**Appendix**

**A1. Pilot experiment**

A pilot experiment was conducted to determine response rates of two different species of paper wasps, *P. metricus* and *P. fuscatus* to mirrors and non-reflective control surfaces. We used 5 individual foundress wasps per species and each wasp was presented with four different stimuli. To assess responsiveness, we counted how many times within our sampling period the wasp was oriented toward the stimulus, and compared mirror stimuli (“Reflect”) to similarly sized non-reflective plastic plates (“Non”). We also tested two different mirror setups as follows: a single small mirror measuring 1.5 × 4 cm (designated below as “1”), or a series of 8 small mirrors (each 1.5 × 2 cm) arranged in a semicircle, that covered 50% of the circumference of the Petri dish (designated below as “50”). The results for each species were analyzed with a non-parametric Kruskal–Wallis rank sum test in R. Pairwise comparisons between stimuli within each species were made using a Wilcoxon test with a Benjamini–Hochberg correction. Data were graphed as boxplots in R using ggpubr. Results for each species are reported below.



**Figure A1.** *Polistes fuscatus* averaged counts (across 5 individual wasps) of behavioural responses to four stimuli, a small single mirror (Reflect1), a small non-reflective plate of the same size (Non1), a semicircular panel of mirrors covering 50% of the circumference of a Petri dish (Reflect 50), and a semicircular panel of non-reflective plates covering 50% of the circumference of a Petri dish (Non50).

For *Polistes fuscatus*, the Kruskal–Wallis rank-sum test showed a significant difference between stimuli (Kruskal–Wallis chi-squared = 8.1936, df = 3, *p* = 0.04218), likely due to the fact that response rates for both “50%” stimuli were higher. However, there were no significant differences between any two stimuli based on pairwise comparisons from the Wilcoxon tests. Overall, the wasps had low response rates. There was no evidence that wasps responded more to a reflective compared to a non-reflective stimulus, thus we interpreted this to mean that *P. fuscatus* were either not able to perceive or were not stimulated by the presence of a reflection. Thus, we chose not to use this species for subsequent experiments.

**Table A1.**

*p*-values from Wilcoxon pairwise tests for *P. fuscatus.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Non1 | Non50 | Reflect1 |
| Non50 | 0.527 | – | – |
| Reflect1 | 0.586 | 0.586 | – |
| Reflect50 | 0.060 | 0.586 | 0.068 |



bc

c

b

a

**Figure A2.** *Polistes metricus* averaged counts (across 5 individual wasps) of behavioral responses to four stimuli, a small single mirror (Reflect1), a small non-reflective plastic plate of the same size (Non1), a semicircular panel of mirrors covering 50% of the circumference of a Petri dish (Reflect 50), and a semicircular panel of plastic plates covering 50% of the circumference of a Petri dish (Non50). Different letters represent significant differences in pairwise Wilcoxon tests.

For *Polistes metricus*, the Kruskal–Wallis rank-sum test revealed a significant difference between stimuli (Kruskal–Wallis chi-squared = 15.404, df = 3, *p* = 0.001502). There was no evidence that wasps responded more to a reflective compared to a non-reflective stimulus, thus we interpreted this to mean that *P. fuscatus* were either not aware of or not stimulated by the presence of a mirror. Response rates with the Reflect50 stimulus were substantially higher than those seen for *P. metricus*, thus we chose to use this species and the 50% setup for all subsequent experiments.

**Table A2.**

*p*-values from Wilcoxon pairwise tests for *P. metricus.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Non1 | Non50 | Reflect1 |
| Non50 | 0.027\*\* | – | – |
| Reflect1 | 0.099 | 0.125 | – |
| Reflect50 | 0.023\*\* | 0.023\*\* | 0.023\*\* |

**A2. Short test statistical analysis results**

**Table A3.**

Antennation Towards–Pairwise contrasts of antennation when facing towards the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | *p* value |
| Additional\_Wasp/Clear\_reflect | 0.543 | 0.0953 | Inf | -3.479 | 0.0091 |
| Additional\_Wasp/Mark\_nonreflect | 0.521 | 0.0906 | Inf | -3.75 | 0.0034 |
| Additional\_Wasp/Mark\_reflect | 0.568 | 0.1004 | Inf | -3.2 | 0.0233 |
| Additional\_Wasp/Nonreflect | 0.794 | 0.15 | Inf | -1.223 | 0.8854 |
| Additional\_Wasp/Reflective | 0.365 | 0.0602 | Inf | -6.115 | <0.0001 |
| Additional\_Wasp/Touch\_reflect | 0.446 | 0.0757 | Inf | -4.753 | <0.0001 |
| Clear\_reflect/Mark\_nonreflect | 0.958 | 0.1395 | Inf | -0.292 | 0.9999 |
| Clear\_reflect/Mark\_reflect | 1.045 | 0.1555 | Inf | 0.299 | 0.9999 |
| Clear\_reflect/Nonreflect | 1.46 | 0.2382 | Inf | 2.321 | 0.2336 |
| Clear\_reflect/Reflective | 0.672 | 0.0903 | Inf | -2.961 | 0.0482 |
| Clear\_reflect/Touch\_reflect | 0.821 | 0.1153 | Inf | -1.401 | 0.8014 |
| Mark\_nonreflect/Mark\_reflect | 1.091 | 0.1606 | Inf | 0.591 | 0.9971 |
| Mark\_nonreflect/Nonreflect | 1.524 | 0.2465 | Inf | 2.604 | 0.1245 |
| Mark\_nonreflect/Reflective | 0.701 | 0.093 | Inf | -2.678 | 0.1037 |
| Mark\_nonreflect/Touch\_reflect | 0.857 | 0.1189 | Inf | -1.111 | 0.925 |
| Mark\_reflect/Nonreflect | 1.397 | 0.23 | Inf | 2.03 | 0.3954 |
| Mark\_reflect/Reflective | 0.642 | 0.0875 | Inf | -3.248 | 0.0199 |
| Mark\_reflect/Touch\_reflect | 0.786 | 0.1117 | Inf | -1.697 | 0.6181 |
| Nonreflect/Reflective | 0.46 | 0.0698 | Inf | -5.116 | <0.0001 |
| Nonreflect/Touch\_reflect | 0.562 | 0.0884 | Inf | -3.662 | 0.0047 |
| Reflective/Touch\_reflect | 1.223 | 0.1554 | Inf | 1.585 | 0.6918 |

**Table A4.**

Antennation Away–Pairwise contrasts of antennation when facing away from the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | *p* value |
| Additional\_Wasp/Clear\_reflect | 1.872 | 0.336 | Inf | 3.499 | 0.0085 |
| Additional\_Wasp/Mark\_nonreflect | 1.872 | 0.336 | Inf | 3.499 | 0.0085 |
| Additional\_Wasp/Mark\_reflect | 2.933 | 0.615 | Inf | 5.13 | <0.0001 |
| Additional\_Wasp/Nonreflect | 1.63 | 0.28 | Inf | 2.847 | 0.0664 |
| Additional\_Wasp/Reflective | 1.397 | 0.229 | Inf | 2.041 | 0.3886 |
| Additional\_Wasp/Touch\_reflect | 2 | 0.366 | Inf | 3.784 | 0.0029 |
| Clear\_reflect/Mark\_nonreflect | 1 | 0.205 | Inf | 0 | 1 |
| Clear\_reflect/Mark\_reflect | 1.567 | 0.363 | Inf | 1.936 | 0.4561 |
| Clear\_reflect/Nonreflect | 0.87 | 0.172 | Inf | -0.701 | 0.9926 |
| Clear\_reflect/Reflective | 0.746 | 0.143 | Inf | -1.532 | 0.7254 |
| Clear\_reflect/Touch\_reflect | 1.068 | 0.222 | Inf | 0.317 | 0.9999 |
| Mark\_nonreflect/Mark\_reflect | 1.567 | 0.363 | Inf | 1.936 | 0.4561 |
| Mark\_nonreflect/Nonreflect | 0.87 | 0.172 | Inf | -0.701 | 0.9926 |
| Mark\_nonreflect/Reflective | 0.746 | 0.143 | Inf | -1.532 | 0.7253 |
| Mark\_nonreflect/Touch\_reflect | 1.068 | 0.222 | Inf | 0.317 | 0.9999 |
| Mark\_reflect/Nonreflect | 0.556 | 0.126 | Inf | -2.602 | 0.1253 |
| Mark\_reflect/Reflective | 0.476 | 0.105 | Inf | -3.371 | 0.0132 |
| Mark\_reflect/Touch\_reflect | 0.682 | 0.16 | Inf | -1.63 | 0.6625 |
| Nonreflect/Reflective | 0.857 | 0.158 | Inf | -0.838 | 0.981 |
| Nonreflect/Touch\_reflect | 1.227 | 0.247 | Inf | 1.016 | 0.9505 |
| Reflective/Touch\_reflect | 1.432 | 0.279 | Inf | 1.841 | 0.5198 |

**Table A5.**

Touching Towards–Pairwise contrasts of touching when facing towards the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | *p* value |
| Additional\_Wasp/Clear\_reflect | 0.207 | 0.0653 | Inf | -4.993 | <0.0001 |
| Additional\_Wasp/Mark\_nonreflect | 0.182 | 0.0568 | Inf | -5.459 | <0.0001 |
| Additional\_Wasp/Mark\_reflect | 0.148 | 0.0456 | Inf | -6.204 | <0.0001 |
| Additional\_Wasp/Nonreflect | 0.343 | 0.1141 | Inf | -3.216 | 0.0221 |
| Additional\_Wasp/Reflective | 0.148 | 0.0456 | Inf | -6.204 | <0.0001 |
| Additional\_Wasp/Touch\_reflect | 0.117 | 0.0354 | Inf | -7.083 | <0.0001 |
| Clear\_reflect/Mark\_nonreflect | 0.879 | 0.1574 | Inf | -0.721 | 0.9913 |
| Clear\_reflect/Mark\_reflect | 0.716 | 0.1226 | Inf | -1.951 | 0.4461 |
| Clear\_reflect/Nonreflect | 1.657 | 0.353 | Inf | 2.371 | 0.2107 |
| Clear\_reflect/Reflective | 0.716 | 0.1226 | Inf | -1.951 | 0.4461 |
| Clear\_reflect/Touch\_reflect | 0.563 | 0.092 | Inf | -3.515 | 0.008 |
| Mark\_nonreflect/Mark\_reflect | 0.815 | 0.1345 | Inf | -1.241 | 0.8781 |
| Mark\_nonreflect/Nonreflect | 1.886 | 0.3924 | Inf | 3.048 | 0.0372 |
| Mark\_nonreflect/Reflective | 0.815 | 0.1345 | Inf | -1.241 | 0.8781 |
| Mark\_nonreflect/Touch\_reflect | 0.641 | 0.1005 | Inf | -2.837 | 0.0684 |
| Mark\_reflect/Nonreflect | 2.314 | 0.4658 | Inf | 4.169 | 0.0006 |
| Mark\_reflect/Reflective | 1 | 0.1564 | Inf | 0 | 1 |
| Mark\_reflect/Touch\_reflect | 0.786 | 0.1162 | Inf | -1.626 | 0.6655 |
| Nonreflect/Reflective | 0.432 | 0.087 | Inf | -4.169 | 0.0006 |
| Nonreflect/Touch\_reflect | 0.34 | 0.0662 | Inf | -5.544 | <0.0001 |
| Reflective/Touch\_reflect | 0.786 | 0.1162 | Inf | -1.626 | 0.6655 |

**Table A6.**

Touching Away–Pairwise contrasts of touching when facing away from the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | *p* value |
| Additional\_Wasp/Clear\_reflect | 1.52 | 0.387 | Inf | 1.643 | 0.6542 |
| Additional\_Wasp/Mark\_nonreflect | 1.583 | 0.409 | Inf | 1.781 | 0.561 |
| Additional\_Wasp/Mark\_reflect | 1.31 | 0.32 | Inf | 1.108 | 0.926 |
| Additional\_Wasp/Nonreflect | 1 | 0.227 | Inf | 0 | 1 |
| Additional\_Wasp/Reflective | 1 | 0.227 | Inf | 0 | 1 |
| Additional\_Wasp/Touch\_reflect | 0.884 | 0.195 | Inf | -0.561 | 0.9978 |
| Clear\_reflect/Mark\_nonreflect | 1.042 | 0.295 | Inf | 0.144 | 1 |
| Clear\_reflect/Mark\_reflect | 0.862 | 0.233 | Inf | -0.55 | 0.9981 |
| Clear\_reflect/Nonreflect | 0.658 | 0.168 | Inf | -1.643 | 0.6543 |
| Clear\_reflect/Reflective | 0.658 | 0.168 | Inf | -1.643 | 0.6543 |
| Clear\_reflect/Touch\_reflect | 0.581 | 0.145 | Inf | -2.179 | 0.307 |
| Mark\_nonreflect/Mark\_reflect | 0.828 | 0.226 | Inf | -0.693 | 0.993 |
| Mark\_nonreflect/Nonreflect | 0.632 | 0.163 | Inf | -1.781 | 0.5611 |
| Mark\_nonreflect/Reflective | 0.632 | 0.163 | Inf | -1.781 | 0.5611 |
| Mark\_nonreflect/Touch\_reflect | 0.558 | 0.141 | Inf | -2.313 | 0.2378 |
| Mark\_reflect/Nonreflect | 0.763 | 0.186 | Inf | -1.108 | 0.926 |
| Mark\_reflect/Reflective | 0.763 | 0.186 | Inf | -1.108 | 0.926 |
| Mark\_reflect/Touch\_reflect | 0.674 | 0.16 | Inf | -1.656 | 0.6453 |
| Nonreflect/Reflective | 1 | 0.227 | Inf | 0 | 1 |
| Nonreflect/Touch\_reflect | 0.884 | 0.195 | Inf | -0.561 | 0.9978 |
| Reflective/Touch\_reflect | 0.884 | 0.195 | Inf | -0.561 | 0.9978 |

**Table A7.**

Grooming Towards–Pairwise contrasts of grooming when facing towards the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | p value |
| Additional\_Wasp/Clear\_reflect | 0.0645 | 0.0471 | Inf | -3.757 | 0.0033 |
| Additional\_Wasp/Mark\_nonreflect | 0.4 | 0.3347 | Inf | -1.095 | 0.9298 |
| Additional\_Wasp/Mark\_reflect | 1 | 1 | Inf | 0 | 1 |
| Additional\_Wasp/Nonreflect | 0.0952 | 0.0705 | Inf | -3.178 | 0.025 |
| Additional\_Wasp/Reflective | 0.2 | 0.1549 | Inf | -2.078 | 0.3659 |
| Additional\_Wasp/Touch\_reflect | 2 | 2.4495 | Inf | 0.566 | 0.9977 |
| Clear\_reflect/Mark\_nonreflect | 6.2001 | 2.9881 | Inf | 3.786 | 0.0029 |
| Clear\_reflect/Mark\_reflect | 15.5 | 11.3081 | Inf | 3.757 | 0.0033 |
| Clear\_reflect/Nonreflect | 1.4762 | 0.4172 | Inf | 1.378 | 0.8138 |
| Clear\_reflect/Reflective | 3.0999 | 1.1273 | Inf | 3.111 | 0.0308 |
| Clear\_reflect/Touch\_reflect | 31.0008 | 31.4969 | Inf | 3.38 | 0.0128 |
| Mark\_nonreflect/Mark\_reflect | 2.4999 | 2.0916 | Inf | 1.095 | 0.9298 |
| Mark\_nonreflect/Nonreflect | 0.2381 | 0.1185 | Inf | -2.884 | 0.06 |
| Mark\_nonreflect/Reflective | 0.5 | 0.2738 | Inf | -1.266 | 0.8677 |
| Mark\_nonreflect/Touch\_reflect | 5 | 5.4773 | Inf | 1.469 | 0.7633 |
| Mark\_reflect/Nonreflect | 0.0952 | 0.0705 | Inf | -3.178 | 0.025 |
| Mark\_reflect/Reflective | 0.2 | 0.1549 | Inf | -2.078 | 0.3659 |
| Mark\_reflect/Touch\_reflect | 2.0001 | 2.4496 | Inf | 0.566 | 0.9977 |
| Nonreflect/Reflective | 2.1 | 0.8068 | Inf | 1.931 | 0.4595 |
| Nonreflect/Touch\_reflect | 21.0008 | 21.495 | Inf | 2.975 | 0.0463 |
| Reflective/Touch\_reflect | 10.0006 | 10.4886 | Inf | 2.195 | 0.2978 |

**Table A8.**

Grooming Away - Pairwise contrasts of grooming when facing away from the mirror for each stimuli group in the short test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Contrast | Ratio | SE | df | *z* ratio | *p* value |
| Additional\_Wasp/Clear\_reflect | 1.2 | 0.36 | Inf | 0.608 | 0.9966 |
| Additional\_Wasp/Mark\_nonreflect | 0.571 | 0.145 | Inf | -2.209 | 0.2906 |
| Additional\_Wasp/Mark\_reflect | 0.522 | 0.13 | Inf | -2.61 | 0.1229 |
| Additional\_Wasp/Nonreflect | 1 | 0.286 | Inf | 0 | 1 |
| Additional\_Wasp/Reflective | 1.714 | 0.571 | Inf | 1.619 | 0.6702 |
| Additional\_Wasp/Touch\_reflect | 0.889 | 0.247 | Inf | -0.424 | 0.9996 |
| Clear\_reflect/Mark\_nonreflect | 0.476 | 0.128 | Inf | -2.758 | 0.0844 |
| Clear\_reflect/Mark\_reflect | 0.435 | 0.115 | Inf | -3.141 | 0.028 |
| Clear\_reflect/Nonreflect | 0.833 | 0.25 | Inf | -0.608 | 0.9966 |
| Clear\_reflect/Reflective | 1.428 | 0.493 | Inf | 1.034 | 0.9463 |
| Clear\_reflect/Touch\_reflect | 0.741 | 0.216 | Inf | -1.028 | 0.9478 |
| Mark\_nonreflect/Mark\_reflect | 0.913 | 0.193 | Inf | -0.431 | 0.9995 |
| Mark\_nonreflect/Nonreflect | 1.75 | 0.443 | Inf | 2.209 | 0.2906 |
| Mark\_nonreflect/Reflective | 3 | 0.917 | Inf | 3.595 | 0.006 |
| Mark\_nonreflect/Touch\_reflect | 1.555 | 0.38 | Inf | 1.809 | 0.5421 |
| Mark\_reflect/Nonreflect | 1.917 | 0.478 | Inf | 2.61 | 0.1228 |
| Mark\_reflect/Reflective | 3.286 | 0.993 | Inf | 3.937 | 0.0016 |
| Mark\_reflect/Touch\_reflect | 1.704 | 0.409 | Inf | 2.22 | 0.2846 |
| Nonreflect/Reflective | 1.714 | 0.571 | Inf | 1.619 | 0.6702 |
| Nonreflect/Touch\_reflect | 0.889 | 0.247 | Inf | -0.424 | 0.9996 |
| Reflective/Touch\_reflect | 0.518 | 0.169 | Inf | -2.014 | 0.4054 |