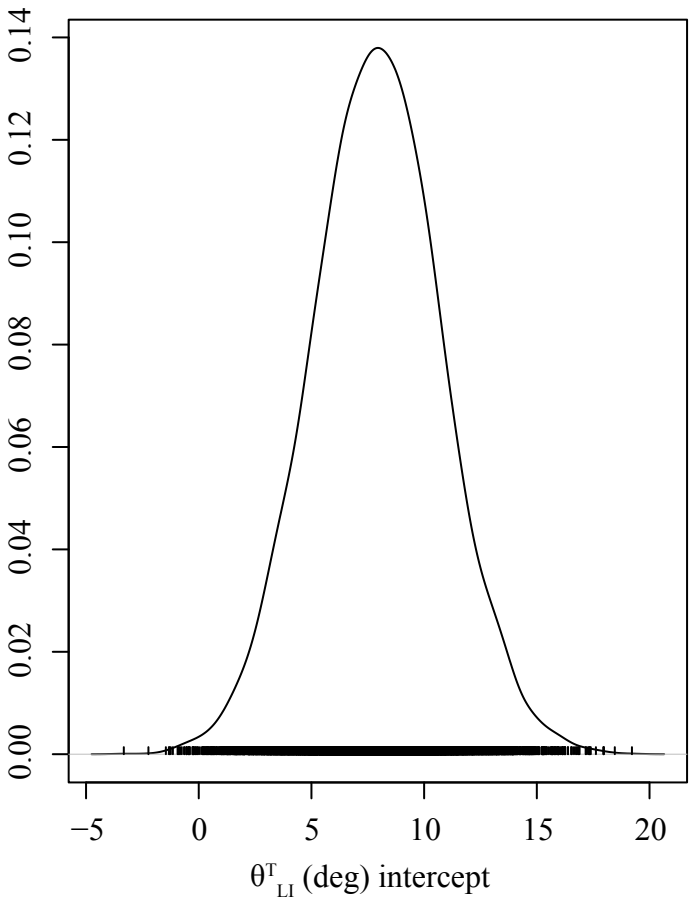
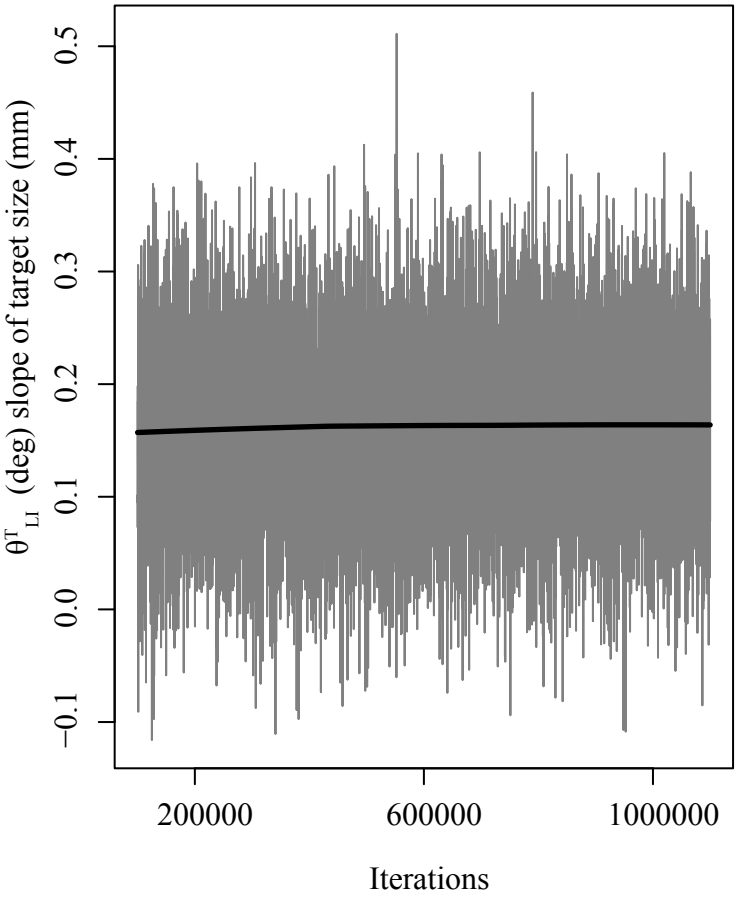


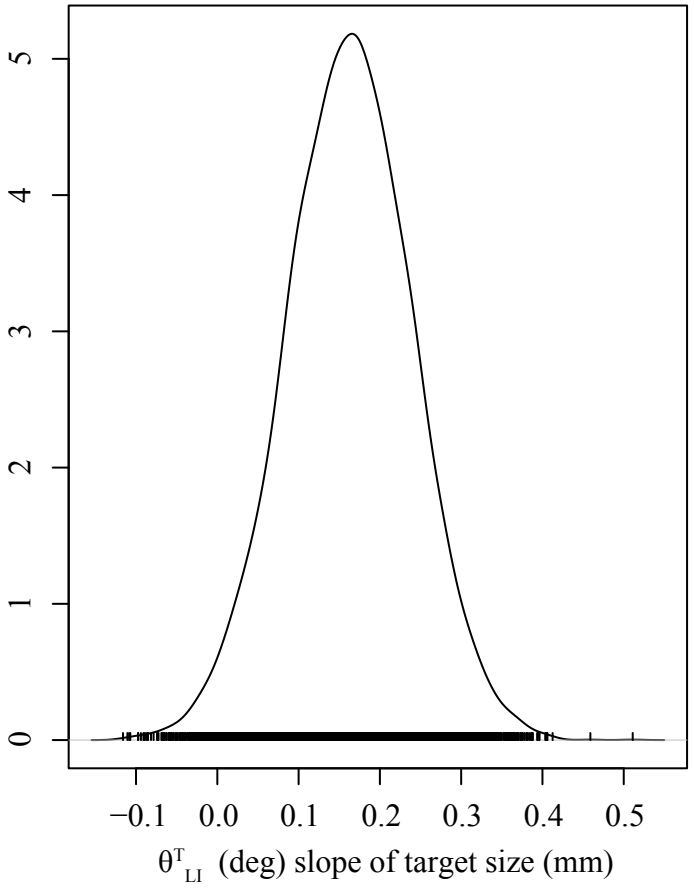
Figure S2:

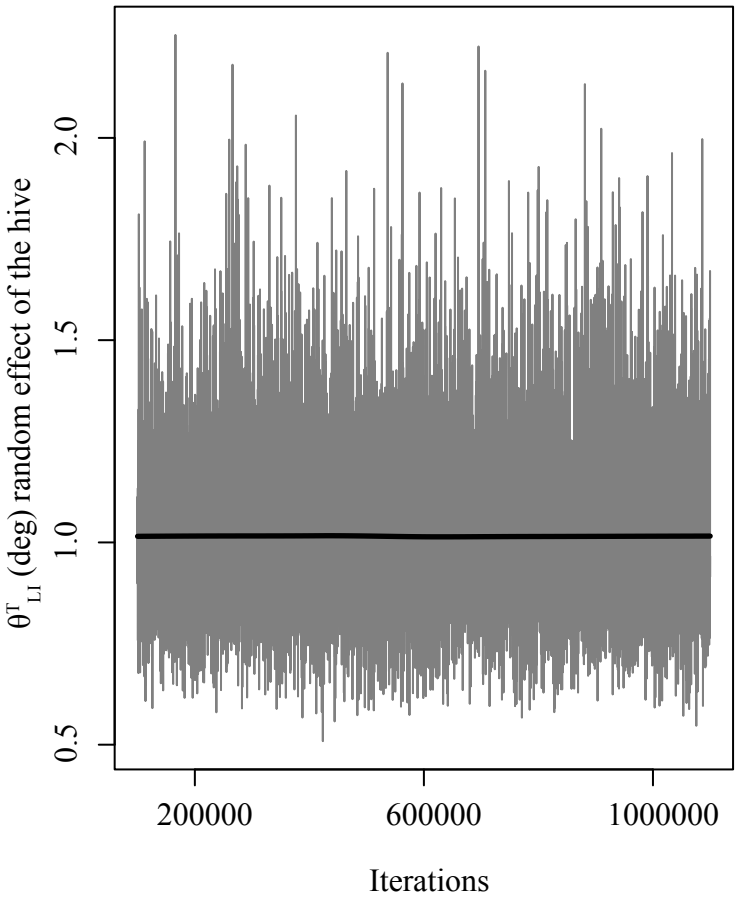
Speed profiles of landing bees in C_{size} as a function of time to contact with different landing types: a final deceleration, 'type 0', a deceleration followed by an acceleration, 'type 1' or a sustained acceleration, 'type 2'. The red arrow indicates the change in acceleration, or landing initiation for profiles of type 1-2. Landing were recorded with white sheets surrounding the hive. The speed profiles in $C_{control}$ are available as supplementary material in Tichit et al. 2020.

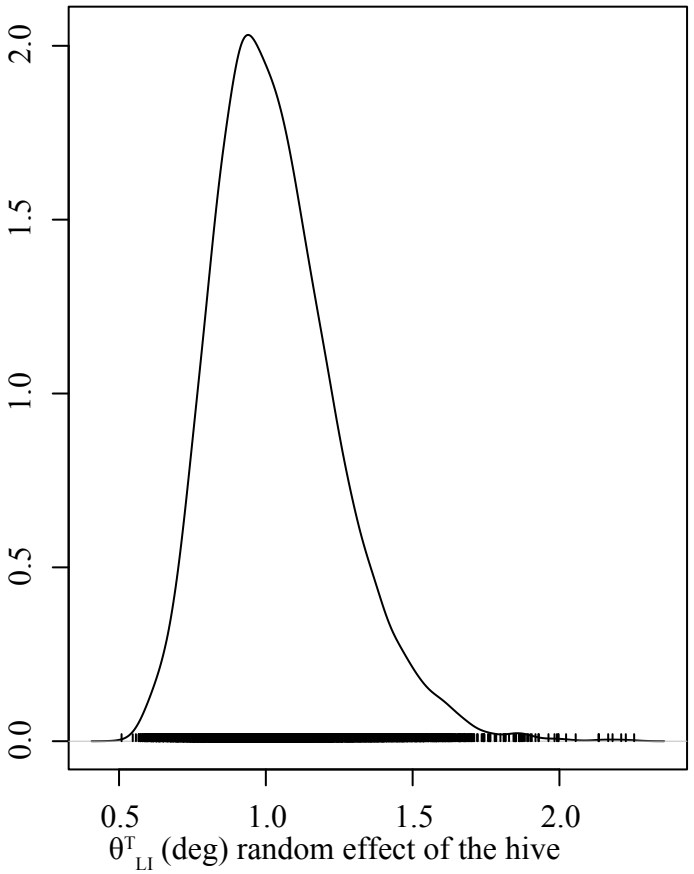

θ^{T}_{LI} (deg) intercept
0
5
10
15
20
200000
600000
1000000
Iterations

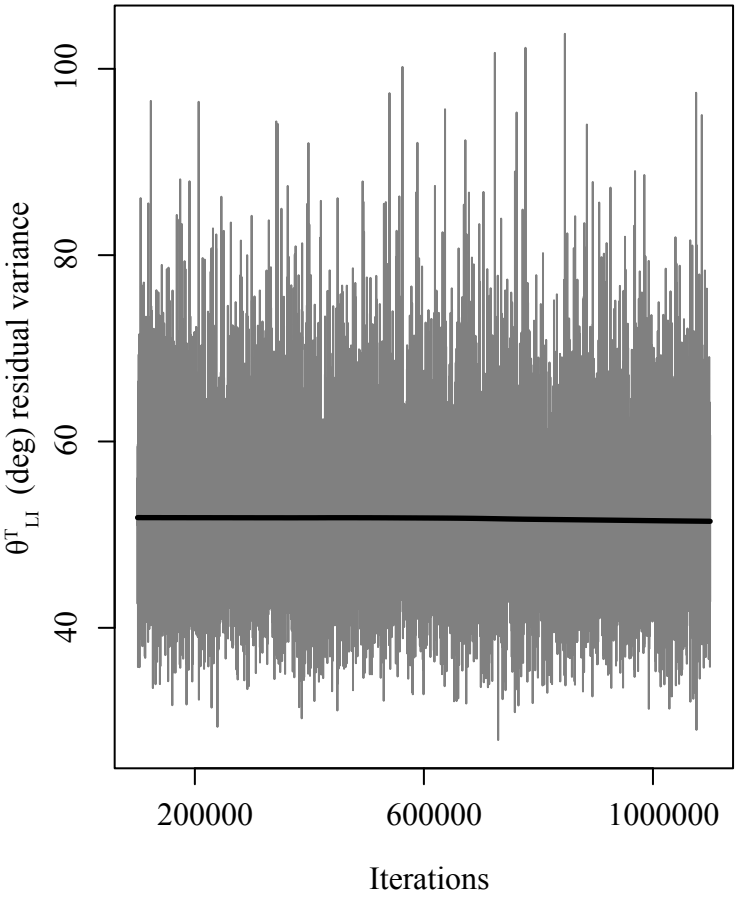

0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
−5
0
5
10
15
20
θ^{T}_{LI} (deg) intercept

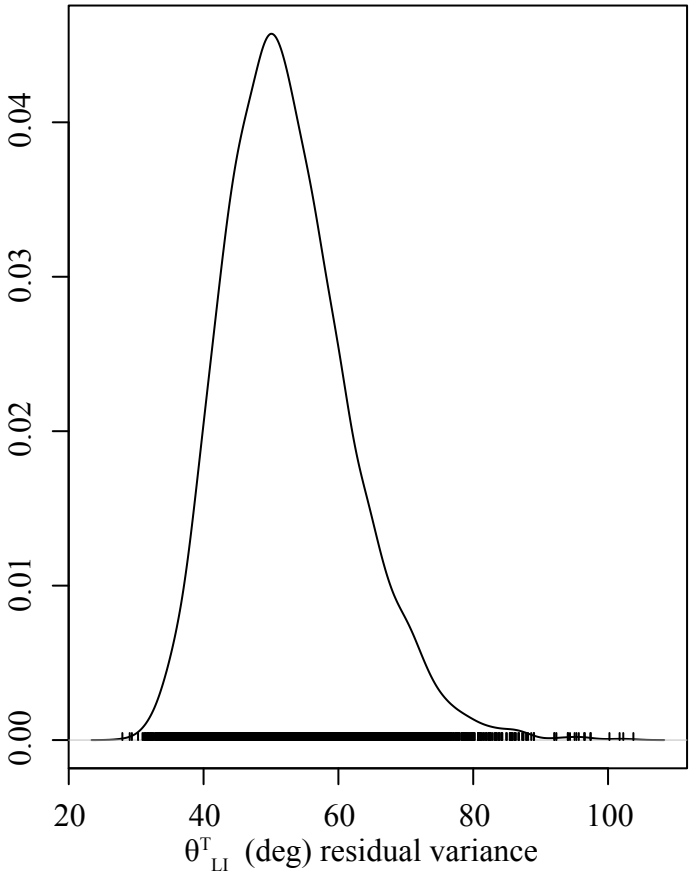

θ^{T}_{LI} (deg) slope of target size (mm)
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
200000
600000
1000000
Iterations

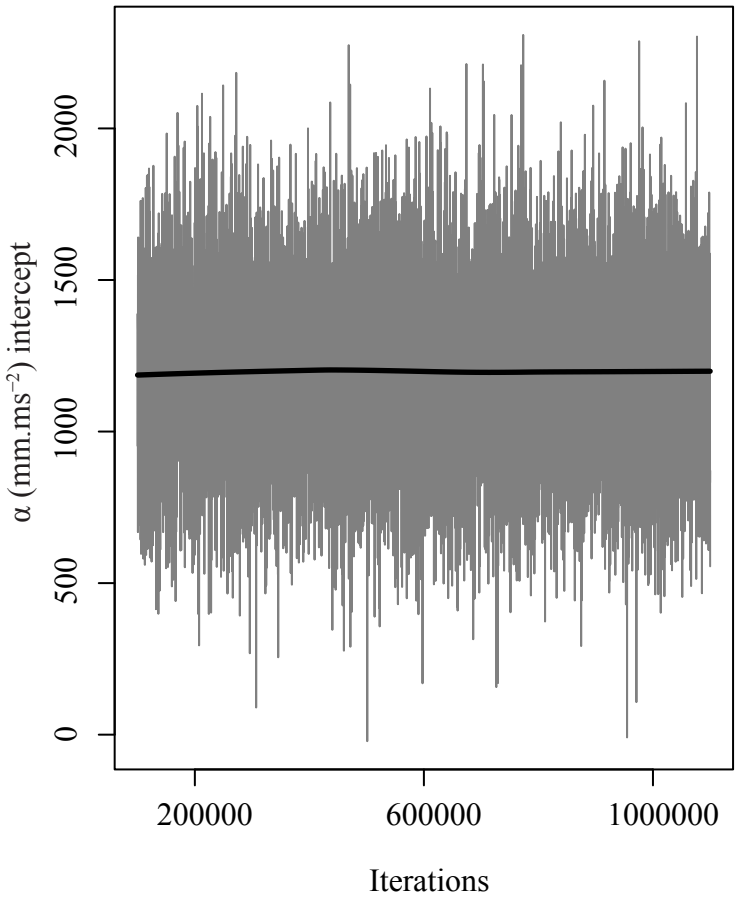

0
1
2
3
4
5
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
θ^{T}_{LI} (deg) slope of target size (mm)

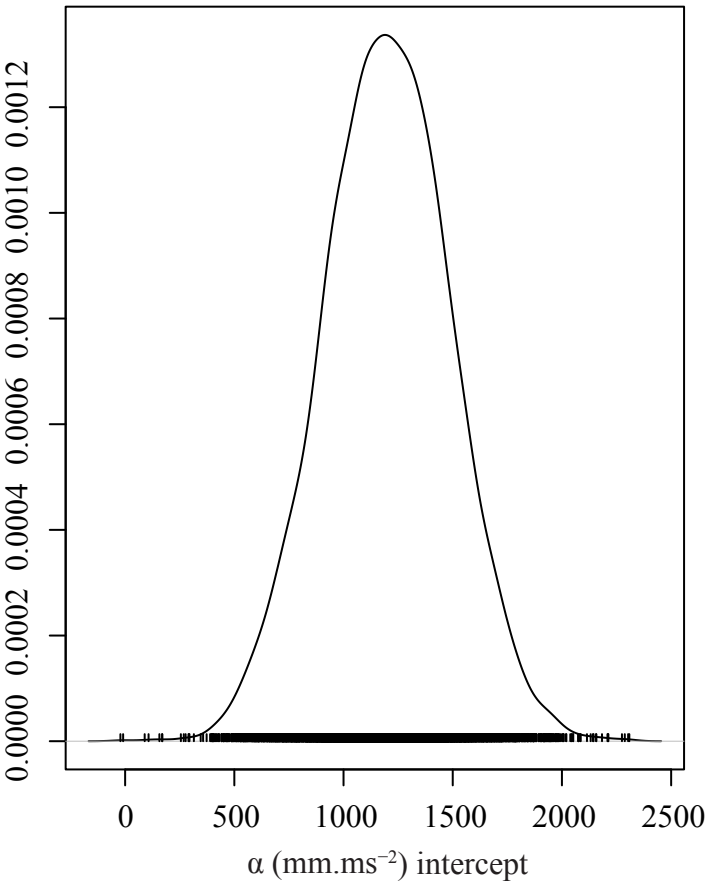

θ^T_LI (deg) random effect of the hive
0.5
1.0
1.5
2.0
200000
600000
1000000
Iterations

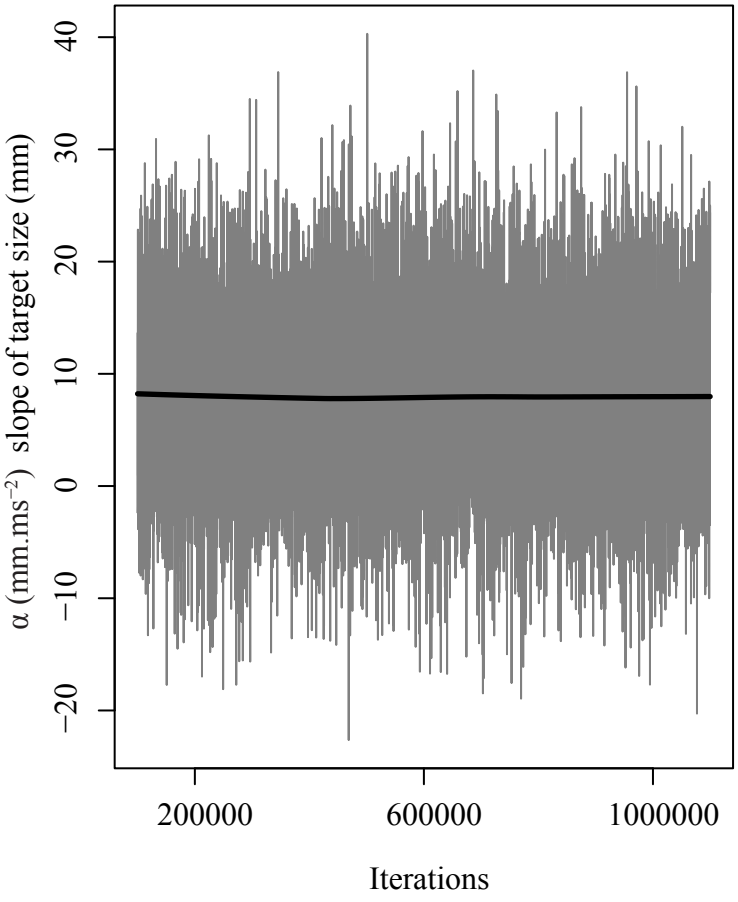

0.0
0.5
1.0
1.5
2.0
0.5
1.0
1.5
2.0
θ^T_LI (deg) random effect of the hive

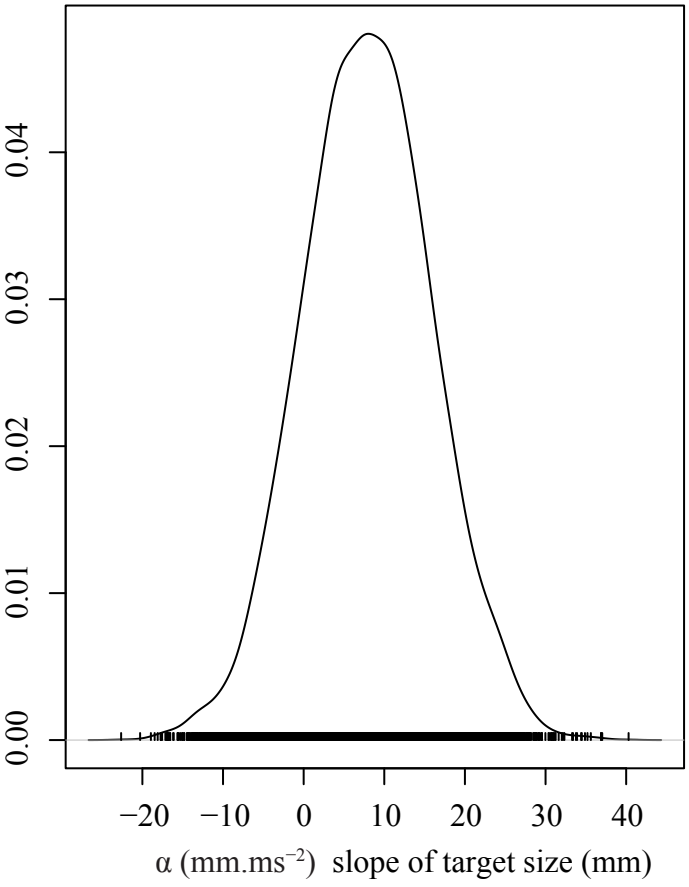

θ^T_LI (deg) residual variance
40
60
80
100
200000
600000
1000000
Iterations

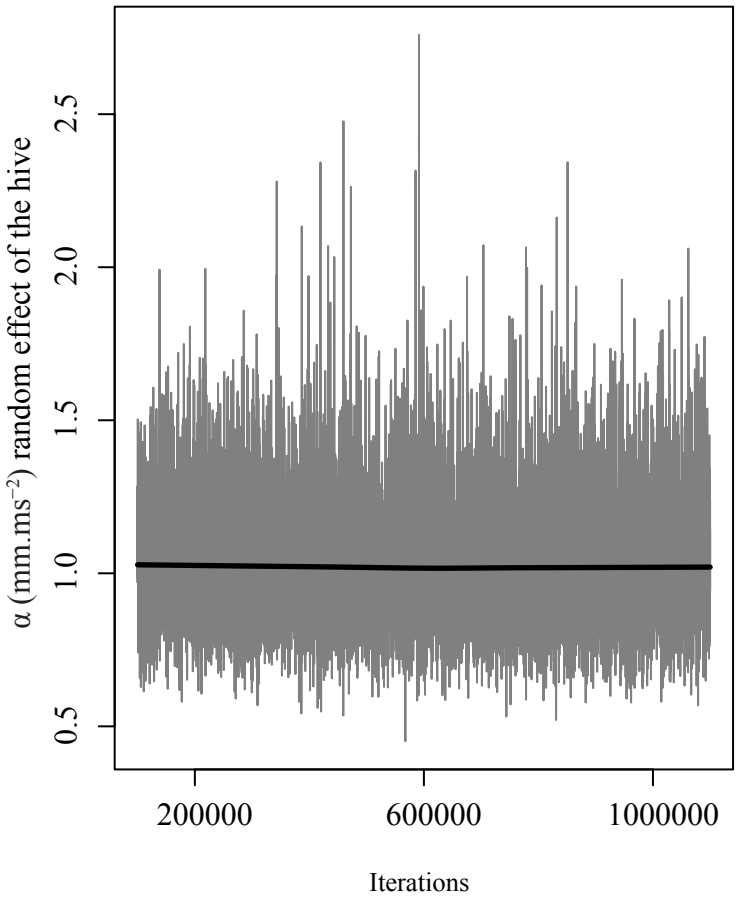

0.00
0.01
0.02
0.03
0.04
20
40
60
80
100
θ^T_LI (deg) residual variance

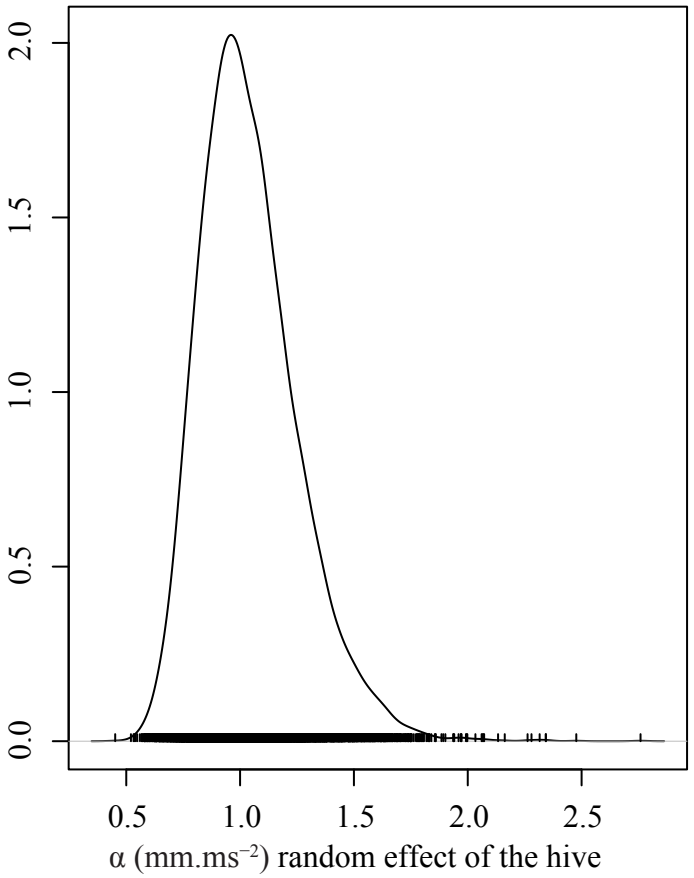

α (mm.ms⁻²) intercept
0
500
1000
1500
2000
200000
600000
1000000
Iterations

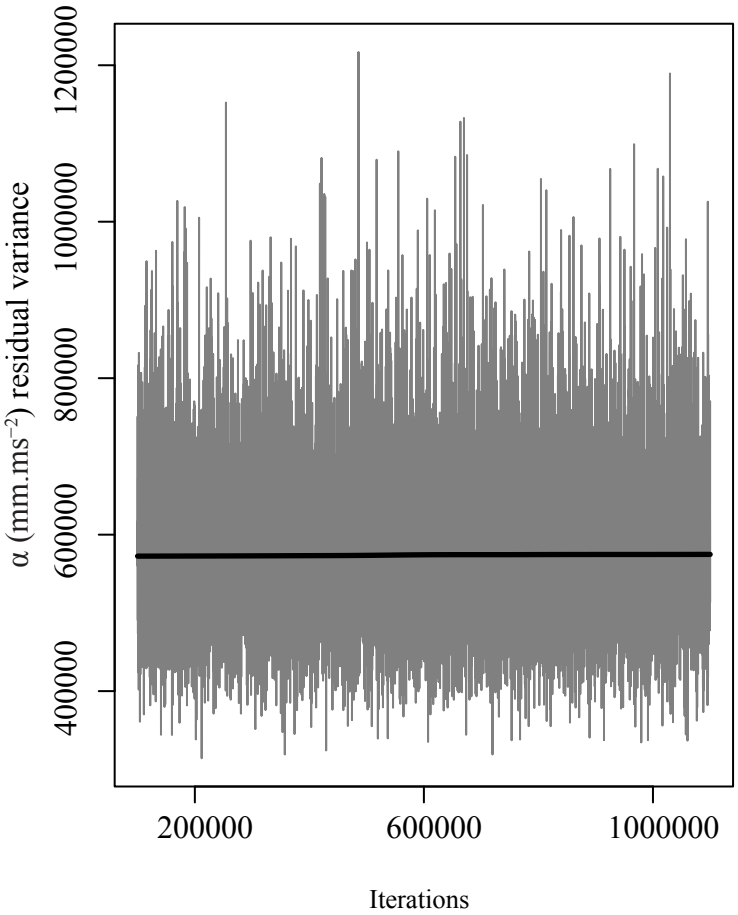

0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
0
500
1000
1500
2000
2500
α (mm.ms⁻²) intercept

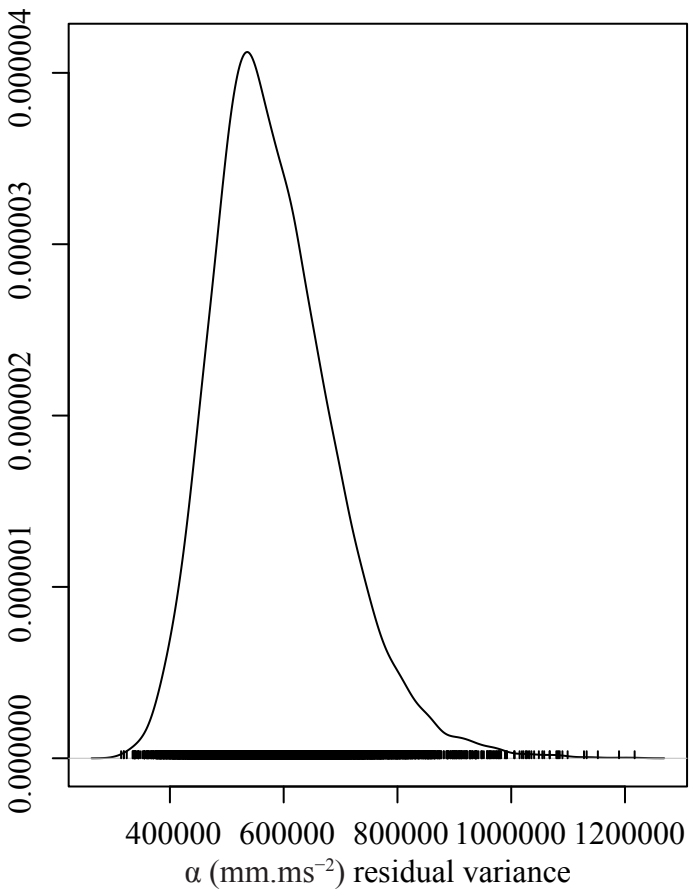

α (mm.ms⁻²) slope of target size (mm)
−20
−10
0
10
20
30
40
200000
600000
1000000
Iterations

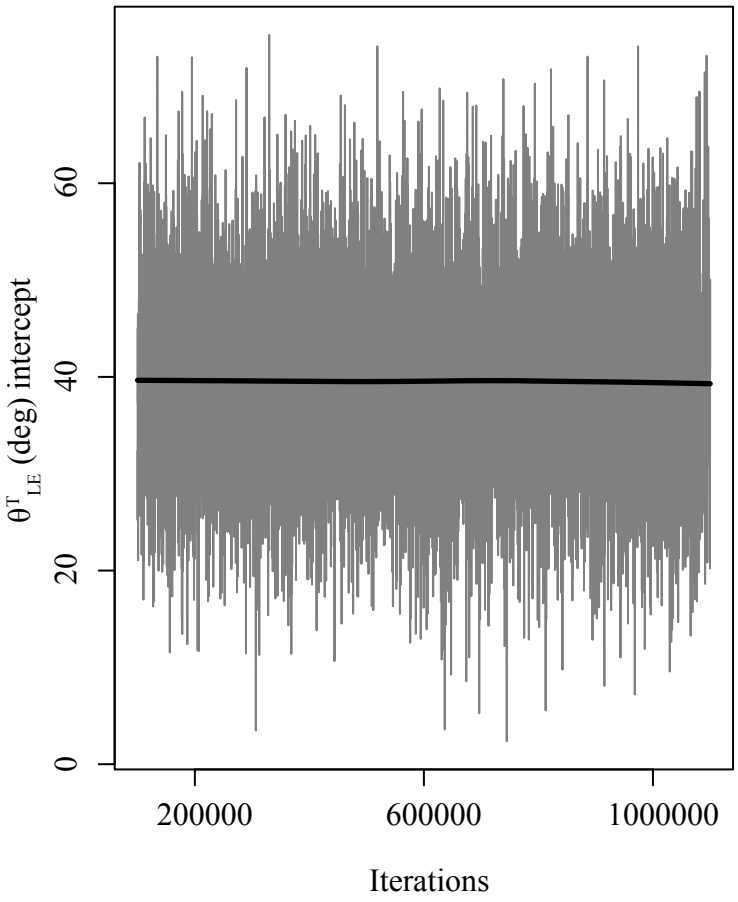

0.00
0.01
0.02
0.03
0.04
−20
−10
0
10
20
30
40
α (mm.ms⁻²) slope of target size (mm)

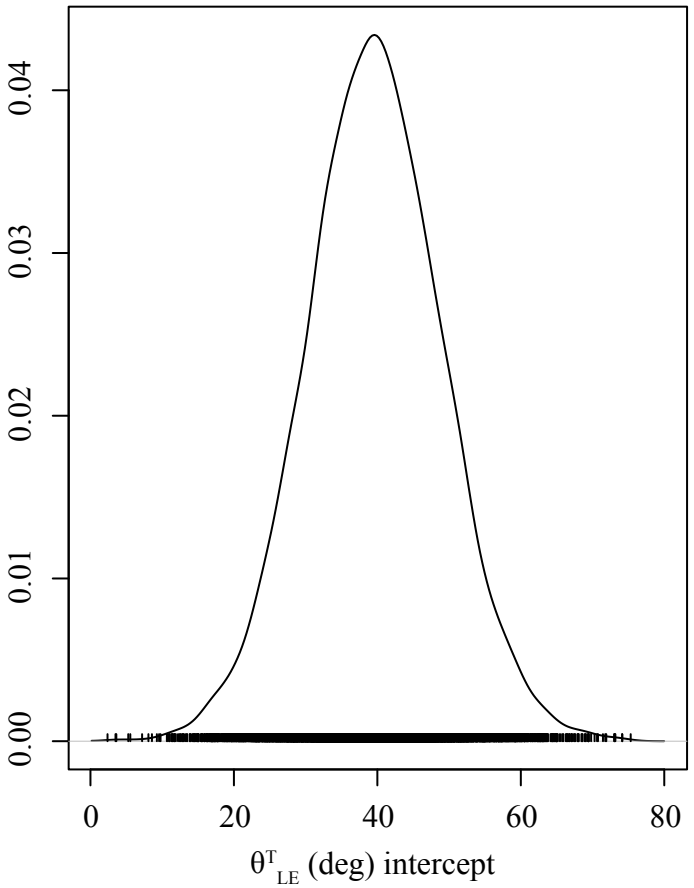

α (mm.ms⁻²) random effect of the hive
0.5
1.0
1.5
2.0
2.5
200000
600000
1000000
Iterations

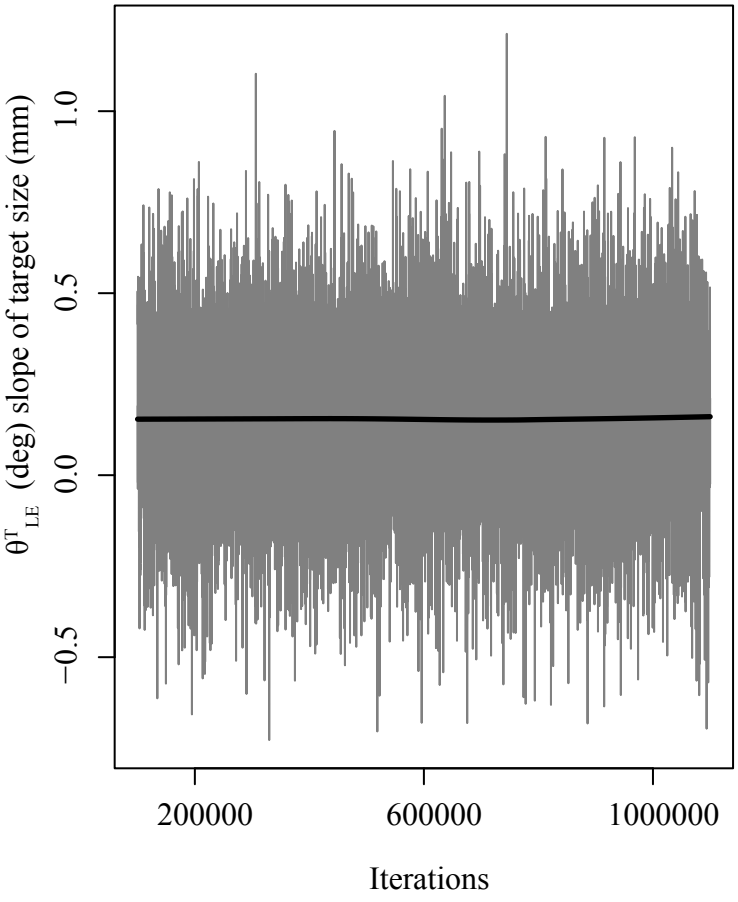

0.0
0.5
1.0
1.5
2.0
0.5
1.0
1.5
2.0
2.5
α (mm.ms⁻²) random effect of the hive

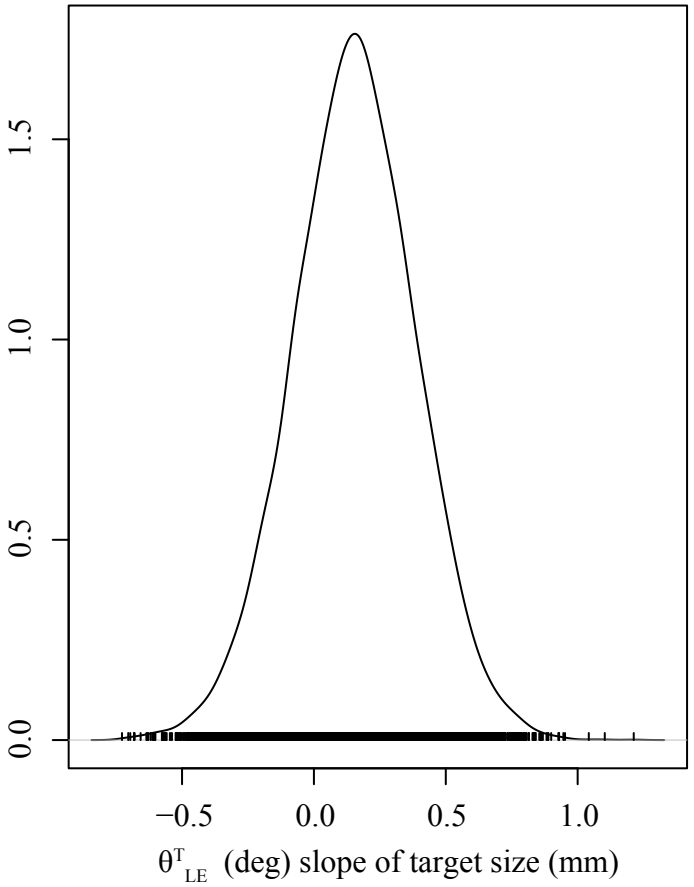

α (mm.ms⁻²) residual variance
400000
600000
800000
1000000
1200000
200000
600000
1000000
Iterations

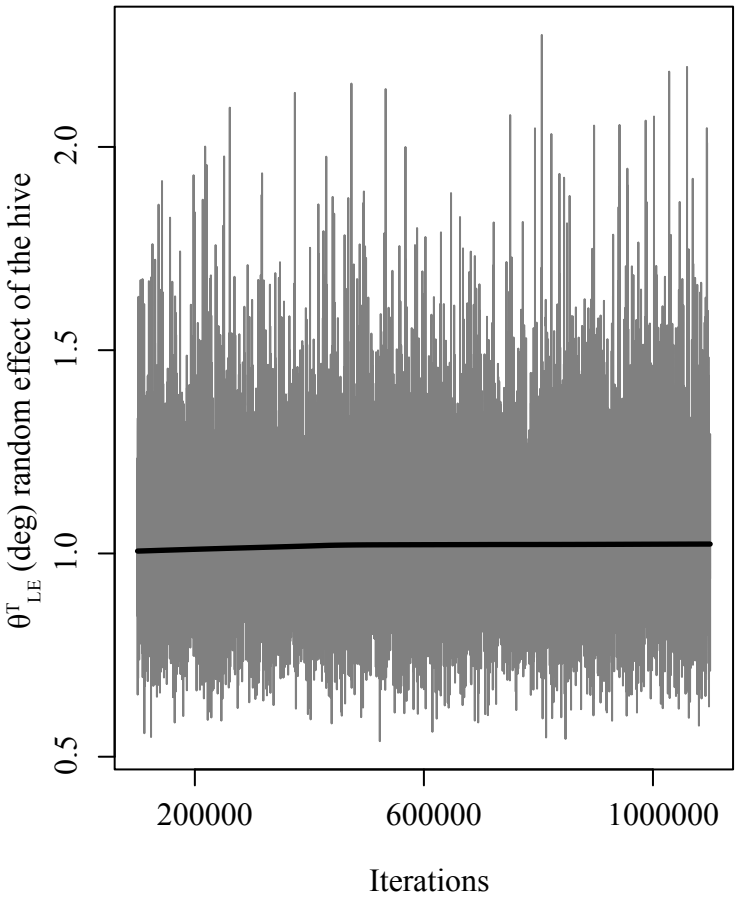

0.000000
0.000001
0.000002
0.000003
0.000004
400000
600000
800000
1000000
1200000
α (mm.ms⁻²) residual variance

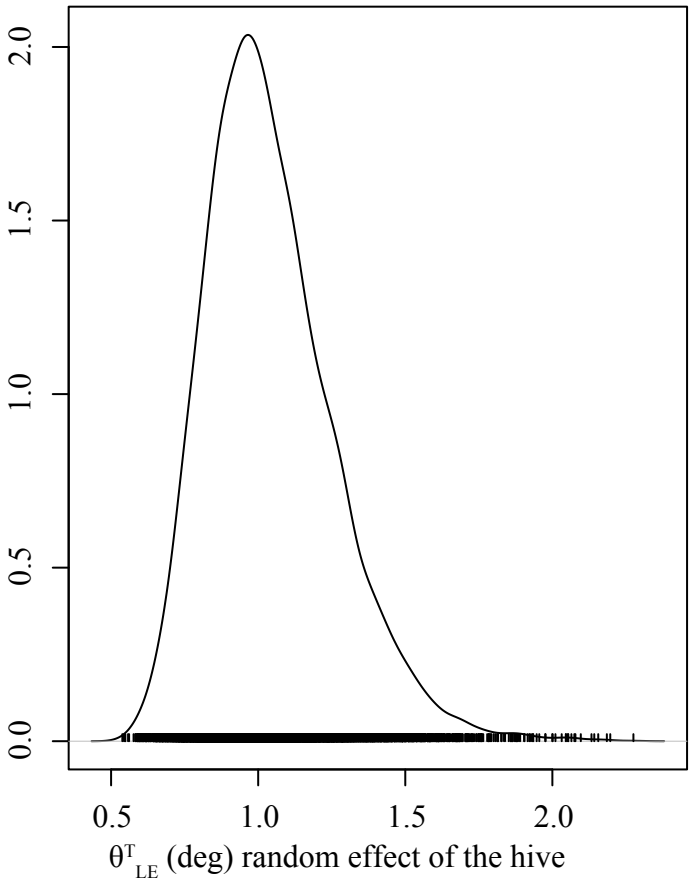

θ^{T}_{LE} (deg) intercept
0
20
40
60
200000
600000
1000000
Iterations

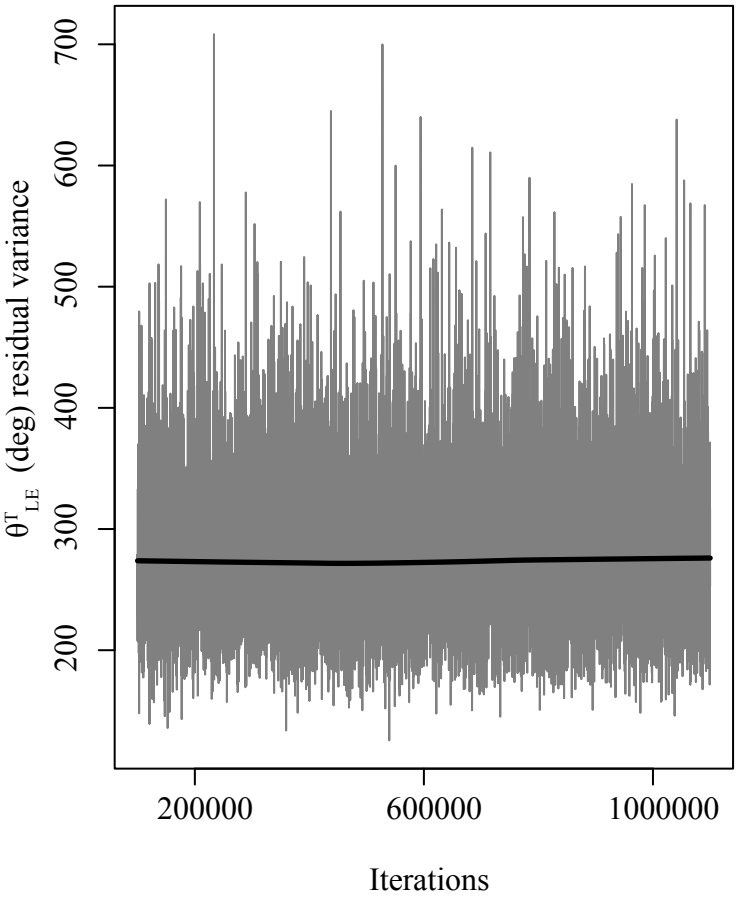

0.00
0.01
0.02
0.03
0.04
0
20
40
60
80
θ^{T}_{LE} (deg) intercept

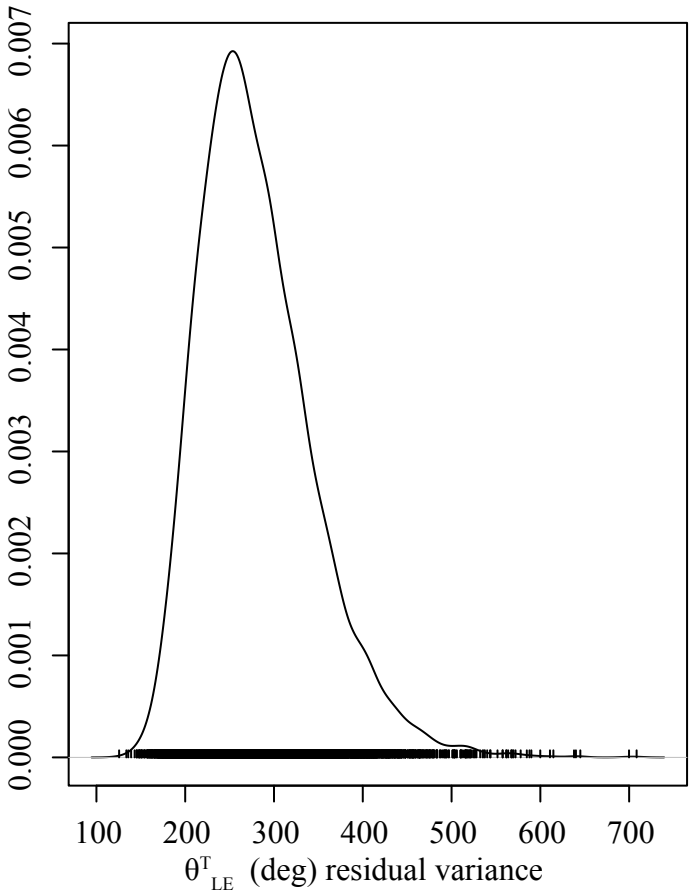

θ^{T}_{LE} (deg) slope of target size (mm)
−0.5
0.0
0.5
1.0
200000
600000
1000000
Iterations

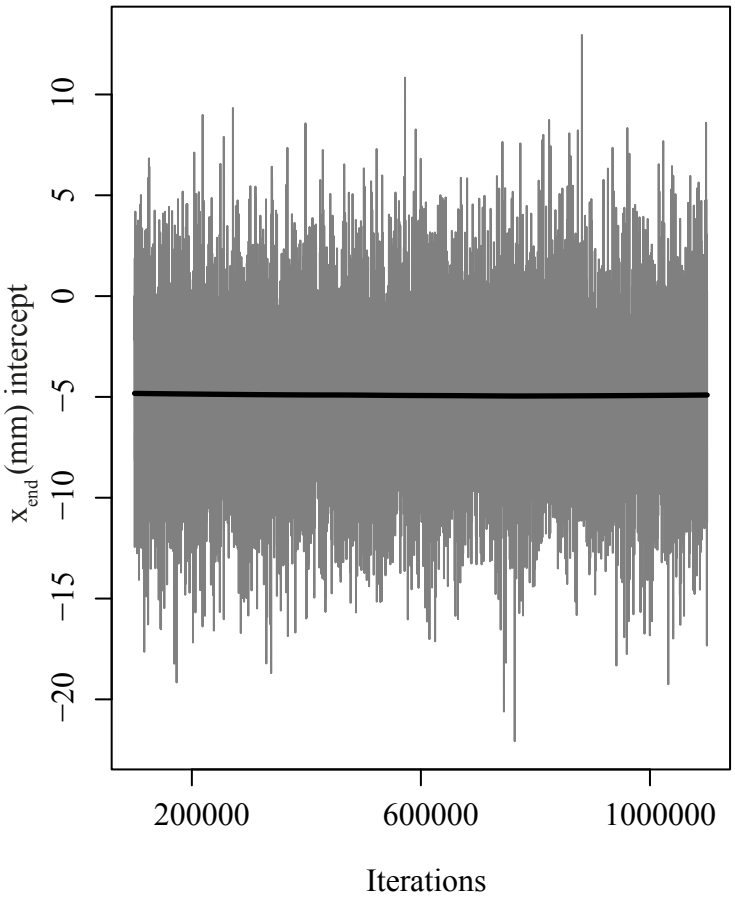

0.0
0.5
1.0
1.5
−0.5
0.0
0.5
1.0
θ^{T}_{LE} (deg) slope of target size (mm)

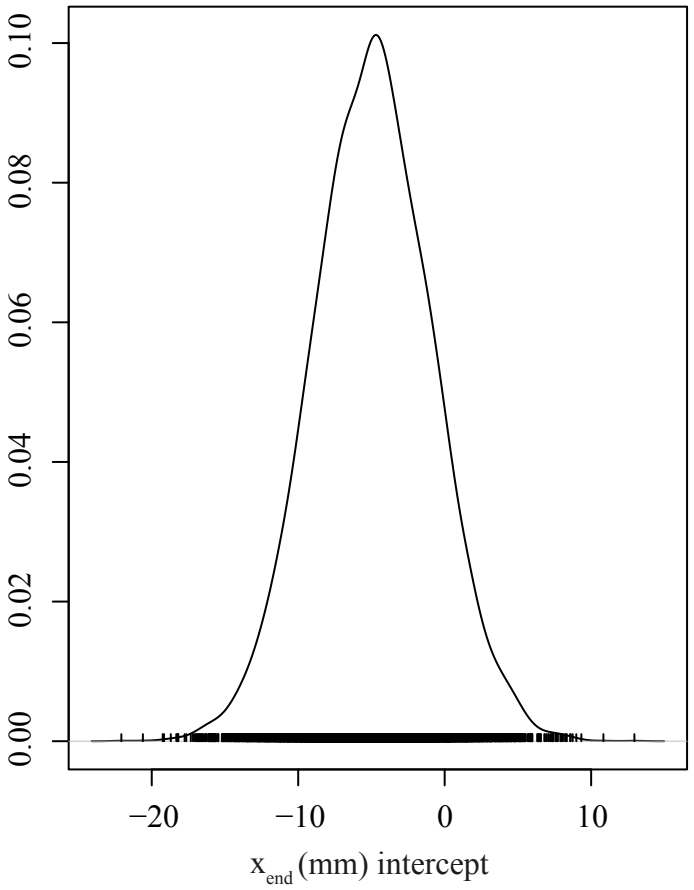

θ^T_LE (deg) random effect of the hive
0.5
1.0
1.5
2.0
200000
600000
1000000
Iterations

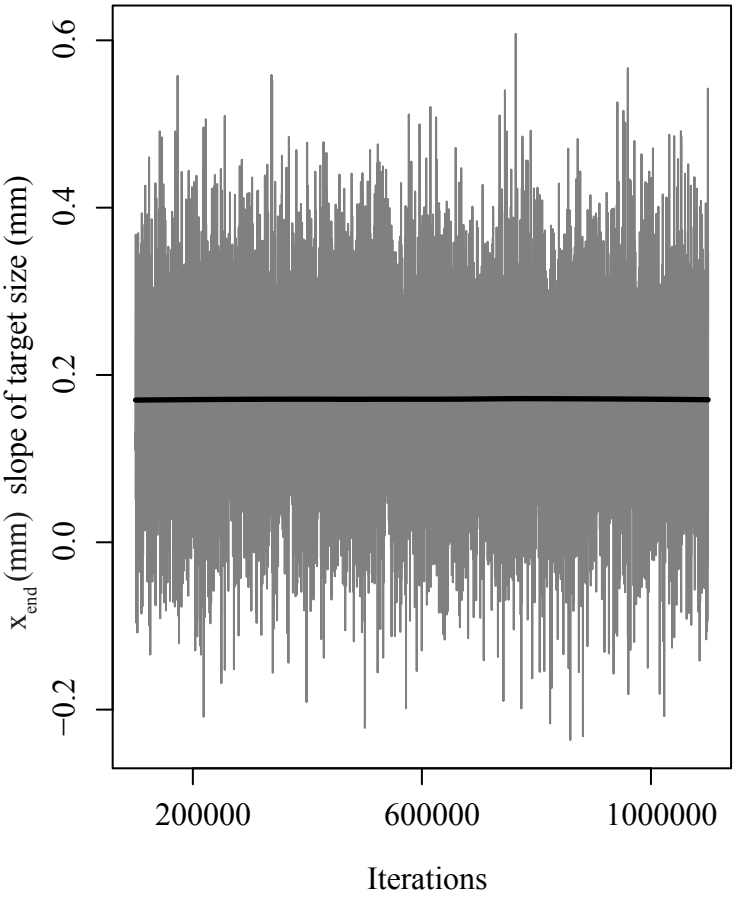

0.0
0.5
1.0
1.5
2.0
0.5
1.0
1.5
2.0
θ^T_LE (deg) random effect of the hive

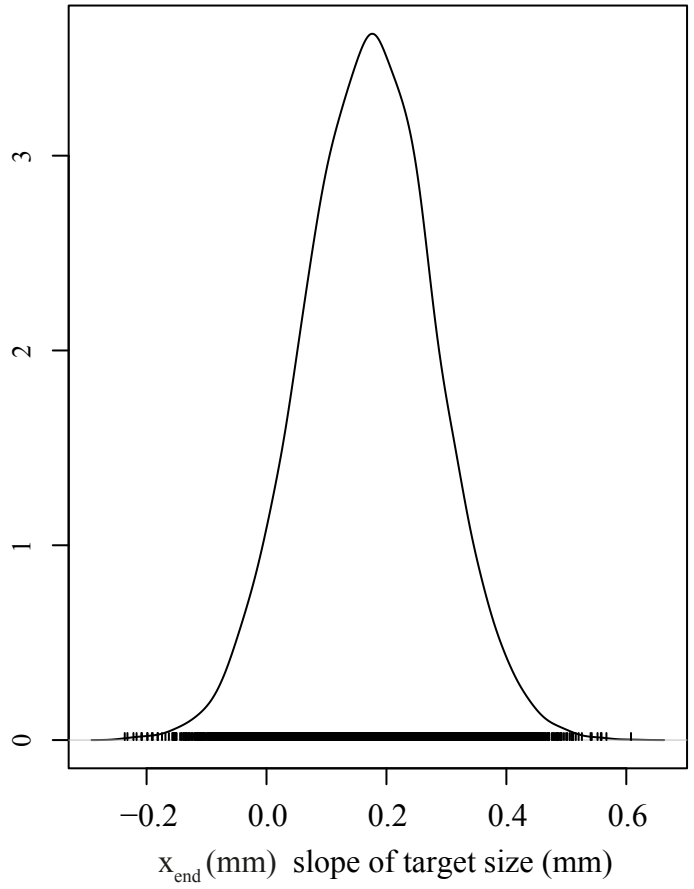

θ^T_LE (deg) residual variance
200
300
400
500
600
700
200000
600000
1000000
Iterations

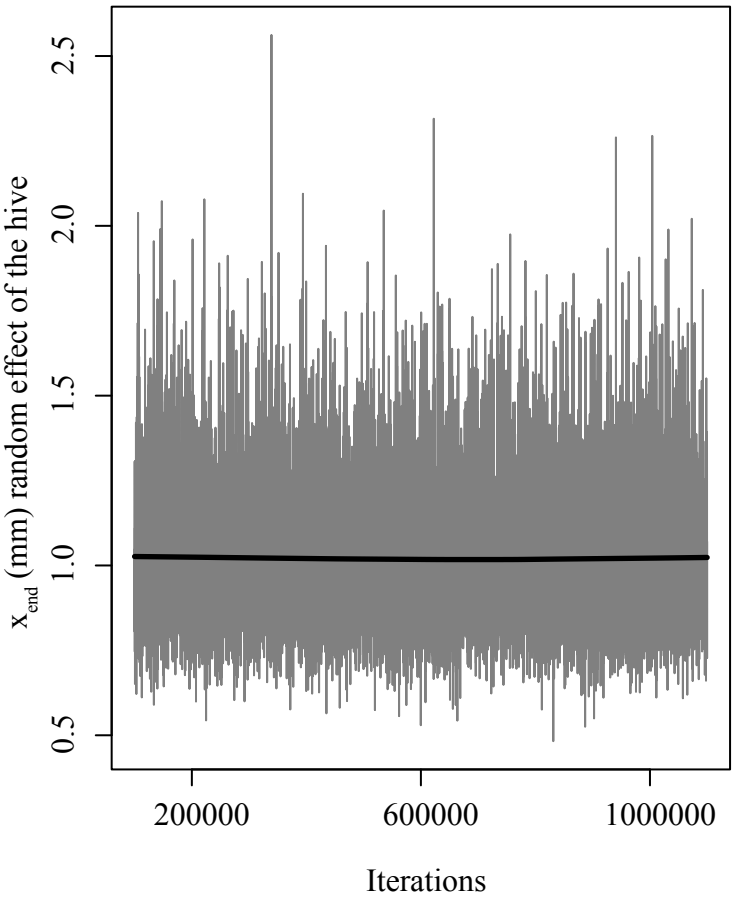

0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
100
200
300
400
500
600
700
θ^T_LE (deg) residual variance

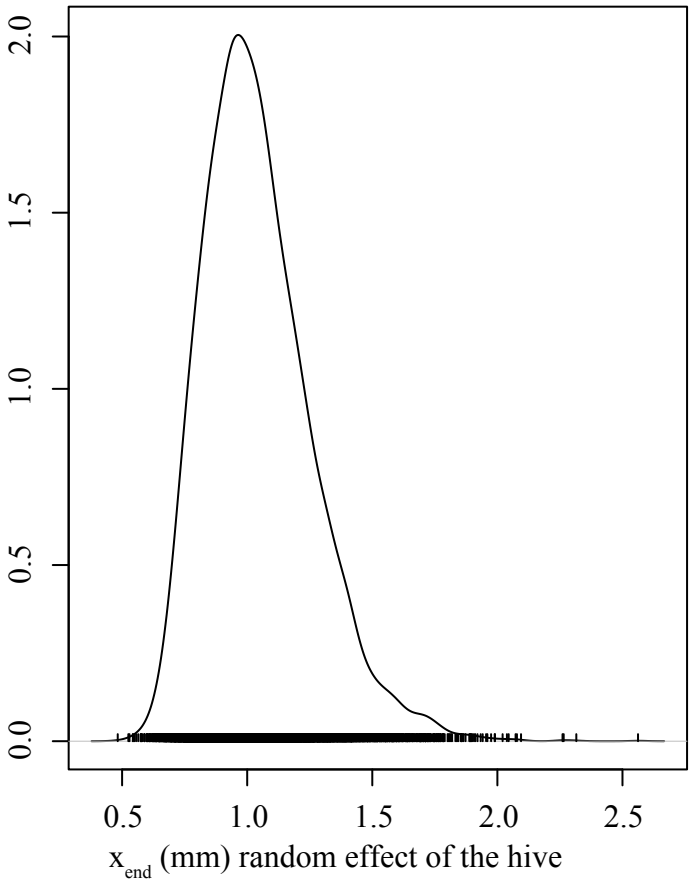

x_{end} (mm) intercept
10
5
0
−5
−10
−15
−20
200000
600000
1000000
Iterations

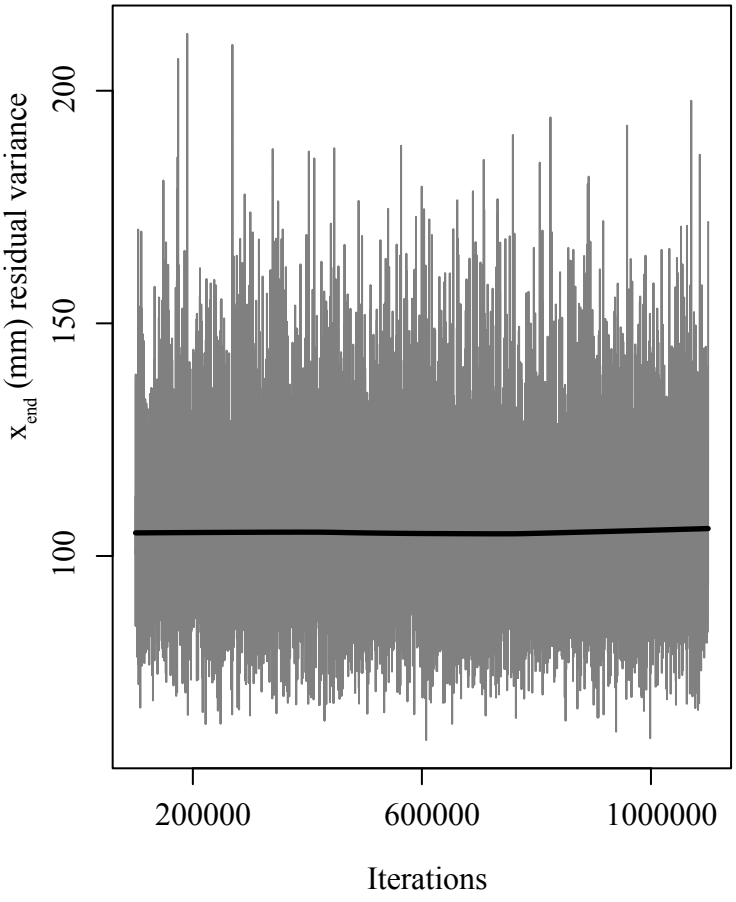

0.10
0.08
0.06
0.04
0.02
0.00
−20
−10
0
10
x_{end} (mm) intercept

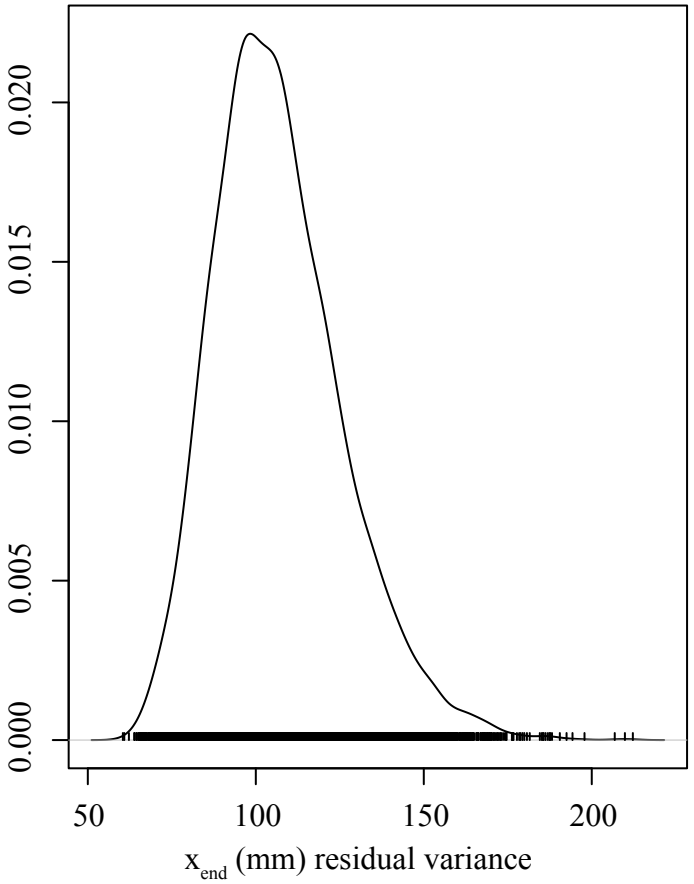

x_{end} (mm) slope of target size (mm)
0.6
0.4
0.2
0.0
−0.2
200000
600000
1000000
Iterations

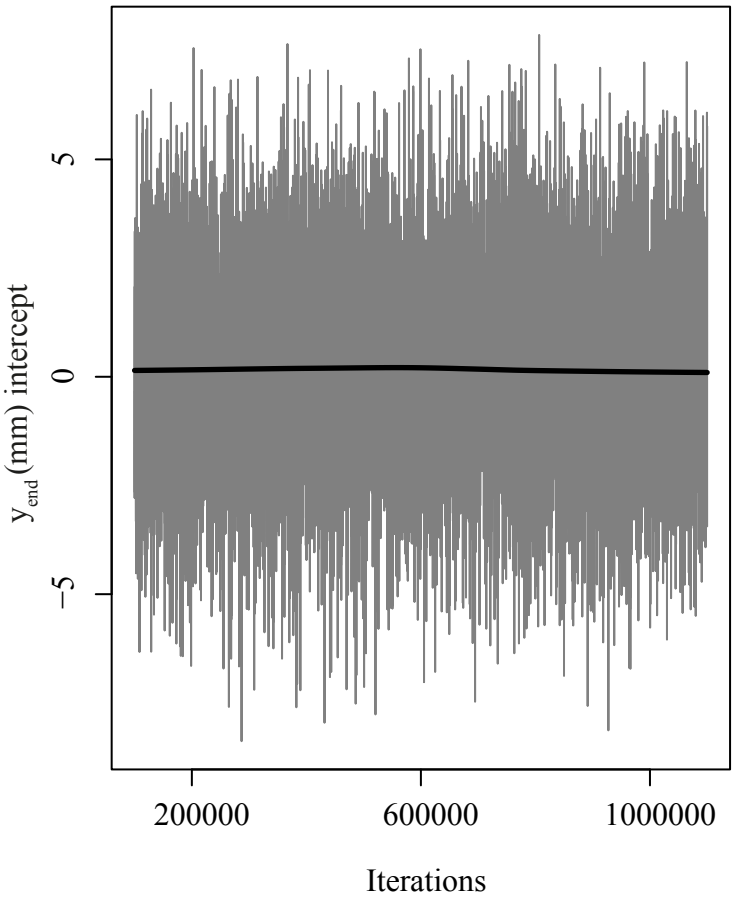

3
2
1
0
−0.2
0.0
0.2
0.4
0.6
x_{end} (mm) slope of target size (mm)

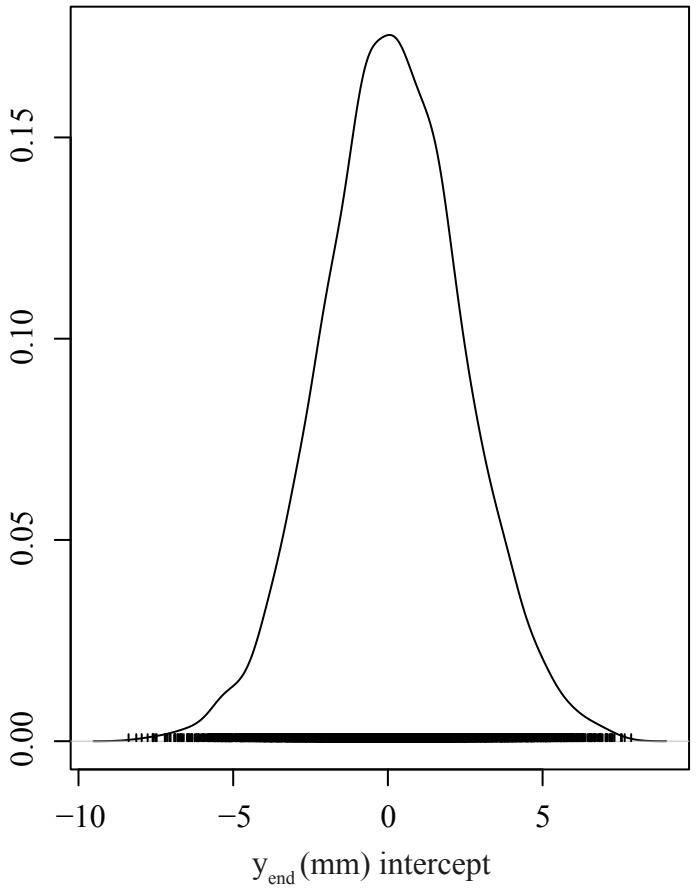

x_{end} (mm) random effect of the hive
0.5
1.0
1.5
2.0
2.5
200000
600000
1000000
Iterations

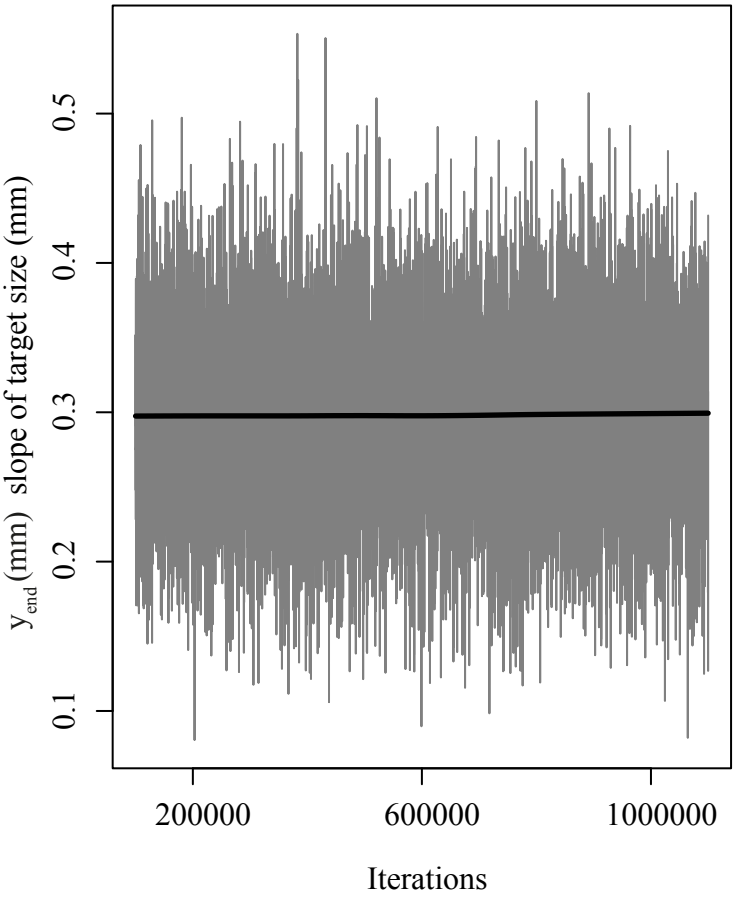

0.0
0.5
1.0
1.5
2.0
0.5
1.0
1.5
2.0
2.5
x_{end} (mm) random effect of the hive

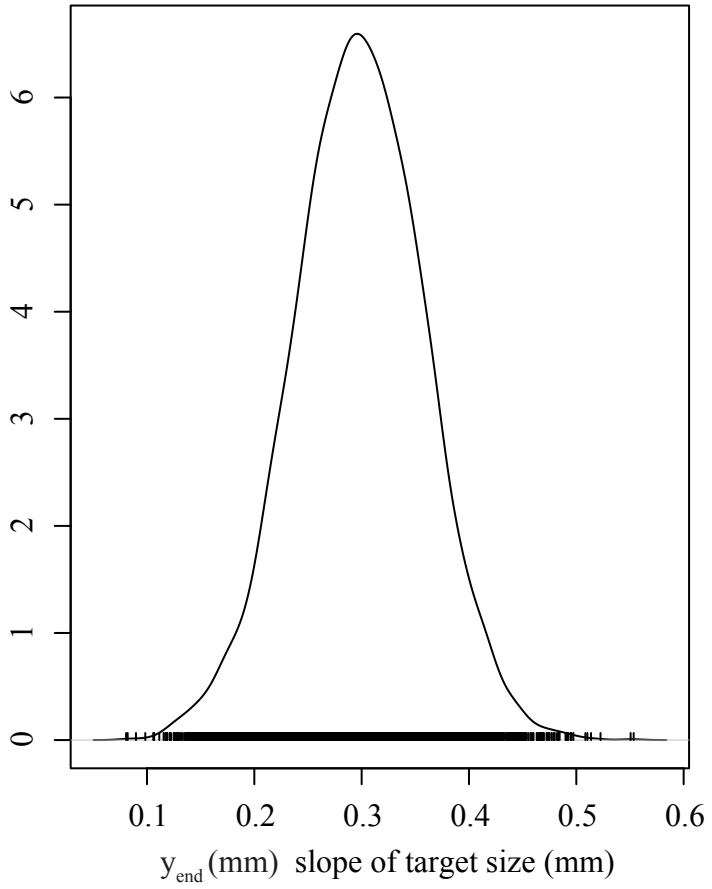

x_{end} (mm) residual variance
100
150
200
200000
600000
1000000
Iterations

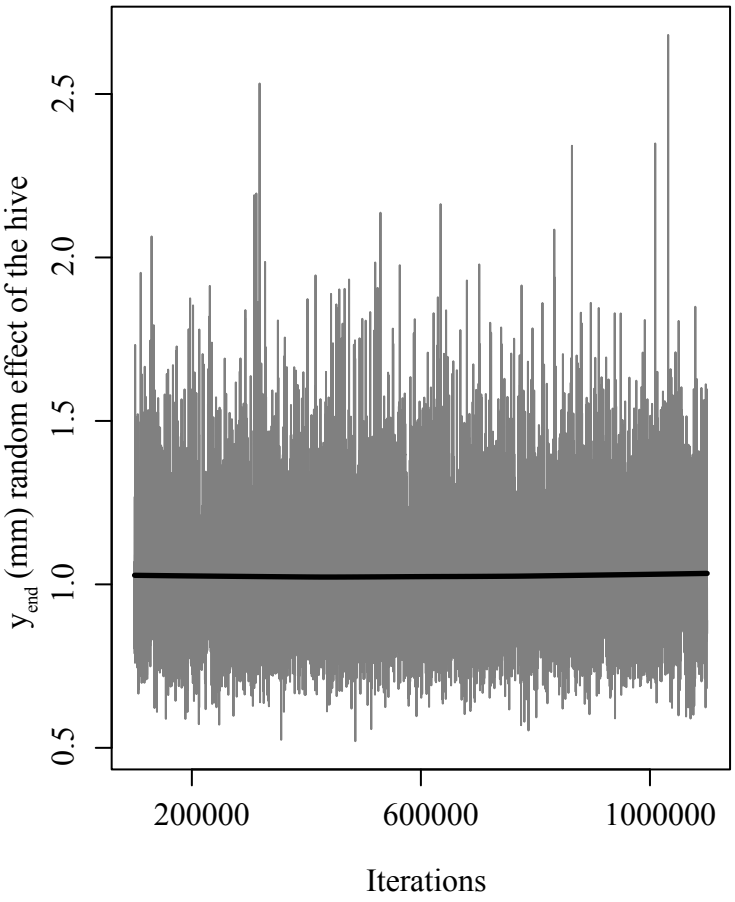

0.000
0.005
0.010
0.015
0.020
50
100
150
200
x_{end} (mm) residual variance

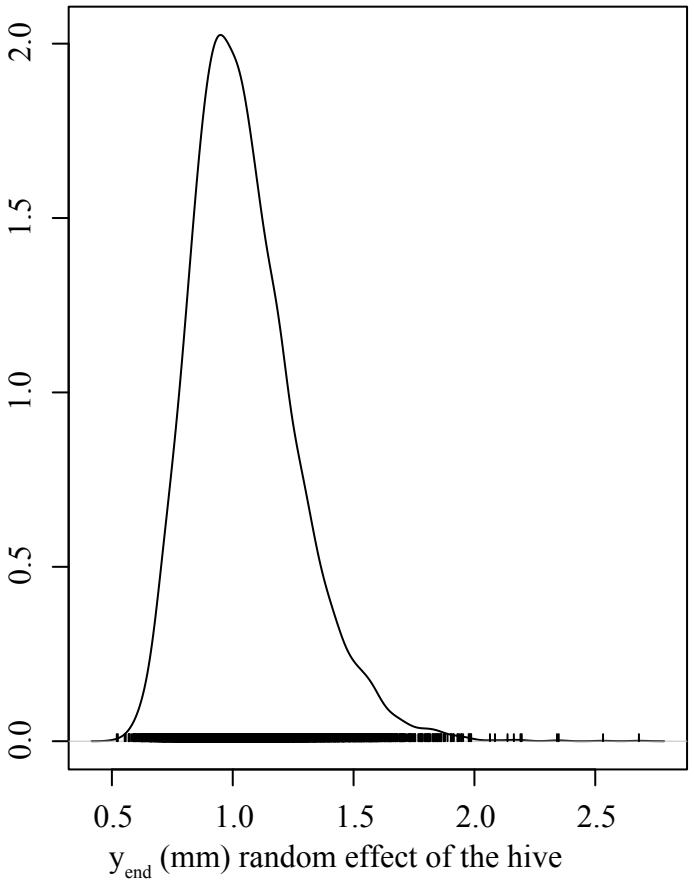

y_{end} (mm) intercept
5
0
−5
200000
600000
1000000
Iterations

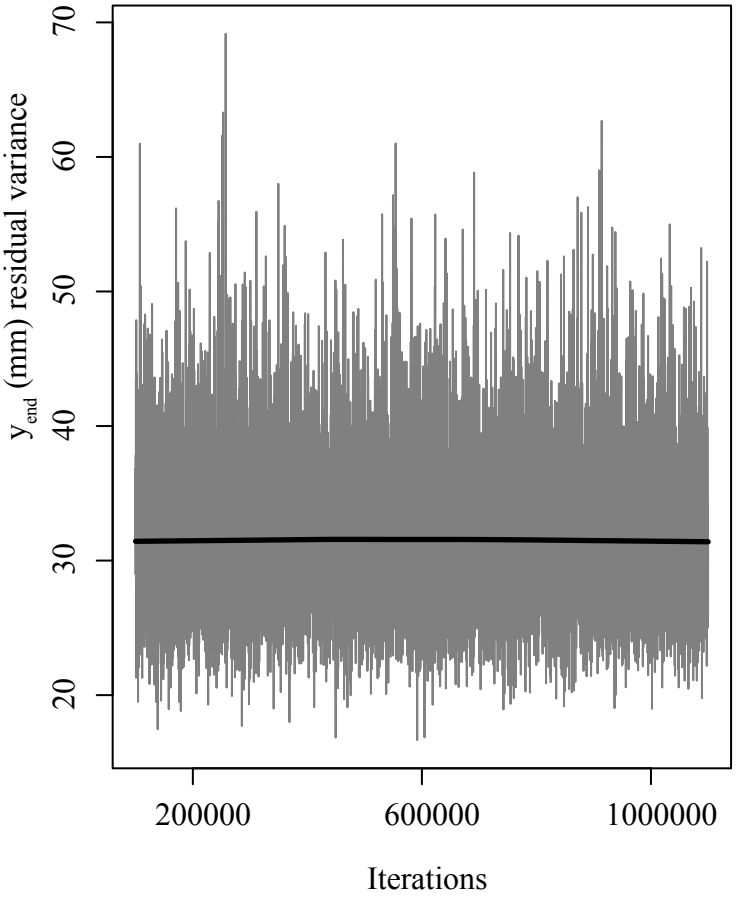

0.15
0.10
0.05
0.00
−10
−5
0
5
y_{end} (mm) intercept


y_{end} (mm) slope of target size (mm)
0.5
0.4
0.3
0.2
0.1
200000
600000
1000000
Iterations


6
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
y_{end} (mm) slope of target size (mm)


y_{end} (mm) random effect of the hive
0.5
1.0
1.5
2.0
2.5
200000
600000
1000000
Iterations


0.0
0.5
1.0
1.5
2.0
0.5
1.0
1.5
2.0
2.5
y_{end} (mm) random effect of the hive


y_{end} (mm) residual variance
20
30
40
50
60
70
200000
600000
1000000
Iterations

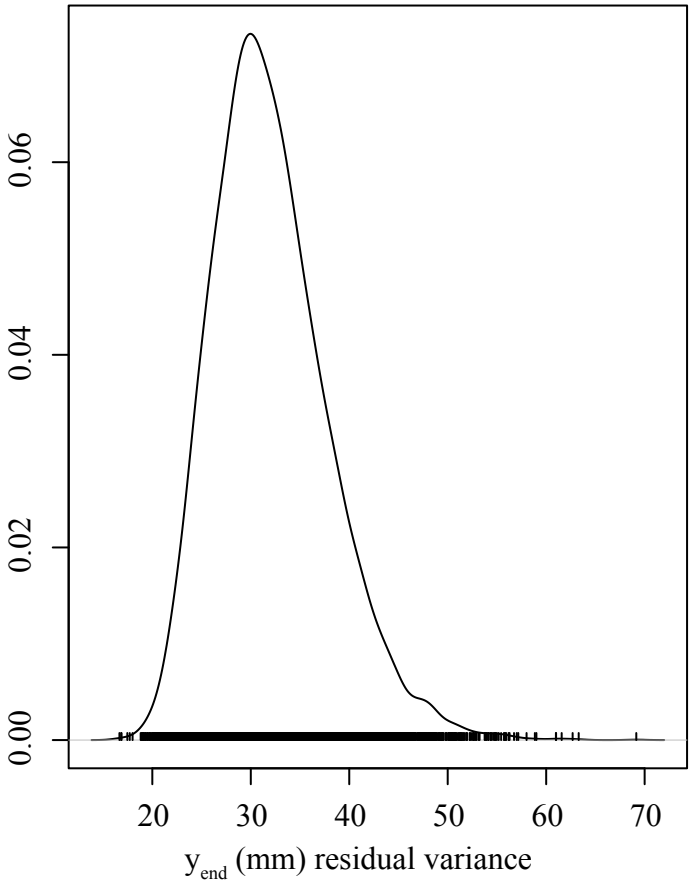

0.00
0.02
0.04
0.06
20
30
40
50
60
70
y_{end} (mm) residual variance

Figure S3:
MCMC traces of the sampled output (left column) and density estimates (right column) of landing parameters for fixed and random effects. Target size (S) was a fixed effect, and hive was a random variable.

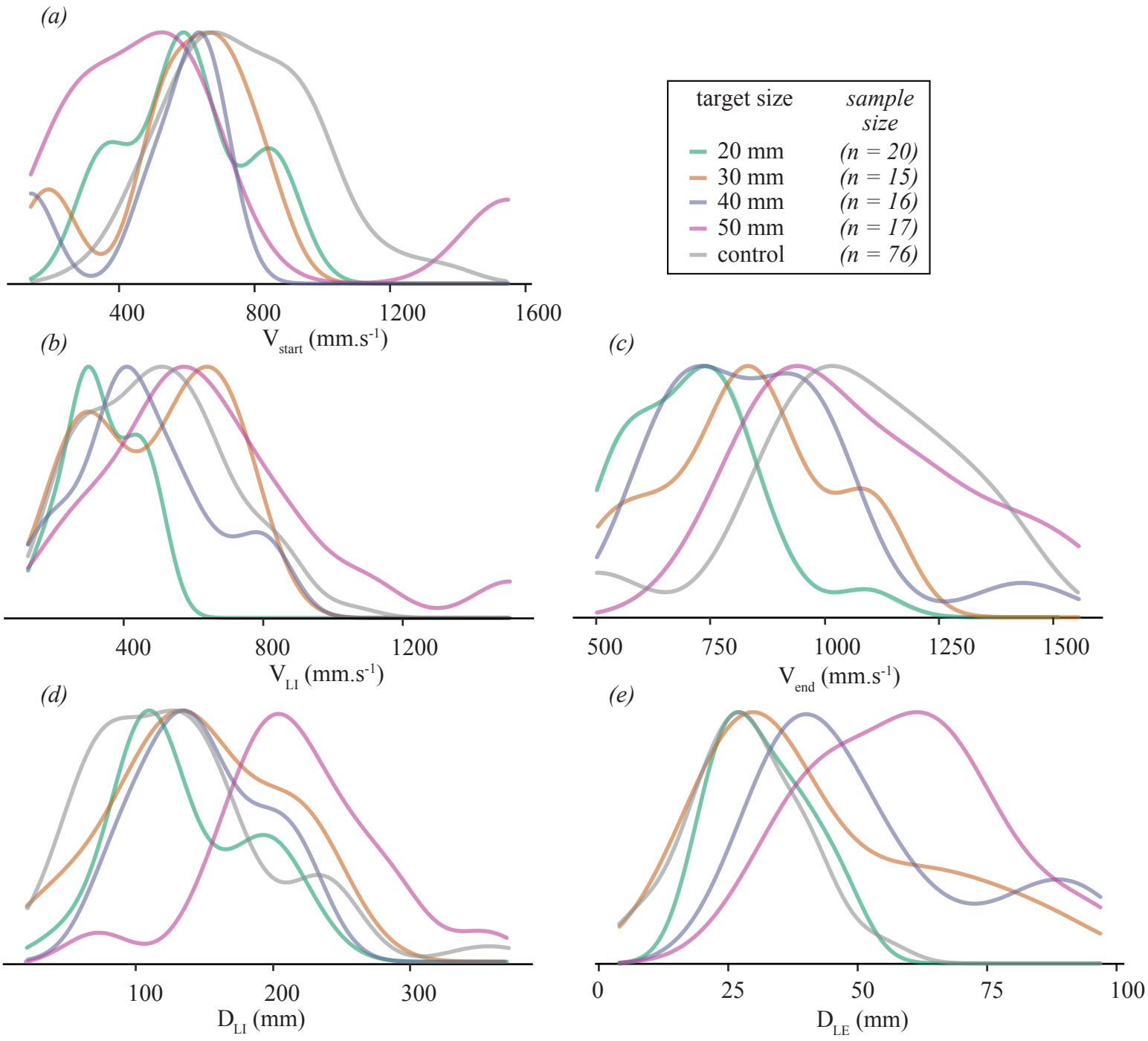


Figure S4:
Normalised densities of the speed at the start V_{start} (*a* - 250 mm from the target), at landing initiation V_{LI} *(b)*, at the end V_{end} *(c)*, the distance from the hive at landing initiation D_{LI} *(d)* and the distance from the hive at leg extension V_{LE} *(e)* separated by target diameter (C_{size}). The profiles for $C_{control}$ are provided for comparison (grey curve).

Smoothing window = 4 frames

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	388	-2.6	ns	[-26;21]	0.72	*	[0.052;1.4]
α	$mm.s^{-2}$	1 + S	794	-625	ns	[-3609;2281]	107	*	[23;187]
θ^{T}_{LE}	deg	1 + S	217	30	*	[6.7;54]	0.41	ns	[-0.19;1.0]
x_{end}	mm	1 + S	317	-6.2	ns	[-16;5.1]	0.21	ns	[-0.11;0.50]
y_{end}	mm	1 + S	274	-1.6	ns	[-8.3;5.0]	0.40	***	[0.17;0.53]

Smoothing window = 8 frames

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	399	9.1	**	[3.1;16]	0.15	ns	[-0.023;0.32]
α	$mm.s^{-2}$	1 + S	984	1254	*	[331;2170]	10.98	ns	[-16;36]
θ^{T}_{LE}	deg	1 + S	318	36	***	[15;57]	0.26	ns	[-0.27;0.81]
x_{end}	mm	1 + S	413	-3.93	ns	[-11;3.8]	0.10	ns	[-0.10;0.31]
y_{end}	mm	1 + S	355	0.62	ns	[-3.8;5.3]	0.30	***	[0.18;0.42]

Smoothing window = 12 frames

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	448	6.0	***	[2.3;9.5]	0.19	***	[0.10;0.28]
α	$mm.s^{-2}$	1 + S	1210	1371	***	[852;1892]	3.2	ns	[-11;18]
θ^{T}_{LE}	deg	1 + S	406	39	***	[23;57]	0.17	ns	[-0.26;0.59]
x_{end}	mm	1 + S	553	-5.8	ns	[-13;1.4]	0.21	*	[0.019;0.40]
y_{end}	mm	1 + S	470	-0.24	ns	[-4.5;3.9]	0.31	***	[0.21;0.43]

Smoothing window = 16 frames

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	476	6.4	***	[2.9;9.9]	0.17	***	[0.084;0.26]
α	$mm.s^{-2}$	1 + S	1289	1283	***	[756;1782]	4.8	ns	[-9.3;19]
θ^{T}_{LE}	deg	1 + S	422	38	***	[22;55]	0.20	ns	[-0.22;0.59]
x_{end}	mm	1 + S	589	-5.2	ns	[-12;1.6]	0.19	ns	[-0.0057;0.37]
y_{end}	mm	1 + S	503	-0.64	ns	[-4.9;3.4]	0.31	***	[0.20;0.42]

Smoothing window = 20 frames

parameter	*unit*	*formula*	*Deviance Information Criterion*	*Intercept*	p_{MCMC}	*CI*	*slope*	p_{MCMC}	*CI*
θ^{T}_{LI}	deg	1 + S	501	6.6	***	[3.3;9.9]	0.15	***	[0.070;0.24]
α	$mm.s^{-2}$	1 + S	1362	1180	***	[713;1687]	6.2	ns	[-6.7;20]
θ^{T}_{LE}	deg	1 + S	453	40	***	[25;56]	0.15	ns	[-0.24;0.53]
x_{end}	mm	1 + S	623	-4.6	ns	[-11;2.2]	0.16	ns	[-0.020;0.34]
y_{end}	mm	1 + S	528	0.42	ns	[-3.8;4.1]	0.28	***	[0.17;0.37]

Tables S3

Linear mixed models of landing parameters in C_{size} with increasing smoothing windows (4 to 20 frames) with target size (S) as a fixed effect and hive as a random variable. The significances of the intercepts and slopes are given by the 95% credible interval (CI) and the bayesian p-value (p_{MCMC}). Significance codes: $<10^{-3}$ ***; $<10^{-2}$ **; <0.05 *; >0.05 ns.

type of curve/ Smoothing window	*0*	*1*	*2*
4 frames	73	37	4
8 frames	57	44	14
12 frames	40	51	24
16 frames	35	52	28
20 frames	30	52	33

Table S4

Proportions of landings of type 0 (final deceleration) of type 1 (deceleration followed by acceleration) and 2 (continuous acceleration) in C_{size} with increasing smoothing windows (4 to 20 frames).

Target diameter (mm)	*20*	*30*	*40*	*50*	*control*
Landing outside of target/hive (%)	10	13	10	17	7

Table S5

Proportions of landings where touchdown occurred outside of the target disk in $C_{control}$ and C_{size}.

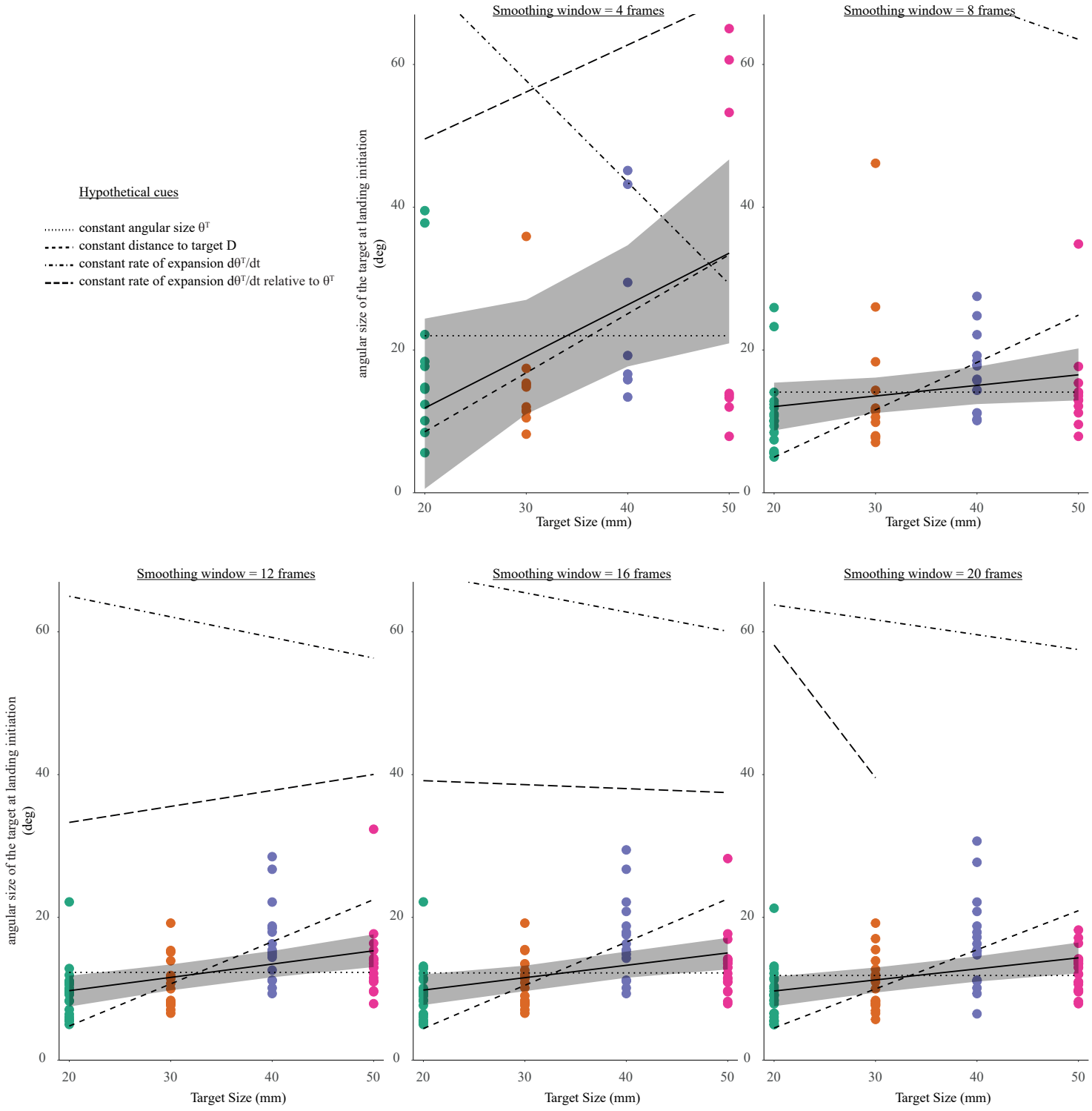


Figure S5

Effect of target size on the angular size of the target with increasing smoothing windows (4 to 20 frames). Solid black lines and grey areas represent a linear mixed model with the 95% credible interval on the observed data (tables S3). Dashed lines represent a linear regression fit on the predicted θ^T if θ^T (medium dashes), D (small dashes), $d\theta^T/dt$ (small and medium dashes), or $d\theta^T/dt$ relative to θ^T(large dashes) would be constant. Note that observed or predicted values of θ^T above 65 degrees are not represented.