The hearing of cricket parasitoids: *Ormia ochracea*

**Sources:**

**Introduction**
Most species of fly (true flies, Diptera) rely heavily on vision and have elaborately developed eyes. Sound is less important but most flies do have specialized hearing organs: Johnston’s organs (antennae). And like other arthropods they have trichoid sensilla widely distributed on their body surface. Both Johnston’s organs and hair sensilla are sound detectors but they operate only in the near field in response to particle velocity. Parasitoid flies of the genus *Ormia* (Tachinidae) are unusual then, in having ears that respond to pressure and in the far field and extract directional information in a radically different way.

As adults *Ormia* females seek out a singing male field cricket by flying and walking and deposit on this host an active larva. The tiny larva penetrates to the haemolymph cavity of the cricket and develops there over the next week in the still-living cricket. It emerges and pupates on the ground and then the adult emerges from the pupa. The cricket’s death coincides with emergence of the parasitoid.

The phonotaxis (oriented locomotion guided by a sound) of the fly is far different than that seen (for example) in crickets: the fly immediately runs almost straight toward the source; whereas cricket females engaging in oriented locomotion toward a conspecific male singer will follow a zig-zag path, turning to the right and then back to the left, back and forth within 60 degrees, as if successively over-correcting. And as those who study cricket phonotaxis know too well, crickets are rather diffident about showing responses. Not so the flies: their phonotaxis is direct and immediate.

All of the problems which attend small animals detecting long sound wavelengths are experienced in maximum severity by the flies. They must localize the source of a calling sound wavelength of 5 kHz, (calculate the wavelength in cm) but their ears are only 0.5 mm apart. No bilateral interaural intensity differences are measurable across this intervening distance. And the binaural time of arrival differences (which in fact the flies use) are occurring within microseconds.

The front aspect of the thorax of the fly bears a pair of eardrums; these meet in the midline and are very low mass in life (light and flimsy), responsive to air pressure (i.e. typical tympana). There is a small skeletal element of cuticle called the cuticular bridge which spans the midline and is embedded in these right and left tympana. A group of sensory neurons attaches at each of the opposite ends of this bridge. The bridge couples the two eardrums together mechanically. The mid-line joint of the bridge allows it to flex in the middle. Sound activating the eardrums causes a complex movement of these structures and small time of arrival differences arising from differing angles of the fly to the sound source are converted into differences in amplitude of movement of ear surfaces and differences in the right and left firing sequence of the right and left neurosensory groups (about 100 auditory receptor neurons in each group).

Polar plots of ear response involve plotting the size of ear response (firings of neurons) as a function of all the angles of the circle: the farther the line is plotted from the origin (where the fly is located) the more effective the source is from that direction.

Bioassay experiments with the flies to determine their localization accuracy: the fly was tethered to a Fliegenkugel (on top of an extremely light (ping pong) ball) floating on air; the walking of the fly turns the spotted ball and the computer monitors the moving spots to provide a trace of the path the fly is trying to follow. Percent correct turns on the y axis are plotted against the angle of incidence of the sound (in degrees) on the x axis: they are more than...
90% accurate at 10 degrees or greater.

Lateralization means to decide upon right vs left and is not the same thing as localization. If the source is more than 30 degrees off straight ahead the fly is not tracking it... it merely knows the source is to the right and turns right or to the left and turns left... i.e. this is lateralization. It turns faster and harder the farther a sound source is located to the side of straight ahead. If the source is within the anterior 60 degrees then localization (tracking) is taking place.

The ears of the fly are only 0.5 mm apart; the time difference resolved is 50 nanoseconds!!!
The neurosensory neurons (auditory receptor neurons) don't fire bursts of action potentials as is typical of such cells. Rather they give a single action potential at sound onset... in other words they show the start very precisely and then stop in order not to present ongoing 'noise' that would hinder the marking of the time difference by the nervous system.

Each cell makes one spike with a highly invariate delay time; but the population of cells have different firing latencies creating a normal distribution of firing latencies. The latency of the group of receptors varies with intensity: to louder sounds the latency is shorter. The sound receptor ipsilateral is earlier in response than contralateral to eccentrically located sources. The collective response curve shifts depending on intensity.

How does this auditory system represent direction? Ipsi vs contra for 90 degree located sound source; receptors pooled for hyperacuity and this removes jitter in receptors.
This research has led toward development of a new type of microphone.
Cicada-hunting parasitoids are in a different fly family: but ears are working by the same principle, an example of convergence.