Indian Institute of Technology Kanpur

SE367A Cognitive Science Course Project

Integration of Monocular Cues in Depth Perception of Short-horned Grasshoppers

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Abstract

Most species of grasshoppers use motion parallax to compute depth of object by exhibiting the stereotype peering behavior. Although monocular depth cues from one eye should be sufficient for depth perception, it has been shown that occlusion of one eye adversely affects the depth perception of grasshoppers. Here we show that monocular depth cues coming from each eye are integrated by the grasshopper and that the occlusion of one eye leads to reduction of peer amplitude by a factor of two. It can be hypothesized that the neural circuitry involved in the computation of depth performs simple averaging on the monocular cues from the compound eyes to provide the animal with an accurate sense of depth.

1 Introduction

Short-horned grasshoppers (family Acrididae) are agile insects that show interesting visual responses. These insects are adapted to accurately gauge depth and evade predators by swiftly jumping through grassy patches.

Fig1.Short-horned grasshopper

The grasshopper visual system consists of two compound eyes and three simple eyes (the ocelli). The compound eyes are made up of numerous visual cells known as ommatidia which collectively form images, while the ocelli provide information about the ambient light intensity.

The compound eyes are far apart on the head providing a large monocular field of vision, as expected for an organism that needs to keep track of approaching predators. A small portion of the visual field is binocular wherein the visual fields of both compound eyes overlap. To accurately calculate the depth of an object that exists beyond the binocular field of vision the grasshopper relies on motion parallax. As an observer moves the objects that are nearer move farther across the field of vision than do objects that are at a distance, this phenomenon is known as motion parallax. By moving its head about its body axis in what is known as peering behavior, the grasshopper exploits motion parallax to compute object distances. Each eye carries the retinal image disparity information resulting from the head movement, which is then used to compute the distance of an object .

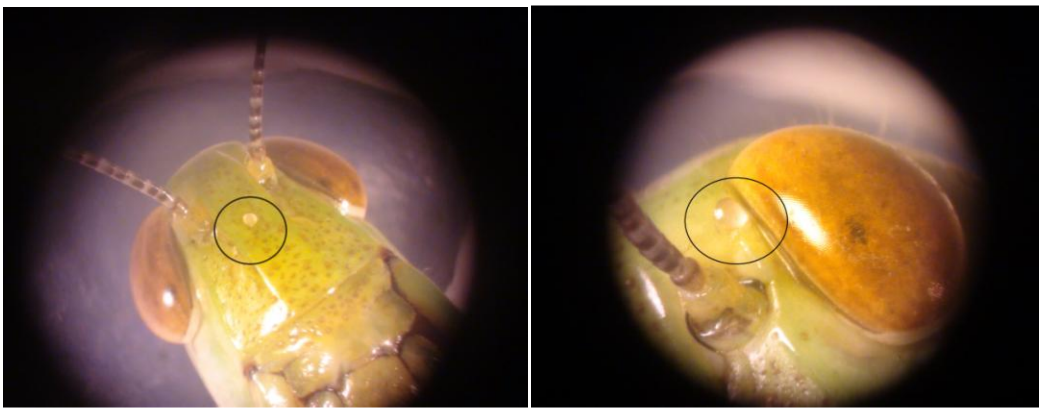


Fig2.Frontal view: Two Compound eyes(median ocellus circled) Side View: Compound eye (lateral ocellus circled)

2 Peering Behaviour

Motion parallax is the phenomenon in which an observer's translational motion through a stationary environment results in the perception of apparent motion of the objects in the environment. It is due to this phenomenon that we see the trees move swiftly while the mountain at a distance appear to move slowly, while travelling in a vehicle. The apparent motion of a particular object depends on its distance from the observer and the extent of the observer's motion. Closer objects appear to move faster and farther than more distant objects.

Due to the characteristics of the compound eyes, motion parallax is widely believed to be the dominant visual cue for perceiving distance among arthropods. The most readily observed example of behaviour used to obtain motion parallax is the peering behaviour seen in locusts and grasshoppers.
When presented with a visual stimulus, the grasshoppers perform a loosely stereotyped behaviour in which it sways its head and body from side to side while pivoting about the tip of the abdomen. Locusts typically perform several peers at a potential target and may change body orientation towards another target and begin peering again. Peering becomes intense immediately prior to jumping and precedes all directed jumps.

Peering behavior is a behavior of choice for studies in insect depth perception, due to its high reproducibility and ease of quantification. We wish to study the effect of occlusion of one eye on the peering behaviour and thus ascertain the contribution of the compound eyes in the exhibition of this behaviour and the computation of depth.

3 Methods

Wild grasshoppers were caught mostly from the academic area and hall gardens and put in plastic containers. They have to be captured before the winter, since most of them do not survive the winters. All the grasshoppers were fed moist fresh grass blades three times a day.

Blinding the grasshopper:
Compound eyes of the grasshoppers are covered with special protective layer which restricts the application of permanent markers and sketch pens. In order to make one of the eyes completely opaque, a layer of Fevicol™ is applied and left to dry till the layer becomes completely firm. When the layer dries up, it is covered with a permanent marker which ensures that no light enters the eyes of the grasshoppers.
Unlike human eyes that have moist outer layers, insect eyes are dry and tough. The layer flakes off after few hours, hence the blinding is temporary.

Fig3.Grasshopper with one eye occluded

Apparatus:

The apparatus is a cardboard box of base dimension **45**X**70**cm and height **35**cm with all the inner surfaces covered with white paper. A circular platform of diameter **4.5**cm is placed in a cylindrical container which is filled with water. The platform is placed such that it just touches the water surface. Two light sources are used to light up the entire arena: one source is placed at the top while the other is placed behind the animal. This is done in order to ensure uniform lighting conditions inside the arena. A black cardboard piece of dimension **10**X**6**cm is used as a stimulus which is placed vertically on a movable platform and set at specific distances of 10 and 30cm from the circular platform.

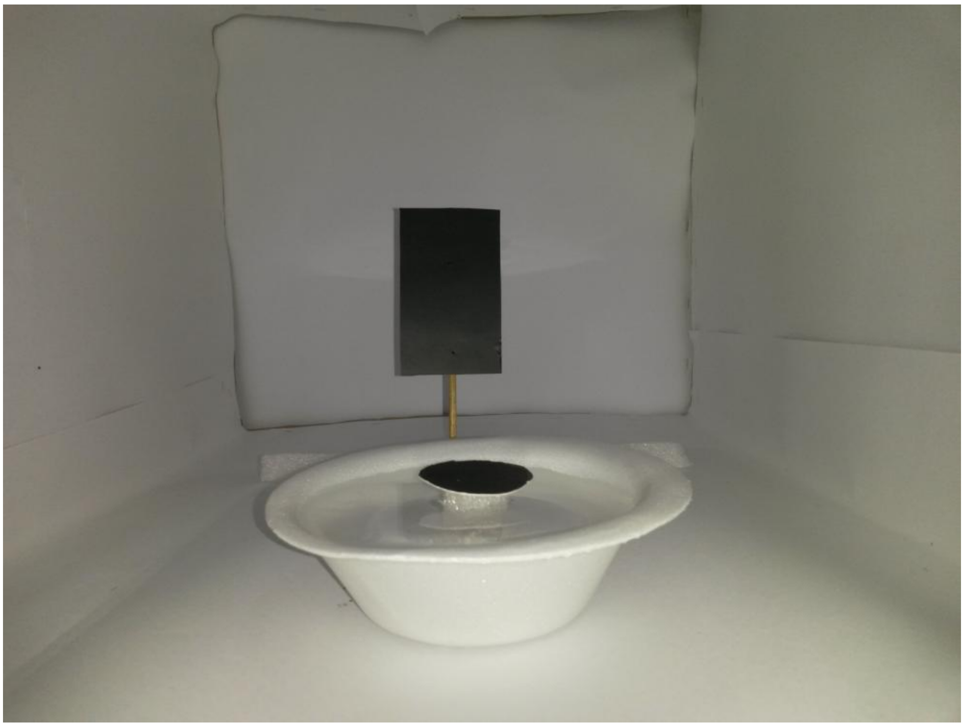
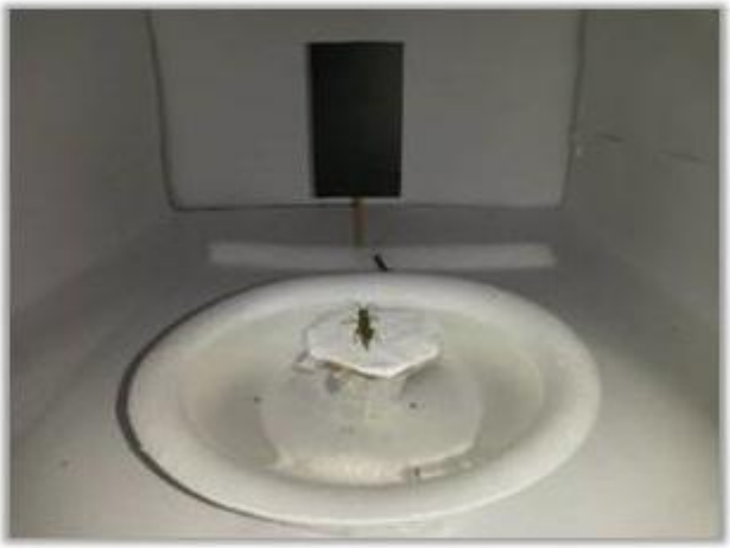


Fig4.The Experimental Apparatus

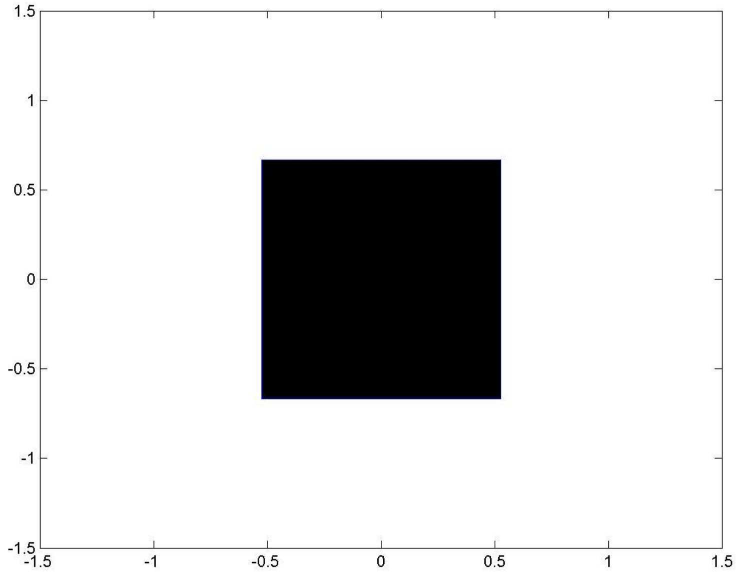
Experimental Paradigm:

The insect is placed on the platform slowly using a stick. When introduced to the novel environment, the insect spontaneously peers repeatedly at the target due to the lack of other prominent features in the environment. Also it has been observed that the grasshoppers are attracted to contrasting edges which in our case results from the black rectangular stimulus placed against the white screen. However, to induce peering the insect can be poked gently with a stick. A video camera is placed directly above the insect which records its motion. The peering motion is then characterized using these videos. For better results, a digital stimulus was used. A screen (tablet) was used to show an image of a square with a white background, thus making the stimulus more prominent. Square of appropriate size was made using MATLAB.

The videos were analysed using the open source Tracker Video Analysis and Modelling Tool. Peer amplitude was calculated for all the peers that were exhibited.


View from one end of the box


View from above the animal

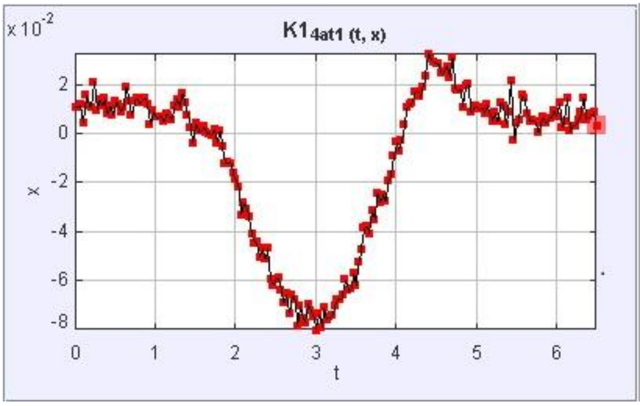


Digital Stimulus

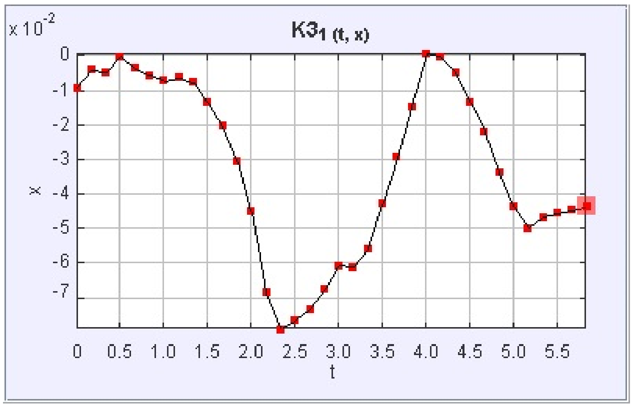
A total of two insects(Animal A and Animal B) were studied for two stimuli distances of 15cm and 30cm from the platform without blinding one of its eyes. The experiment was repeated for each animal after occluding one of its eyes with the black layer.

4 Results

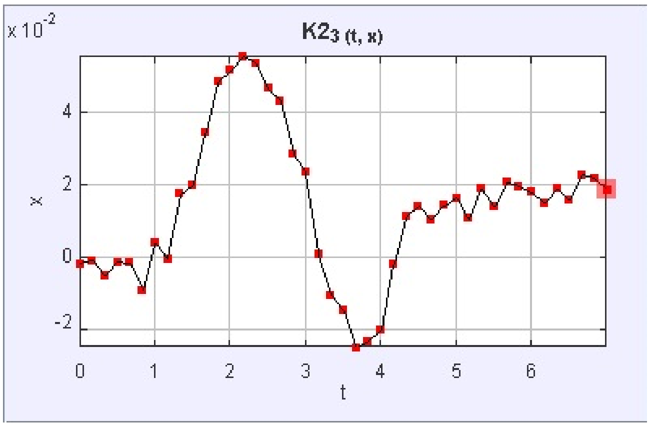
We present results showing the amplitude of peering plotted for the two animals and the two stimulus distances once under normal conditions(Binocular) and the other after covering one of the eyes of the insect(Monocular).



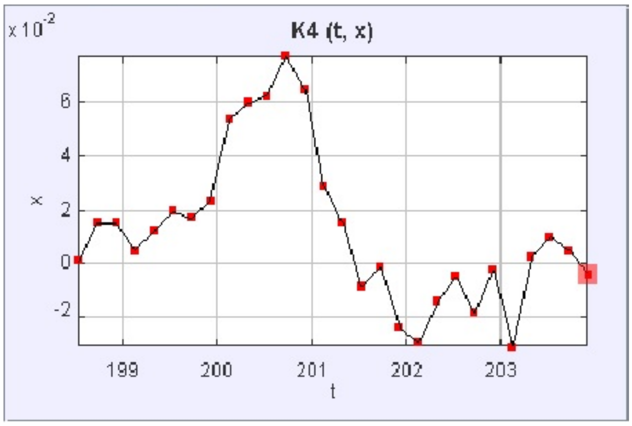
K 1- Animal A | 15cm | Binocular



K 3- Animal A | 15cm | Monocular



K 2- Animal A | 30cm | Binocular



K 4- Animal A | 30cm | Monocular

The above results are for the insect A for the distances of 15cm and 30cm for both binocular and monocular conditions, the graphs show x, the amplitude of peering with respect to time.

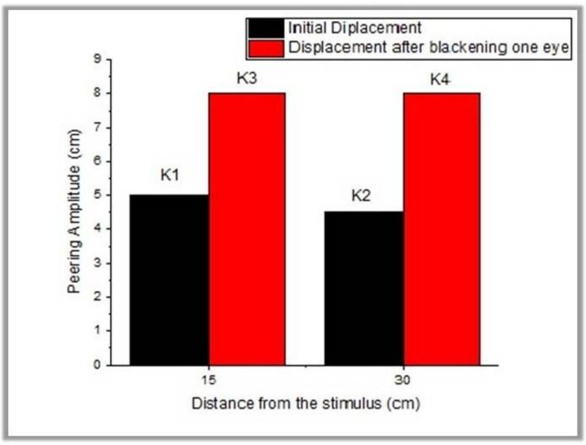
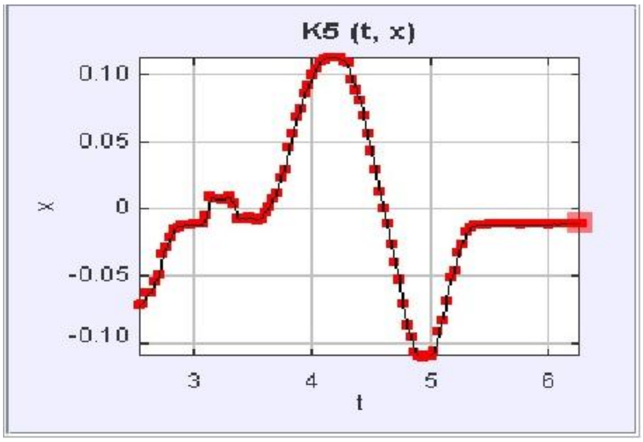
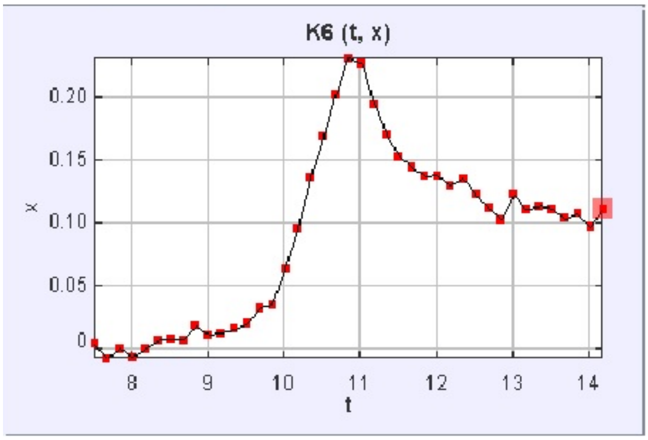


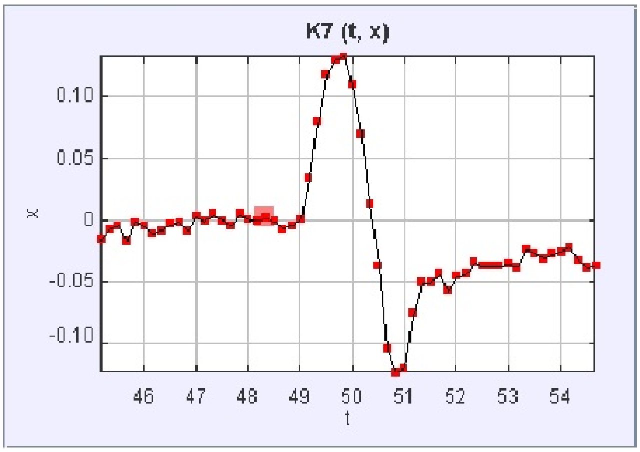
Fig 5. Peering Amplitude



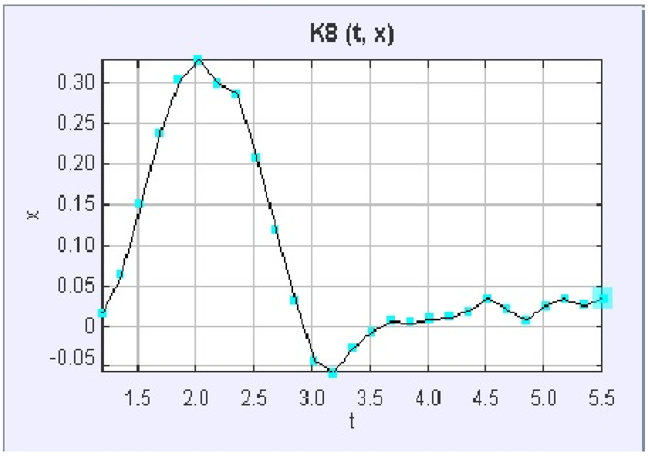
K 5- Animal B | 30cm | Binocular



K 6- Animal B | 30cm | Monocular



K 7- Animal B | 30cm | Binocular



K 8- Animal B | 30cm | Monocular

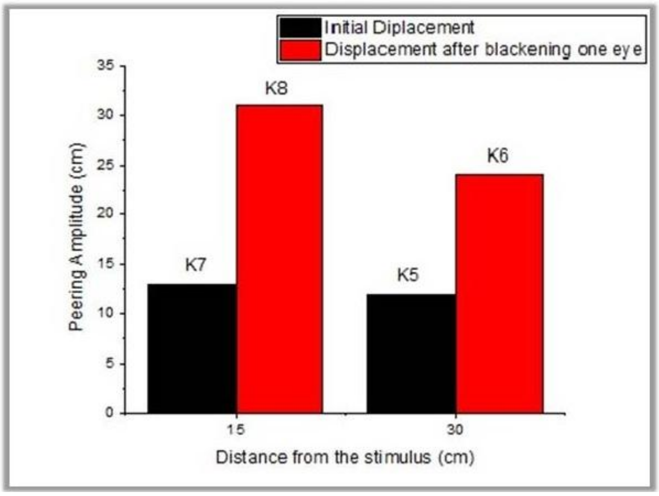


Fig6. Peering Amplitude

5 Conclusions

Data shows that the peering was one sided when one eye was occluded, as is evident from the peer amplitude vs time graphs. Fig5 and Fig6 show that the peering amplitude approximately doubled when one of the eyes was occluded. Thus,

- In the insects with one eye occluded the peering was lopsided, more towards the side that was opposite to the side of occluded eye.
- The peer amplitude increased by two-folds in the insects with one eye occluded, suggesting that the inputs from both the eyes are simply averaged, that determines the peer amplitude for the insect. Further experiments are needed to ascertain how exactly this computation is done by the grasshopper.

The neural pathways that perform the exhibition of peering behavior and subsequent computation of depth have evolved over a long period of time. It can be said that the peering behavior has evolved to accommodate inputs from two eyes.
It would be interesting to observe whether this alteration in peering amplitude persists and the animal continues to compute erroneous depth or whether it adapts over time and learns to use only the monocular cue to accurately gauge depth.

6 Acknowledgement

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7 References and Supplementary Data

Supplementary Data can be downloaded from here-
https://www.dropbox.com/sh/t520zfl0acdtbn9/AADtsESWO1nVRnqAU5kUcL-Ea?dl=0

Video showing peering behaviour- https://www.youtube.com/watch?v=r9efxsCWyjM

References-

1. The locust's use of motion parallax to measure distance- Eric Sobel(1990)

2. Visual Scanning in the desert locust *Schistocerca gregaria*- G. K. Wallace*(1959)*

3. Movement parallax and depth perception in grasshoppers *Phaulocridium vittatum*- Ericksson (1979)

4. Head Movements and Depth perception- Martina Wicklein(2002)

5. Tracker Video Analysis and Modelling Tool (Download from http://www.cabrillo.edu/~dbrown/tracker)

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