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FASTER THAN A FLASH: THE FASTEST VISUAL STARTLE REFLEX RESPONSE IS FOUND IN A LONG-LEGGED FLY, *CONDYLOSTYLUS* SP. (DOLICHOPODIDAE)

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Recently, fast reflex responses of skipper butterflies (Hesperiidae) to the photographic flash were reported and were found to be among the fastest ever recorded (<17 ms)—comparable to the fastest reflexes of the vertebrates (Sourakov 2009). Using a similar photographic technique, but a faster and more precise camera, even faster response times were found in *Condylostylus* flies (Diptera: Dolichopodidae). This new record reported here undoubtedly constitutes the fastest reflex response of a member of the animal kingdom ever recorded.

The observations were made in the Natural Teaching Laboratory, a forested area on the University of Florida campus, Gainesville, Florida. A *Condylostylus* sp. was photographed with a Canon EOS camera the built-in flash at a shutter speed of $1/200$ s = 5 ms. Photographs in Fig. 1 were taken with an interval of ca. 20 s within a 4-min period. The fly, startled by the flash, was able to take flight 9 out of 10 times before the image was taken. As a result, the fly's image was repeatedly captured in flight (Fig. 1). The fly's visual startle reflex caused by the flash had a latent period of less than 5 ms and, perhaps, only 2 ms. Some habituation can occur as evidenced when the camera was fired consecutively 4 times: the fly did not react to the fourth flash and hence the fly remained in a resting position (Fig. 1D). However, the fly quickly recovered and continued reacting to the flash 20 s later. No other species of insects photographed during the same time in the same location with the same equipment, have exhibited similar behavior, which leads to conclusion that this extraordinary reaction time is particular to the long-legged flies.

While earlier studies considered startle reflexes to be particular to mammals, Hoy (1989) stated that "all behaviors that have survival value are likely to be found in all animals facing similar problems." For many insects, a quick escape by crawling or flying is the primary mode of defense. When moths react to the ultrasound produced by bats (Order Chiroptera), this evading behavior can be classified as an acoustic startle response (Hoy et al. 1989). The response latencies in noctuid moths (*Feltia* spp., *Leucania* spp., *Amathes normaniana* Grote, *Agrotis ypsilon* Rottemberg, *Ochropleura plecta* L. and *Euxoa obelis-*

coides Gueneé) are very short, on the order of tens of milliseconds (Roeder 1967). Mechano-receptive hairs on tail appendages of a cockroach, *Periplaneta americana* L., detect the change in air pressure caused by a fast approaching object, and can trigger an escape response in less than 50 ms (Camhi & Tom 1978). House flies, *Musca domestica* L., have a similar reaction time of 30–50 ms to a visual threat (Holmqvist 1994). The startle reflex of *Condylostylus* fly most certainly constitutes the fastest in insects, as it is 3–10 times faster than the previously reported reflex response times.

Considering a great variety of insect species (estimates range between 2 and 30 million species) it is not surprising that the fastest escape response time should be found in that particular group of animals. However, many insects rely on camouflage, living in shelters, thick exoskeleton with sharp spines, venomous bites, and toxic substances for defense. Defense by fast escape response can be costly to maintain, as it assumes a very high metabolic rate as well as constant alertness, which for a cold-blooded animal can be problematic. Skipper butterflies and dolichopodid flies—as different as they are—both have a habit of perching openly on the upper surfaces of leaves in sunny areas of forests. This allows them to attract mates and repel competitors by territorial behavior, but it also makes them obvious prey for birds.

Capturing these insects can be very difficult, whether for the entomologist with a net or for a bird, because of their rapid escape responses. The *Condylostylus* flies and some of the very fast species of skipper butterflies possess bright metallic colors. Why would animals that are not chemically defended advertise themselves so openly to potential predators? The explanation may lie (as suggested by Daniel Janzen, pers. comm.) in the ability to escape repeatedly from predators, and thereby instill in the memories of predators the learned reflex of avoiding this particular prey. Just like yellow-and-black coloration signals the poisonous nature of their certain prey to birds, the bright metallic colors probably became a sign of fast escape response. In nature, these energy-saving signals are beneficial to both prey and predators; and hence these related



Fig. 1. The response to a visual startle reflex caused by a photographic flash exhibited by a long-legged fly, *Condyllostylus* (Dolichopodidae). All photographs except (D) show the fly jumping in the air when the flash was fired with 20 second intervals. (D) shows that habituation had occurred on the fourth firing of the flash, but the reflex response resumed 20 seconds later. Reflex response time is <5 milliseconds. Photos by A. Sourakov.

behaviors tend to co-evolve in a number of species. The fact that the bright coloration occurs in a variety of fast-flying insects supports this hypothesis. Metallic, vibrant colors, similar to those of dolichopodid flies, are also found in other fast-flying insects, such as hairstreak butterflies (Lepidoptera: Lycaenidae: Theclinae), orchid bees (Hymenoptera: Apidae: Euglossinae), cuckoo wasps (Hymenoptera: Chrysidae), and some fast flying skippers (e.g., *Astraptes* (Lepidoptera: Hesperidae)). Other metallically colored insects with fast escape responses include leaf beetles (Coleoptera: Chrysomelidae), which do not have fast flight, but have either fast hopping escape responses or fast “play-dead” re-

sponses. It would be very interesting to test if a mimicry complex exists among metallically colored insects, where mimics take advantage of fast escape responses developed by models and capitalize on their success without having to invest in the development of their own fast escape mechanism.

SUMMARY

An extremely fast escape response time of less than 5 milliseconds was found in a long-legged fly of the genus *Condyllostylus* (Dolichopodidae). This response to a visual startle reflex caused by a photographic flash was recorded repeatedly on camera and the synchronized shutter speed made it possi-

ble to measure the reflex time. Habituation was also observed in these trials. This newly recorded reflex is 3 times faster than any other previously reported.

On 30 March 2011, an opportunity arose to measure the speed of reaction of another *Condyllostylus* sp. in the same location using the same technique and equipment, and the results were very similar to those reported here.

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