Research Articles

Threshold and directional sensitivity of air-current-sensitive giant interneurons of a cricket

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Summary. Some of the directional characteristics of air-current-sensitive giant interneurons (GIs) of a cricket were investigated by using an exactly defined unidirectional air-current stimulus. In each GI, the velocity thresholds for the stimulating air-current in two different directions were measured, using various time-courses of the velocity change (frequency). Each GI showed identical velocity threshold curves, depending on the stimulus direction.

Key words. Cricket; air-current sense; cercus; giant interneuron; directional sensitivity.

Crickets and cockroaches have a pair of appendages called cerci at the tip of the abdomen. The cerci are equipped with a large number of filiform hairs sensitive to air-motion[1,2]. Air-fluctuation, such as is caused by the motion of a predator, is detected by the hairs and the information is transmitted to several GIs in the terminal abdominal ganglion via the filiform afferents[3,4]. The axons of GIs extend from the terminal abdominal ganglion at least to the thoracic ganglia. The information carried by the GIs eventually flows into the leg motor system[5,6] and mediates the escape behavior of the insects[7,8]. It is a characteristic of such escape behavior that the insects usually run away from the stimulus source[7,11]. Obviously, the sensory system can recognize the direction of the air-current, i.e. the direction of the stimulus source. In this study, I quantitatively investigated some of the directional characteristics of GIs of a cricket, *Gryllus bimaculatus*, by using a unidirectional air-current stimulus. The air-current stimulus was produced by a wind-tunnel stimulator consisting of a pair of push-pull driven loud-speakers set one at each end of an acrylic tube[2,5,9,10]. This wind-tunnel ensured precise control of the air-current velocity and of its rate of change.

As shown in figure 1A, an electrical signal was fed to the moving coils of the two speakers, which were connected in series so that they moved in antiphase (push-pull fashion). The signal started from the bottom of a cosine wave. When it reached the peak of the wave (180 degree; 1/2 cycle) the signal was held at that level during 500 ms. As the speaker displacement is proportional to the driving signal, a unidirectional air-current is produced in the tunnel (velocity of the air-current is shown in fig. 1B). The fundamental frequency (note that a whole cycle was not used) and the amplitude (i.e. velocity of air) could be controlled separately[9]. The signal returned to the initial level after being held steady for 500 ms. However, this returning phase was not used for the threshold measurement because it was not specifically controlled.

A decapitated cricket was mounted in the tunnel and the responses of GIs were intracellularly recorded from the right ventral nerve cord at the point where it just left the terminal abdominal ganglion. Velocity thresholds of the GIs, defined as the minimum peak velocity of the stimulus air-current required to elicit an action potential, were measured at various frequencies (2–100 Hz), and threshold curves were obtained. After the physiological investigations, the fluorescent dye lucifer yellow, which was placed in the glass microelectrode beforehand, was iontophoretically injected into the GIs for morphological identification. The experimental procedures were the same as those described in a previous paper[9].

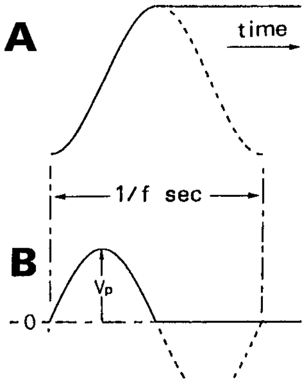

Figure 1. *A* Electrical signal driving the speakers. This wave form also expresses the time course of speaker displacement (i.e. air motion) because it is proportional to the driving signal. The two speakers, facing each other, were connected in series so as to move in antiphase (push-pull fashion) to make a unidirectional air-current. Dashed line shows one whole cycle of the fundamental cosine wave. f, frequency. *B* Velocity of air-current in the tunnel when the speakers were driven by the signal as in A. V_p, peak velocity of the air-current.

Velocity thresholds of the previously identified GIs 8-1 (MGI: medial GI), 9-1 (LGI: lateral GI), 9-2, 9-3, 10-2 and 10-3[9] were measured. In the experiments, two directions of stimulus air-current parallel to the body axis were employed; from anterior to posterior and from posterior to anterior (inset in fig. 2A). The inter-stimulus interval was 2 s.

8-1 (MGI): The threshold curves of 8-1 (fig. 2A) show that this GI is more sensitive to the air-current from posterior to anterior than to that from anterior to poste-

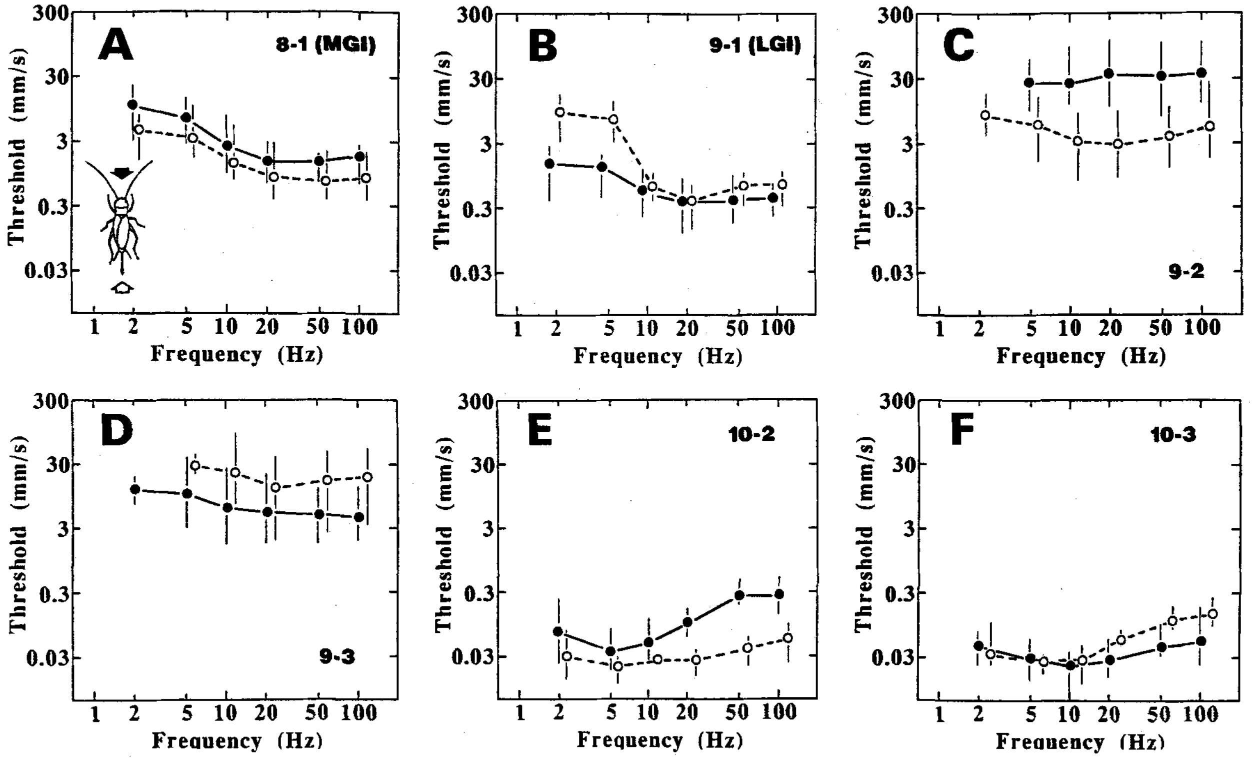

Figure 2. Threshold curves of GIs 8-1 (A), 9-1 (B), 9-2 (C), 9-3 (D), 10-2 (E) and 10-3 (F). Arrows in the inset in A indicate the directions of the stimulus air-current used in this study, and correspond with the symbols of the threshold curves, i.e. filled dots for air-current from anterior to posterior as indicated by the filled arrow, and vice versa. Data points are at 2, 5, 10, 20, 50 and 100 Hz. Numbers of animals used are 10, 7, 6, 9, 4 and 4 in A, B, C, D, E and F respectively.

rior by about 7 dB, over the whole range of the stimulus frequencies used (2–100 Hz). In the low frequency range (2–20 Hz), both curves show a slope of about –20 dB/decade. This means that the GI is sensitive to the acceleration of air-currents in both directions[9].

9-1 (LGI): The GI 9-1 is more sensitive to the air-current from the anterior than to that from the posterior direction (fig. 2B) especially in the low frequency range (2–5 Hz; the threshold difference is about 20 dB).

9-2: The GI 9-2 shows quite different threshold curves for the air-currents in the two directions used (fig. 2C). The GI is more sensitive to the air-current coming from the posterior than from the anterior direction by about 20 dB. The threshold curve for response to the air-current from anterior to posterior is almost parallel to the abscissa. This means that the GI is sensitive to the velocity of the air-current in this direction[9].

9-3: The GI 9-3 is more sensitive to the air-current from anterior to posterior than from the opposite direction. The two threshold curves are almost parallel with each other and the threshold difference is about 10 dB (fig. 2D).

10-2: The GI 10-2 is more sensitive to the air-current from posterior to anterior (fig. 2E) and is velocity-sensitive to the air-current in this direction.

10-3: This GI is velocity-sensitive to the air-current in the anterior to posterior directions (fig. 2F). In the high frequency range (20–100 Hz), the GI is slightly more sensitive to the air-current from the anterior than from the posterior direction.

The results demonstrate that all the GIs show threshold curves or sensitivities depending on the direction of the stimulus air-current, i.e. the GIs 9-1, 9-3 and 10-3 are sensitive to the air-current blowing from anterior to posterior, and the GIs 8-1, 9-2 and 10-2 are sensitive to the air-current blowing from posterior to anterior. In crickets, the combined activity of GIs with different directional sensitivities could play a significant role in recognizing the direction of the stimulus source. For further understanding of the neural mechanism by which the crickets recognize the direction of the air-current, the investigations are being extended by using air-currents in other directions.

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