Jumping spider uses fuzzy eyesight to judge distance

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Anterior view of the jumping spider, Hasarius adansoni. A pair of principal eyes is located at the anteromedial area of the body, lying between two lateral eyes. Image © Science/AAAS

(PhysOrg.com) -- One of the ways in which humans determine distance is by estimating the sharpness of an image—closer objects produce a sharp image, while those further away are out of focus. For us, this is a minor additional method of judging distance, but now scientists in Japan have for the first time found an animal that appears to use this method as its primary means of depth perception.

Adanson's jumping spider (Hasarius adansoni) captures prey by jumping from a distance. The question that has puzzled scientists is, how do their eyes allow them to perceive depth? Their front eyes do not give them the two distinct but overlapping views needed for binocular vision, used by humans. They also do not use the motion parallax many insects use, since their head remains motionless when they are about to jump. (Motion parallax is a system in which the animal moves its head from side to side so that close objects move further across the field of view than those further away.) Now the new study reveals that the spiders use an image defocus system to enable them to judge distances.

Adanson's jumping spider has excellent eyesight, provided by eight eyes: a pair of primary eyes (large and at the front), two anterior lateral eyes, one at either side of the primary eyes and also facing forward, and two smaller pairs of eyes on the top of their heads, one of which is almost undetectable by the naked eye.

The research team, led by Takashi Nagata, from Osaka City University, blocked the anterior lateral pair of eyes of the jumping spider and found that they use this smaller pair of eyes to detect motion, but blocking their vision had no effect on the spider's ability to judge distance.

It has been known since the 1980s that the retinas in the principal eyes in jumping spiders have a unique structure that is shaped like a staircase, and they contain four layers of photoreceptors rather than one layer, as human eyes have. The new study revealed that the two deeper retinal layers contain pigments sensitive to green light and the two layers closest to the surface contain pigments sensitive to ultraviolet light. Of the two layers most sensitive to green light, only the deepest receives focused images, and the other receives an out of focus image.

To test the idea that the spiders could judge depth from the amount of defocus in the second green pigment layer, the researchers placed spiders one at a time in a container, along with some fruit flies and then tested their ability to catch the flies under red and green lights.

The results showed that green light was necessary for accuracy since the spiders were able to judge their jumps successfully in green light, but often misjudged in red light (which does not contain the shorter wavelength green light). The researchers also created a mathematical model to predict how far off the jumps would be under different wavelengths of light, and found that the model did accurately predict the spiders' performance.

The researchers concluded that the spiders were indeed using the extent of defocus in the second green pigment layer of the retina to judge distance, and they are the only known animals to use this system as their primary means of depth perception. Since other jumping spiders have the same type of retina, they may also use the same method.

In a paper published in the journal *Science*, the researchers conclude that further study of the vision system used by jumping spiders is necessary and that it could have applications in robotic and other computer vision systems.

More information: Depth Perception from Image Defocus in a Jumping Spider, Science 27 January 2012: Vol. 335 no. 6067 pp. 469-471. DOI:10.1126/science.1211667

ABSTRACT
The principal eyes of jumping spiders have a unique retina with four tiered photoreceptor layers, on each of which light of different wavelengths is focused by a lens with appreciable chromatic aberration. We found that all photoreceptors in both the deepest and second-deepest layers contain a green-sensitive visual pigment, although green light is only focused on the deepest layer. This mismatch indicates that the second-deepest layer always receives defocused images, which contain depth information of the scene in optical theory. Behavioral experiments revealed that depth perception in the spider was affected by the wavelength of the illuminating light, which affects the amount of defocus in the images resulting from chromatic aberration. Therefore,

we propose a depth perception mechanism based on how much the retinal image is defocused.