

# Role of vision in odor tracking behaviors of male American cockroaches, *Periplaneta americana*.

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## Introduction

Successful tracking of wind-borne odor plumes in insects requires both odor and wind information. Most insects sense odors with their antennae, but wind speed and direction can be detected in multiple ways. Flying insects stabilize their flight and steer through the environment using optic flow feedback detected by their visual systems. When they are tracking an odor plume to find a food source or mate, these insects can use optic flow information to determine the wind direction. Less is known about the role of optic flow and other visual stimuli in the guidance of walking insects as they track wind-borne odors.

Our study investigates the role of vision in the odor tracking behaviors of virgin male American cockroaches, *Periplaneta americana*. Like most insects, cockroaches have two separate visual systems: (1) compound eyes that detect motion and patterns, and (2) a set of ocelli (simple eyes) which seem to function mainly in detecting changes in light intensity. The ocelli are more sensitive to light than the compound eyes and can transmit their output directly to the insects' motor system.

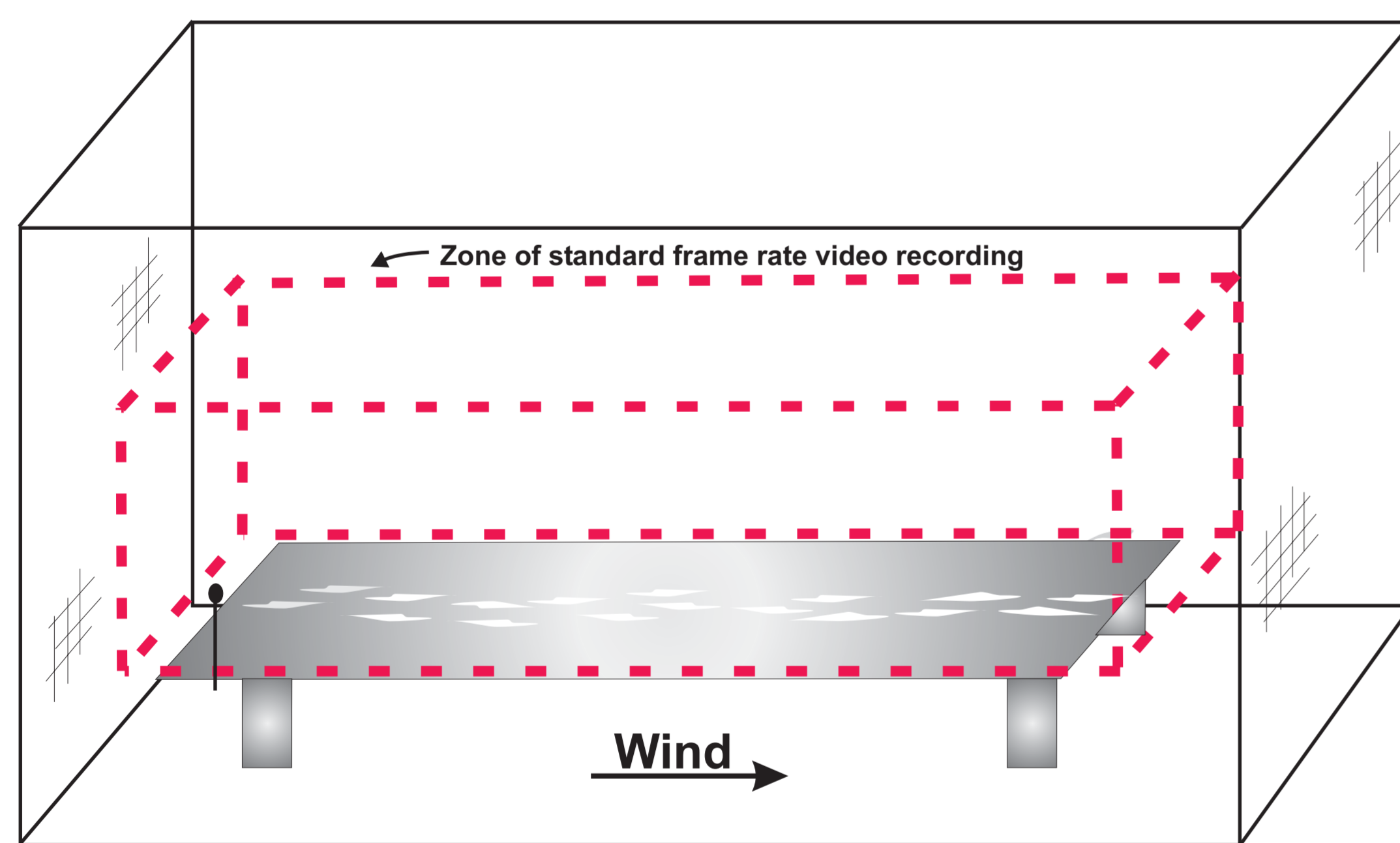
### Hypothesis:

Visual information associated with movement through the environment (e.g., landmarks, optic flow) is important to odor tracking in cockroaches.

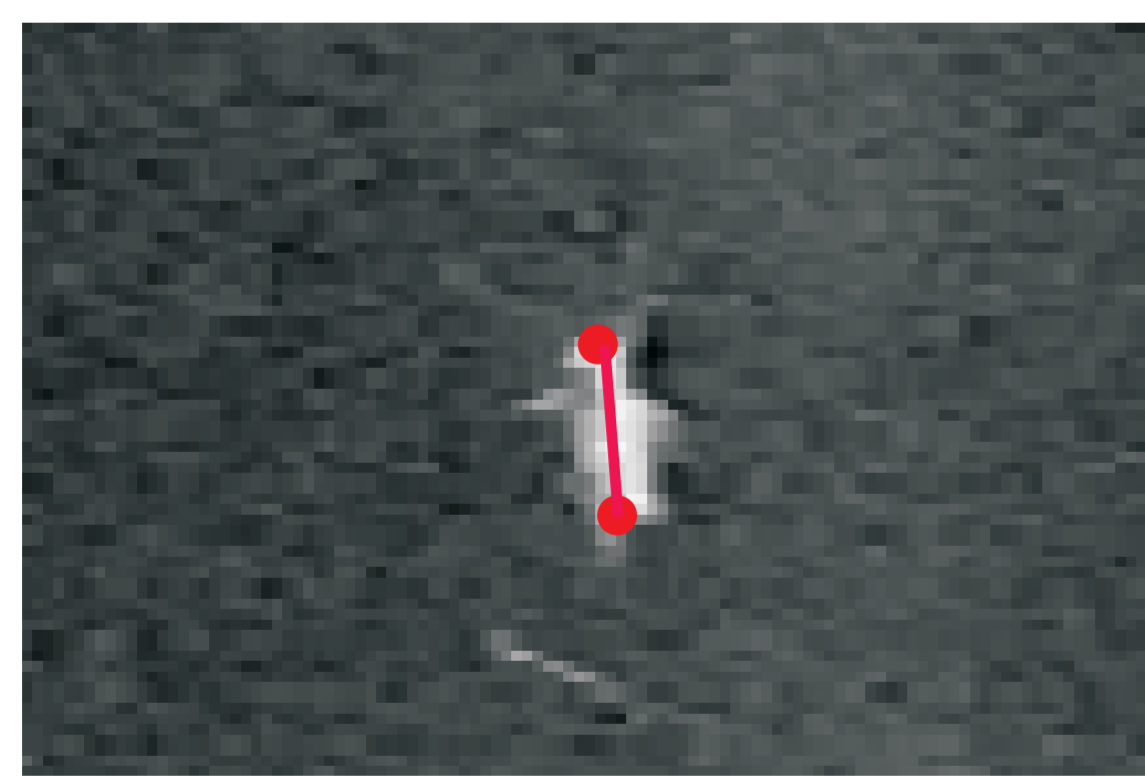
### Predictions:

- (1) Manipulating visual input will degrade the ability of male cockroaches to track wind-borne plumes of sex pheromone.
- (2) This degradation in performance will be observable in the guidance of walking orientation.

## Controlling wind speed and odor presentation enables study of multi-sensory control of navigation.

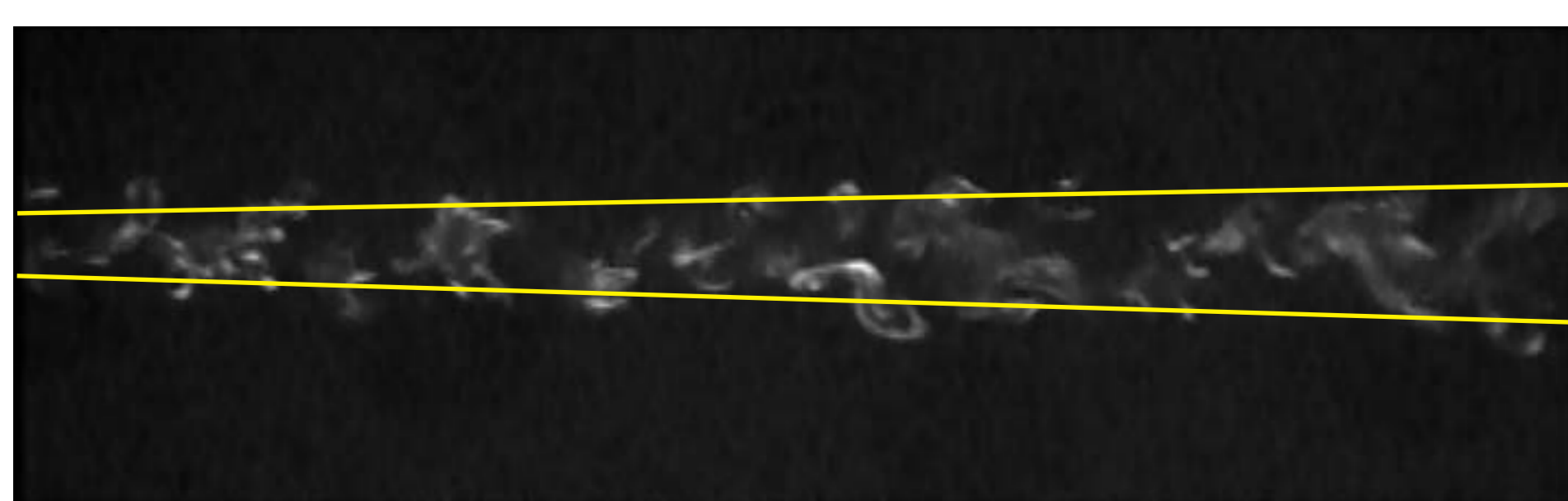


The roaches tracked the pheromone plumes on a raised aluminum floor in a wind tunnel with 25 cm/s wind speed. In this diagram wind flows from left to right with the pheromone source positioned at the upwind end.



The position and orientation of the roach's body were digitized using Motus motion analysis software (Vicon, Inc.) to measure kinematic and track parameters. A large field of view camera recorded the movement path and body orientation.

## Chemical smoke allows us to visualize the odor plume.



Titanium tetrachloride, applied to the same size and shape source we used in our experiments, generated smoke visualizations of the odor plume our cockroaches tracked. Here the yellow lines represent the time averaged plume boundary.

## Obstructing input to the different visual systems should alter odor tracking ability.

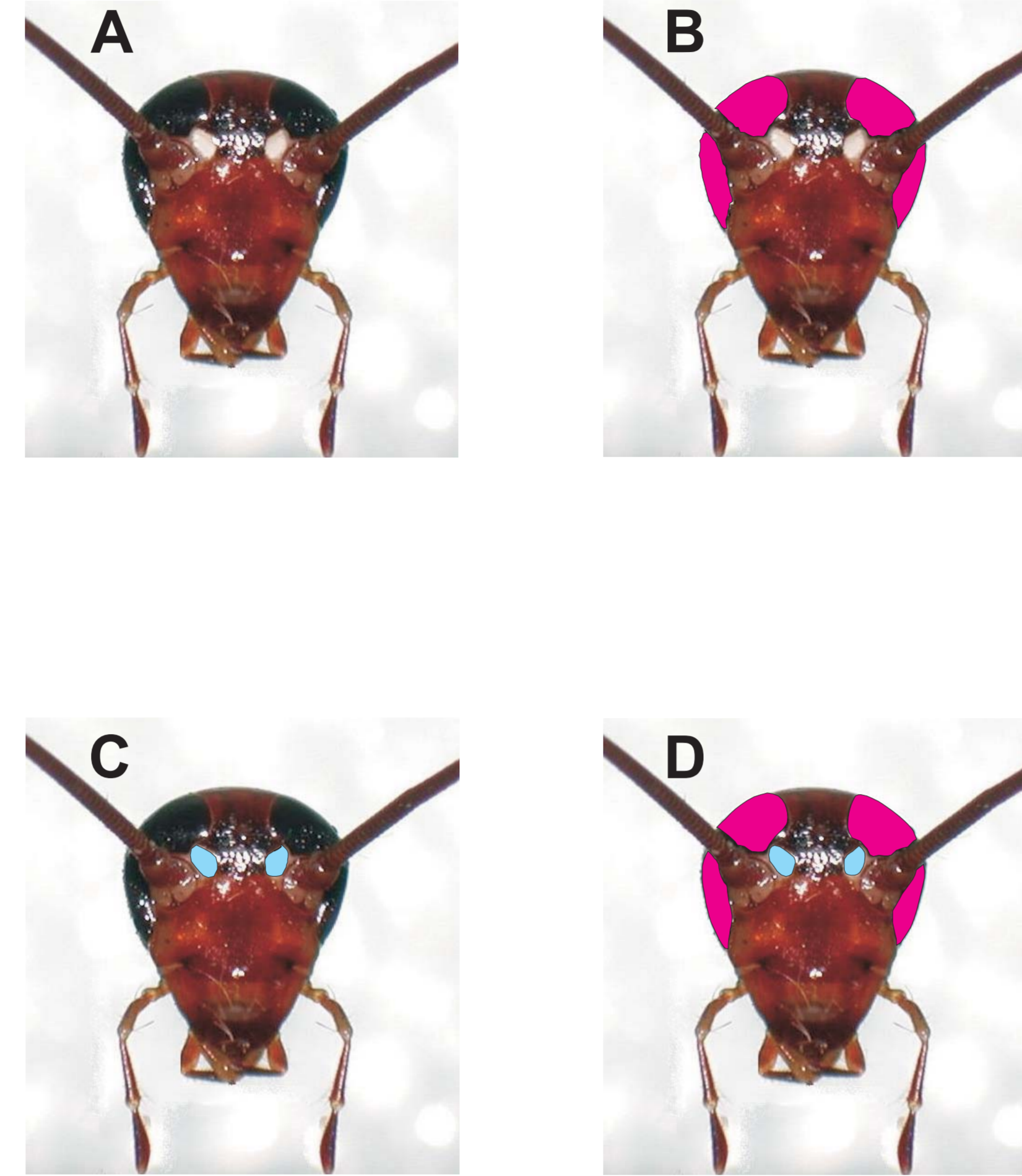
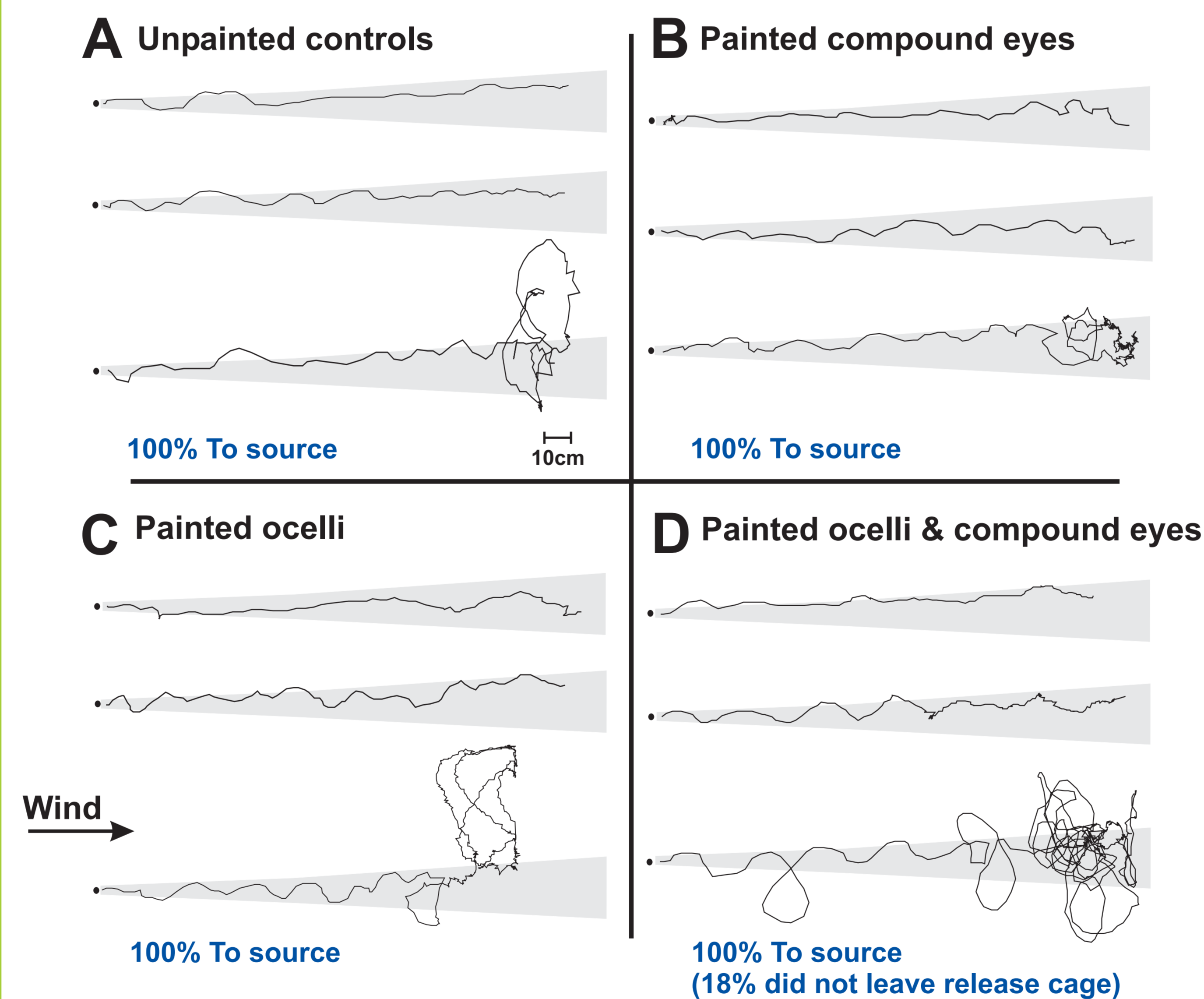


Illustration of the four treatment groups in our experiment. Cockroach faces with A) unpainted eyes, B) painted compound eyes, C) painted ocelli, and D) painted compound eyes and ocelli. In our experiment, the compound eyes and ocelli were covered first with a layer of red enamel paint to ensure complete coverage, followed by a layer of black acrylic paint to keep as much light out as possible.

## Male cockroaches are able to track pheromone upwind with little or no visual input.



Examples of *P. americana* males tracking a plume from a point-source of pheromone upwind (right to left) in a wind tunnel with: A) unpainted eyes, B) painted compound eyes, C) painted ocelli, and D) painted ocelli and compound eyes. The percentage of cockroaches successfully tracking the pheromone to the source is also given in blue. The time average plume boundaries of titanium tetrachloride smoke visualization, as viewed from above, are illustrated in gray. In this figure, wind blows from left to right at 25cm/s.

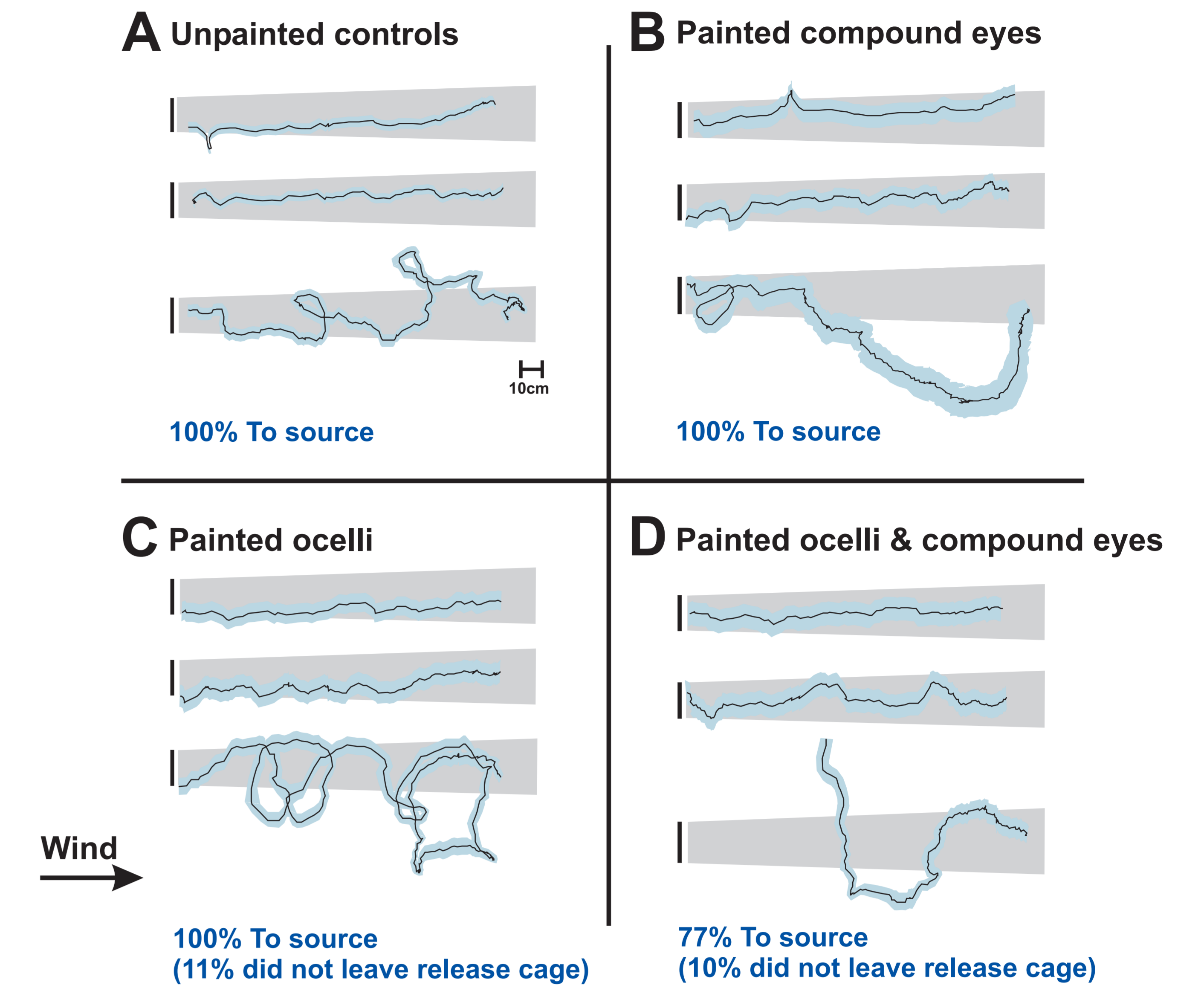
## Cockroaches with painted ocelli walk slower than those in other treatment groups.

Mean  $\pm$  S.D. of track parameters measured from *P. americana* males while tracking a pheromone plume with their visual sensors blocked to varying degrees.

Treatment*	n	Net Velocity (cm/s)	Groundspeed (cm/s)	Track Angle* (degrees)	Body Axis* (degrees)	Track width (cm)	Inter-turn Duration (s)	Number of stops	Stop duration (s)
Unpainted	19	16.67 $\pm$ 8.95°	23.89 $\pm$ 4.75°	20.89 $\pm$ 9.04°	16.09 $\pm$ 8.74°	3.18 $\pm$ 1.57°	0.55 $\pm$ 0.20°	0.39 $\pm$ 0.98°	0.04 $\pm$ 0.12°
Compound painted	20	16.82 $\pm$ 6.28°	20.69 $\pm$ 4.45°	21.24 $\pm$ 6.92°	16.18 $\pm$ 11.24°	2.67 $\pm$ 1.48°	0.54 $\pm$ 0.40°	0.86 $\pm$ 2.10°	0.05 $\pm$ 0.10°
Ocelli painted	20	13.72 $\pm$ 7.87°	20.10 $\pm$ 3.95°	25.72 $\pm$ 10.75°	20.07 $\pm$ 11.91°	2.92 $\pm$ 1.10°	0.54 $\pm$ 0.16°	0.65 $\pm$ 1.04°	0.06 $\pm$ 0.08°
Compound and Ocelli painted	18	11.68 $\pm$ 7.49°	19.39 $\pm$ 5.87°	25.50 $\pm$ 12.61°	17.21 $\pm$ 12.21°	3.70 $\pm$ 3.91°	0.64 $\pm$ 0.42°	1.39 $\pm$ 2.03°	0.09 $\pm$ 0.15°

Values in the same column with the same letters do not differ significantly according to a split-plot ANOVA ( $p < 0.05$ ) and post hoc Tukey test. \*All angles depicted are absolute values of the distributions measured. °Refers to the eyes painted prior to experimentation.

## Manipulating olfactory "landmarks" had little effect on the ability to track wind-borne odor.



Examples of *P. americana* males tracking a wide (14.3cm wide source) pheromone plume upwind (right to left) in a wind tunnel with A) unpainted eyes, B) painted compound eyes, C) painted ocelli, and D) painted ocelli and compound eyes. The shaded blue area around the track represents an estimated range of antennal position. The percentage of cockroaches successfully tracking the plume to the source is given in dark blue. The time average plume boundaries of a titanium tetrachloride smoke-visualization, as viewed from above, are illustrated in gray. In this figure, wind blows from left to right at 25cm/s.

## Altered olfactory environments had no significant effect on male cockroaches with diminished vision.

Mean  $\pm$  S.D. and coefficient of variation (CV) of track parameters measured from *P. americana* males walking in a wide plume in a laboratory wind tunnel.

Treatment (n)	Net Velocity (cm/s)	Ground-speed (cm/s)	Track Angle* (degrees)	Body Axis* (degrees)	Track width (cm)	Inter-turn Duration (s)	Number of stops	Stop duration (s)	Linearity index	Angular velocity (degrees/sec)
Not painted (10)	17.23 $\pm$ 6.04 (35.1)	20.77 $\pm$ 4.62 (22.2)	31.82 $\pm$ 13.64 (42.9)	29.65 $\pm$ 22.77 (76.8)	3.67 $\pm$ 2.59 (70.6)	0.61 $\pm$ 0.41 (67.2)	2.80 $\pm$ 3.58 (127.8)	0.23 $\pm$ 0.14 (60.9)	0.77 $\pm$ 0.16 (20.7)	293.20 $\pm$ 95.80 (32.7)
Ocelli painted (8)	12.26 $\pm$ 5.84 (47.6)	15.61 $\pm$ 5.35 (34.3)	31.60 $\pm$ 17.06 (54.0)	27.72 $\pm$ 23.52 (84.8)	5.60 $\pm$ 7.51 (134.1)	0.83 $\pm$ 0.65 (78.3)	4.38 $\pm$ 2.44 (55.7)	0.41 $\pm$ 0.27 (65.9)	0.76 $\pm$ 0.21 (27.6)	303.93 $\pm$ 100.89 (33.2)
Compound eyes painted (9)	15.96 $\pm$ 5.71 (35.8)	18.61 $\pm$ 5.22 (28.1)	29.71 $\pm$ 12.14 (40.9)	19.93 $\pm$ 8.23 (41.3)	4.56 $\pm$ 2.14 (46.9)	0.85 $\pm$ 0.60 (70.6)	3.77 $\pm$ 3.0 (79.6)	0.21 $\pm$ 0.11 (52.4)	0.79 $\pm$ 0.16 (20.3)	297.17 $\pm$ 137.68 (46.3)
Ocelli and Compound eyes painted (9)	11.51 $\pm$ 4.89 (42.5)	18.51 $\pm$ 6.68 (36.1)	39.12 $\pm$ 23.41 (59.8)	35.19 $\pm$ 23.41 (66.5)	4.82 $\pm$ 5.75 (119.3)	1.27 $\pm$ 1.91 (150.4)	3.22 $\pm$ 2.59 (80.4)	0.20 $\pm$ 0.15 (75.0)	0.71 $\pm$ 0.19 (26.8)	290.01 $\pm$ 200.58 (69.2)

There are no significant differences within any of the variables among treatments according to a repeated measures ANOVA ( $p < 0.05$ ) and post hoc Tukey test. \*All angles depicted are absolute values of the distributions measured.

## Summary

1. When all visual input is removed, *P. americana* can still successfully track female pheromone upwind to its source.
2. When the olfactory environment is altered (i.e., a wider plume), *P. americana* with diminished visual input can still successfully track female pheromone to its source.
3. Together our results indicate that visual input is not required for this task. Our hypothesis is NOT supported by our results.

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