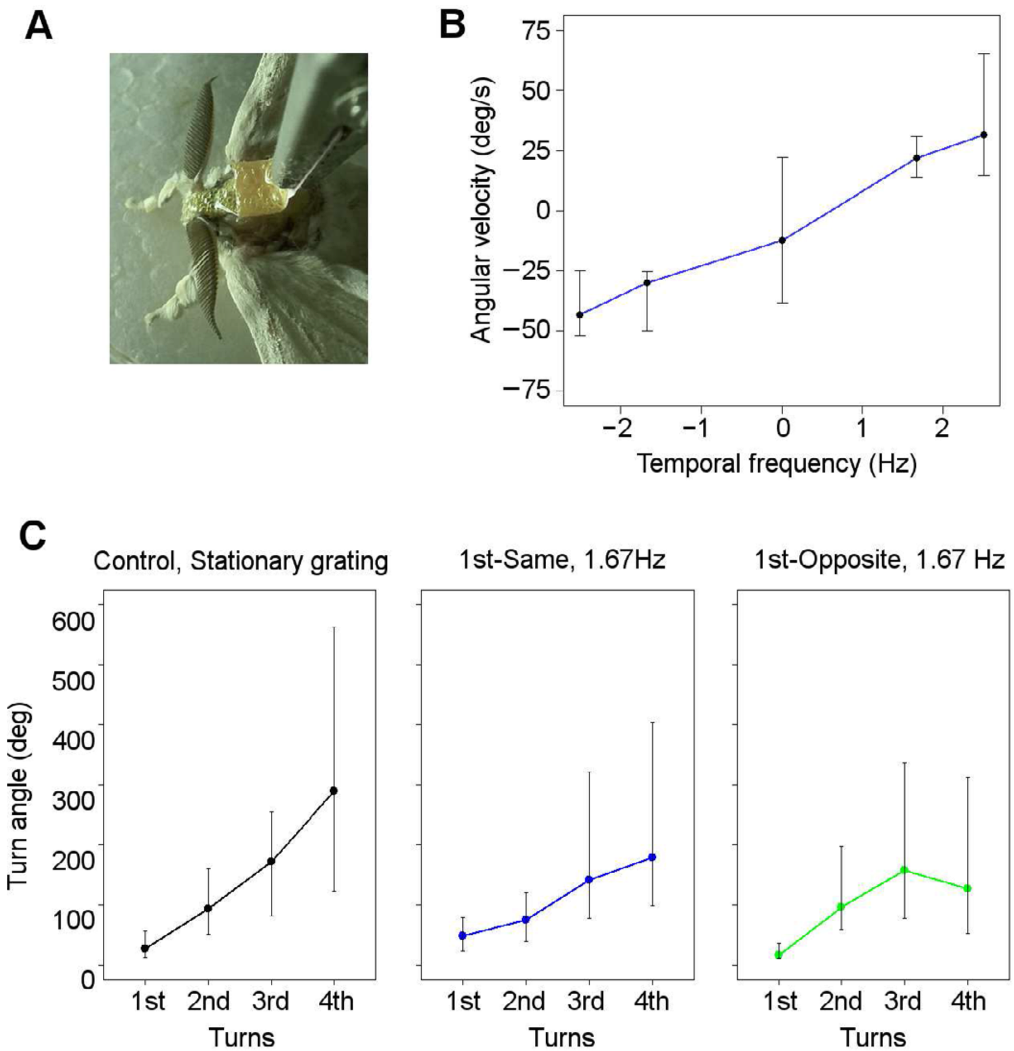

Fig. S1. Results from the experiment with a head-fixed moth. (A) Head-fixed preparation. The head and prothorax of the silkmoth were glued together to fix head movement. The same open-loop experimental procedure for normal moths was conducted on head-fixed moths. (B) The behavioural response during the surge of a head-fixed moth to constant optic-flow. Similar to a normal moth, the head-fixed moth elicited an optomotor response during the surge. (C) The behavioural response of the head-fixed moth during zigzag in response to 1.67 Hz constant optic-flow after being stimulated with a single-pulsed pheromone. Results from both experimental groups (C, middle and right) showed a consecutive increase in turn angle, which was similar to the response of the control group. Although the results in the experimental group whose first turn was to the direction opposite to constant optic flow (1st-Opposite) showed a slightly decreasing turn angle in the fourth turn, it did not explicitly imply that the behavioural response was different from normal moths or the control group, as variations in fourth turns are normally large. Furthermore, we did not find any modulation in the experimental group whose first turn was to the same direction as constant optic flow (1st-Same). Therefore, we assumed that there was no visual modulation during zigzag in the head-fixed moth and that the behavioural response was considerably similar to that of a normal moth. In A and B, dots represent median of samples, lower and upper limits on error bars represent 25th and 75th percentiles, respectively. Kendall's tau-b correlation coefficient between the order of the turn and the rank of the turn angle by size in the control, 1st-Same and 1st-Opposite groups were 0.81***, 0.40*** and 0.35**, respectively (**$P < 0.01$; ***$P < 0.001$), suggesting that the size of the turn angle significantly increased with the order of the turn in both the control and experimental trials, although the correlation coefficients measured in the experimental trials were lower than that measured in the experiment with normal moths (Table 1).

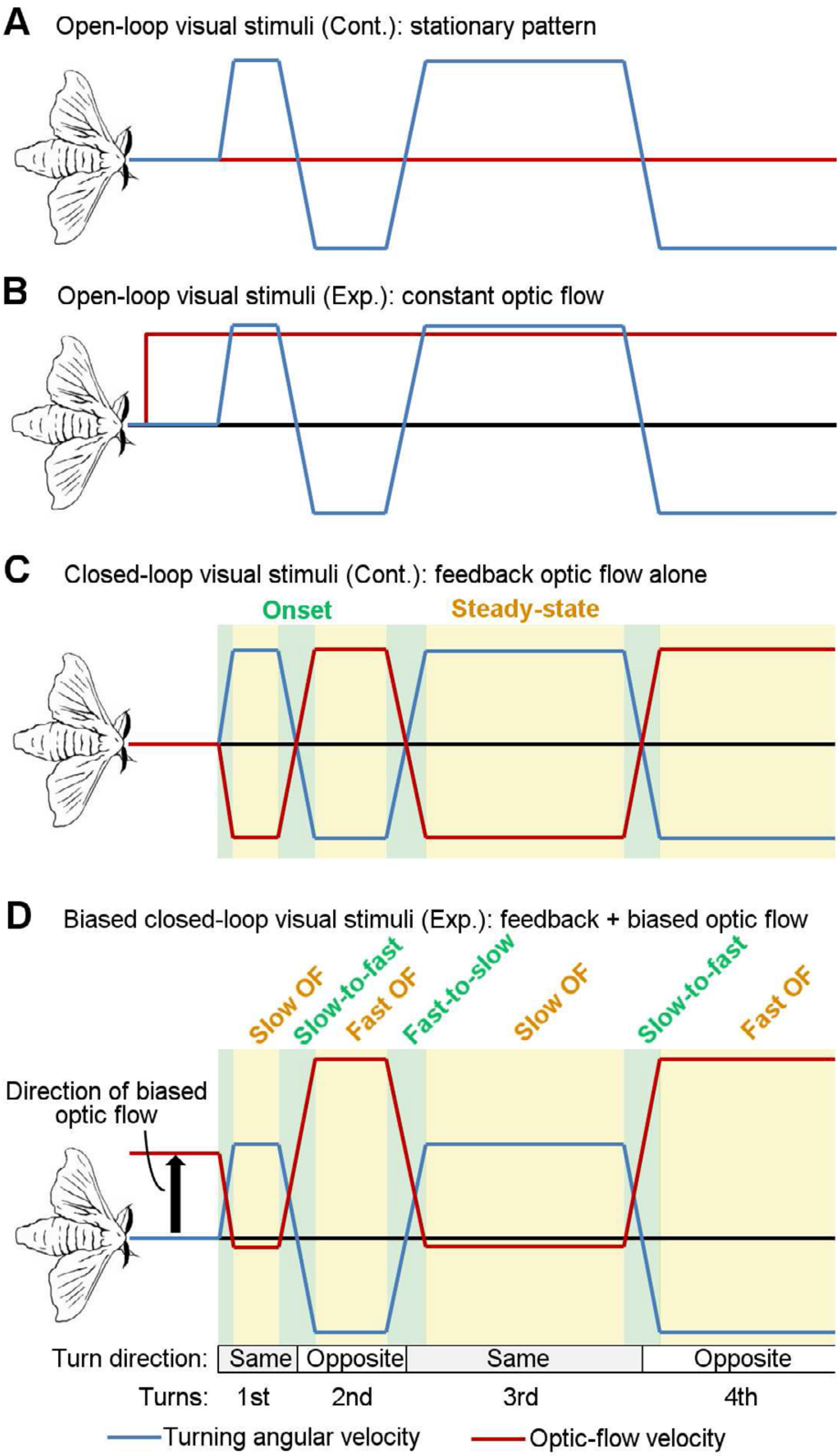

Fig. S2. Schematic plots for optic flow velocity during experiments with open- and closed-loop visual stimuli. (A) Open-loop visual stimulus for control trials (cont.). A stationary grating pattern was presented (red line, optic-flow velocity is zero). A positive value represents turning to the left, and a negative value represents turning to the right. (B) Open-loop visual stimuli for experimental trials (exp.). Optic flow with a constant temporal frequency was presented. (C) Closed-loop visual stimuli for control trials. Feedback optic flow with a unity gain, comprising transient (yellow) and relatively constant optic flow (green), was presented. (D) Biased closed-loop visual stimuli for experimental trials. Due to the biased optic flow (to the left), optic flow velocity became slower when the moth turned to the same direction as biased optic flow (to the left) and became faster when it turned to the opposite direction (to the right). There were two states of steady-state optic flow: fast and slow optic flow (OF), and there were two states of onset optic flow: slow-to-fast and fast-to-slow.

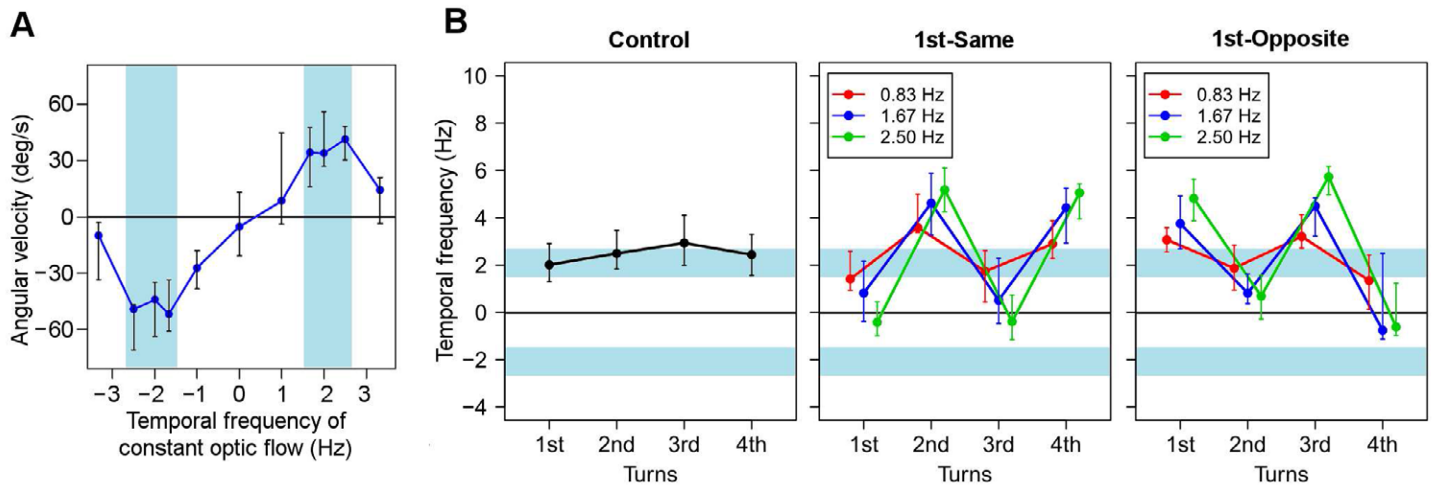

Fig. S3. Temporal frequency of optic-flow in experiments with biased closed-loop visual stimuli. (A) Temporal frequency tuning curve of turn angular velocity during surge in the experiment with open-loop visual stimuli (adopted from Fig. 3A). Assuming that the magnitude of angular velocity in the tuning curve corresponds to the strength of visual input to silkmoths, its maximum is achieved by optic flow stimuli with temporal frequencies ranging from ±1.5 to ±2.5 Hz (blue-shaded area). Positive or negative values indicate optic flow direction, negative for right and positive for left. (B) The temporal frequency of optic flow stimuli during each turn in the experiments with biased closed-loop visual stimuli. Positive values indicate the opposite direction to corresponding turns and negative values indicate the same direction as turns. In the control condition, which was only comprised of feedback optic flow, its temporal frequency mostly fell into the blue-shaded area corresponding to the peak of the tuning curve in A. In contrast, temporal frequencies of accelerated or decelerated biased optic flow due to self-motion (1st-Same and 1st-Opposite) fell outside the blue-shaded area, except for the experimental groups with 0.83 Hz biased optic flow, suggesting that the accelerated and decelerated optic flow were not perceived as strong visual inputs to the moths. 1st-Same, experimental groups whose first turn is to the same direction as biased optic flow; 1st-Opposite, experimental groups whose first turn is to the direction opposite to biased flow. Dots represent median of samples, lower and upper limits on error bars represent 25th and 75th percentiles, respectively.

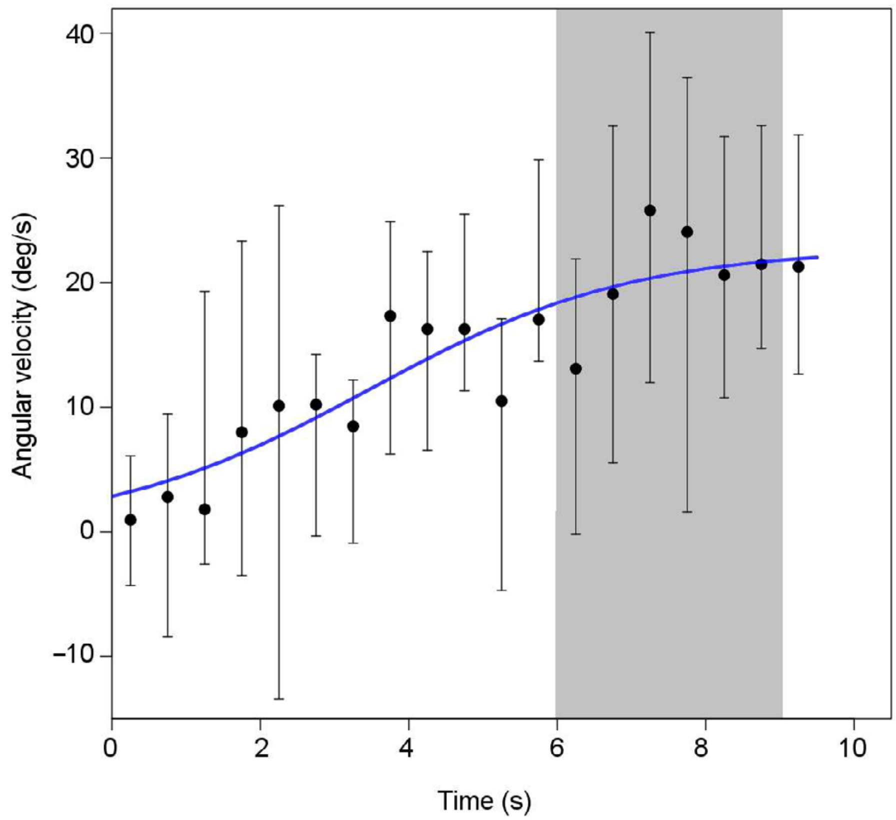

Fig. S4. Relationship between angular velocity and duration of continuous-pulsed pheromone stimuli (N = 15) measured in the biased closed-loop experiment. Pheromone pulse train onset was at 0 s and lasted for 10 s. Temporal frequency of biased optic flow (OF) was set to 2.50 Hz (move to the left) for all samples. Dots represent median of samples, lower and upper limits on error bars represent 25th and 75th percentiles, respectively. Silkmoth activity was triggered by the pheromone stimulus and angular velocities of turning increased gradually until they reached a steady-state at approximately 6 s. Absolute turn angle during 6−9 s (grey shade) were used in our analysis to calculate angular velocity of silkmoths during the surge.

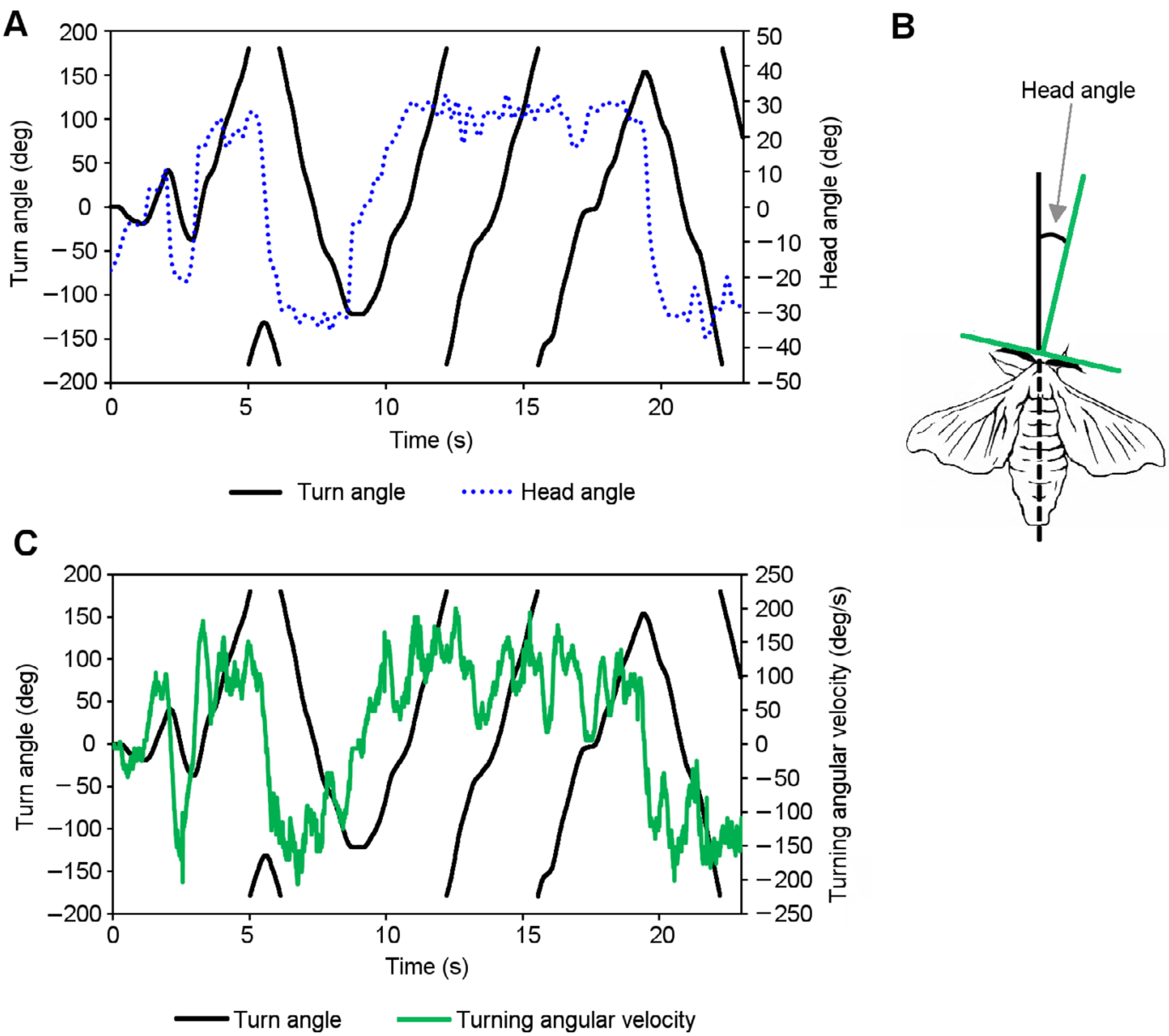

Fig. S5. One trial of silkmoth's locomotion and head angle. The silkmoth's behaviour was triggered by single-pulsed pheromone stimulus with a 1 s duration and onset at 0 s. The visual stimulus was a stationary pattern. A short-lived surge was followed by successive zigzag turns. (A) Plots of turn angle and head angle of a silkmoth during walking. Black line represents the turn angle of the moth detected by the optical mouse. The blue dotted line represents the head angle deviated from the centre (B) manually measured from a movie recorded by a video camera (GZ-MG275, Victor Co. of Japan, Kanagawa, Japan), which was positioned over the experimental apparatus. Head angle was measured every 200 ms. (C) Plots of turn angle and angular velocity of the silkmoth. In A and C, positive turn angle represents turning to the left, and negative value represents turning to the right.

Movie 1. The experiments with single-pulsed pheromone stimuli under four different visual stimuli conditions.