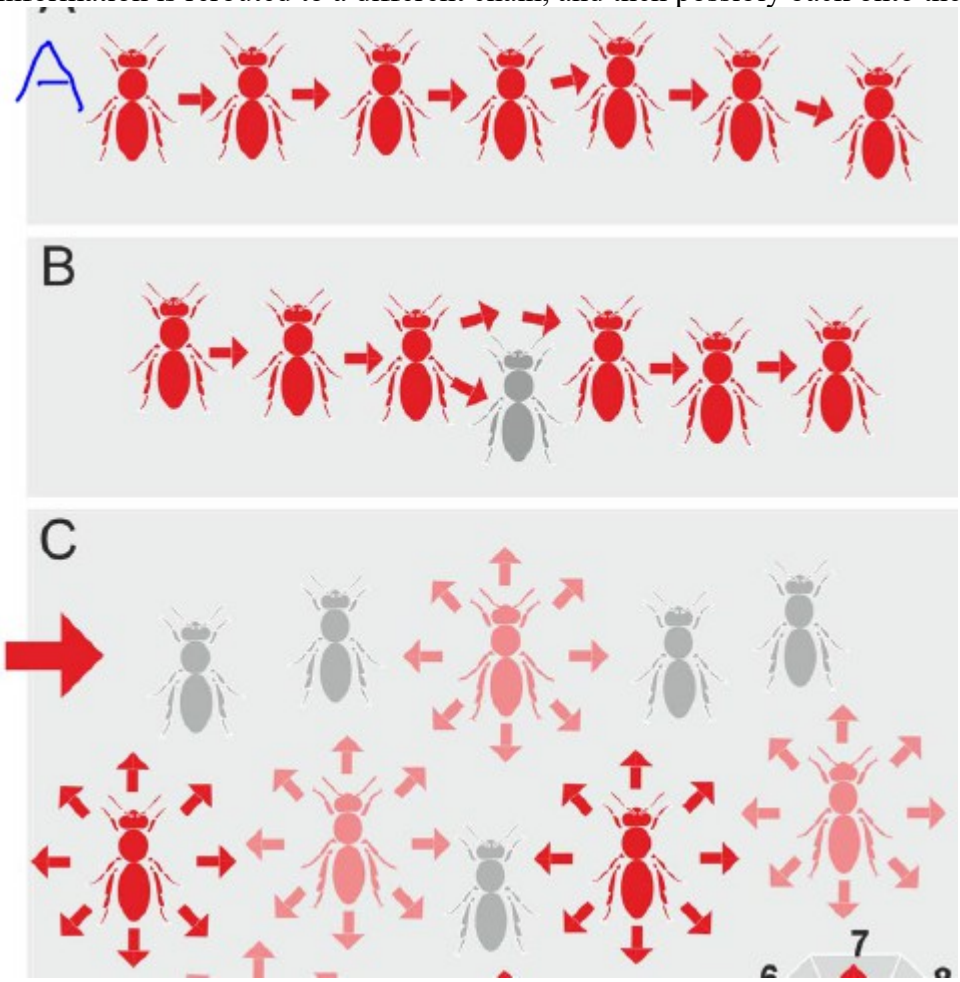
Paper focuses on bucket-bridging.

GENERAL THEORETICAL ASSUMPTIONS AND DEFINITIONS

Three problems can occur in a bucket-bridged chain; resulting in one of three "solutions" (or stopping)

a) The information is delayed, but ultimately continues down the chain.
b) The information skips an unwilling participant and then propagates down the chain.
c) The information is rerouted to a different chain, and then possibly back onto the same chain.



Three bucket-bridging assumptions:

Linearity-Information is delivered sequentially
Continuity- None of the problems from above occur
Graduality- A proportional relationship between the strength of the neighbors movement and the given focus bee's movement.

The directed-trigger hypothesis:

The coincidence of the individual trigger direction and the wave's direction.

The active-neighbors hypothesis:

The coincidence of the individual trigger direction and the sector (a 45° slice) of the majority of activity among neighbors.

BEE FACTS

Abdominal width: 6mm
Abdominal-flipping phase lasts 200 ms. (12 frames of the 60 fps camera's used in the experiment)

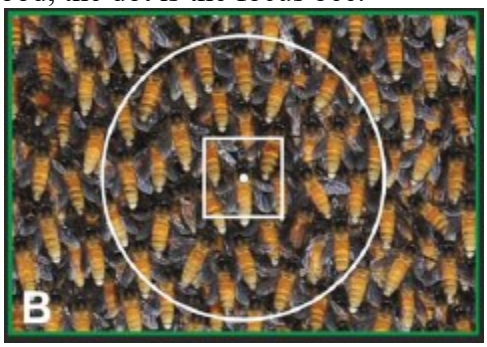
Hive is divided up into different zones, and primarily surface bees in the quintessence zone are the ones to exhibit shimmering. Bees in this zone are also more orderly in their orientation.

EXPERIMENTAL FACTS

Divided wave directions into 4 enumerated groups, starting from right to left, then bottom to top, left to right, and top to bottom (from the camera's point of view)

Using differences in luminance between successive frames determined to strength of the individual in the wave (interested in the change in luminance, which is at rest 3 per pixel (a bee taking up 20px)).

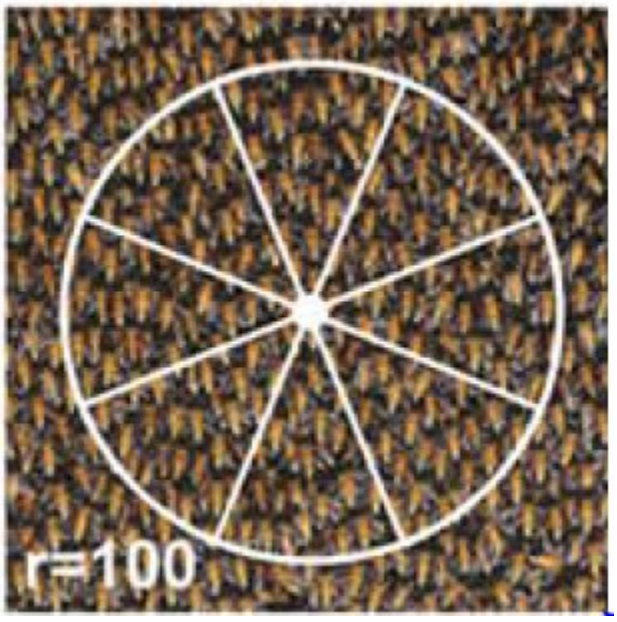
Near neighborhood is 40mm (approx 2 bees along the length away and 3 bees across) in radius. Here the white circle is that neighborhood, the dot is the focus bee.



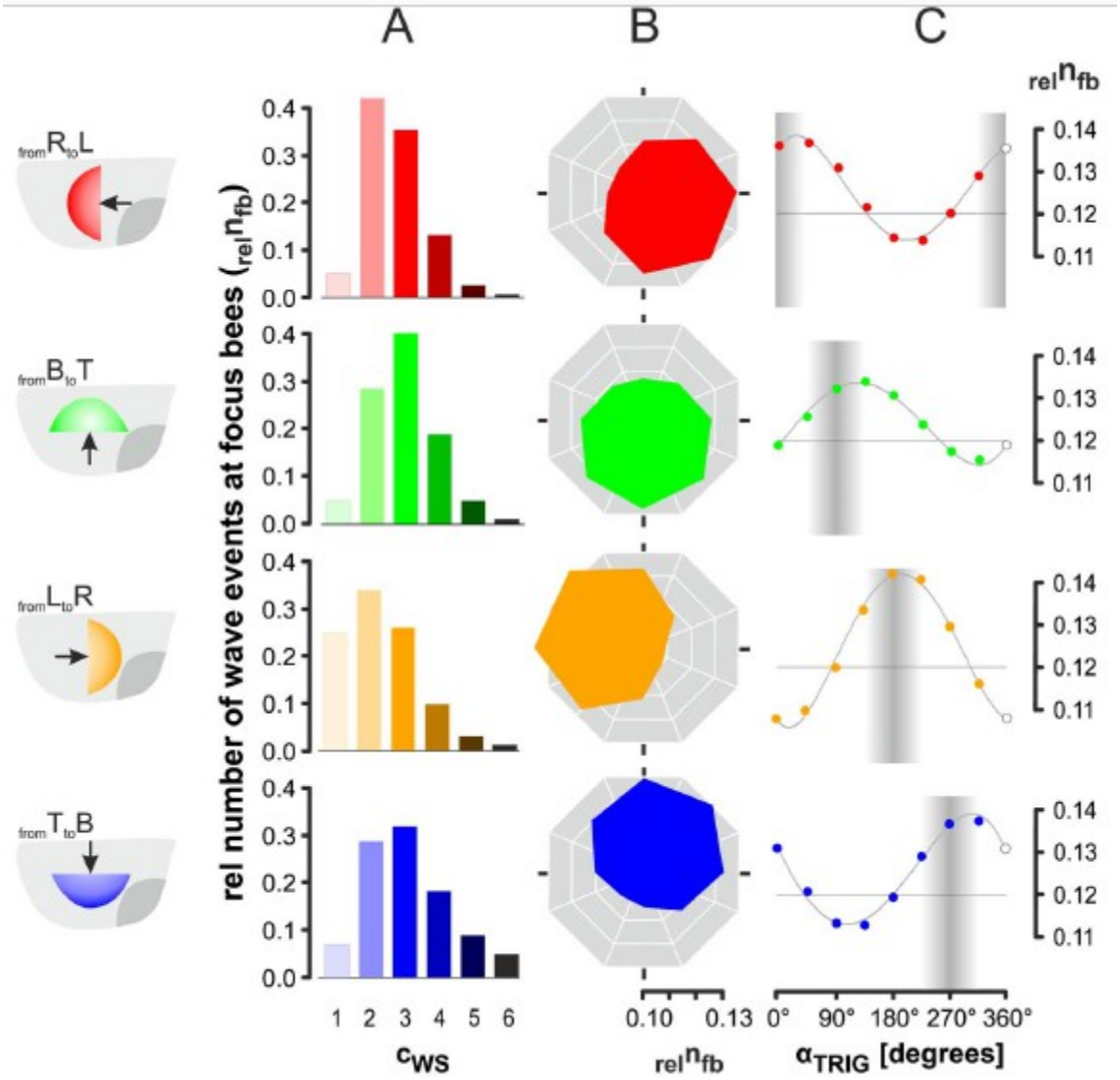
The far neighborhood is 100 mm in radius.

Divided the bee's neighborhood into 8 45° sectors as such:

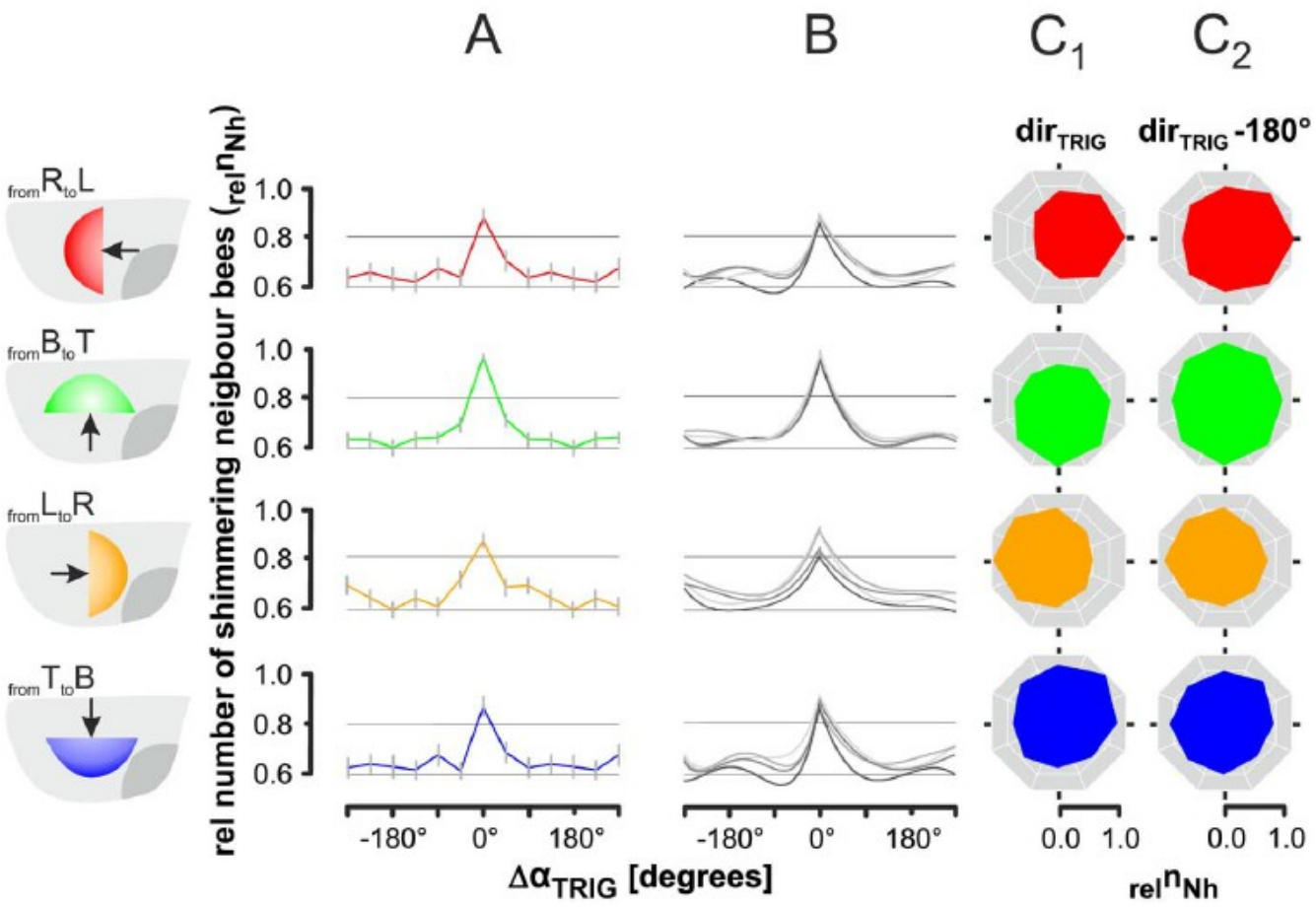
or



Determined the time zero for the wave hitting the focus bee by defining it to be the frame before t_1.
This t_1 was a sharp rise in the change in luminance in the area of the focus bee; also they had to exceed the threshold of 10 for at more than 5 sequential frames to count as part of the wave (to eliminate noise).
This was then used to synchronize data.
These parameters (the change in luminance and length of "shimmer") were both later used to develop a 1-8 scale of agent bee participation.
The focus bee was considered triggered if the trigger neighborhood had participated in the wave for no more than 5 frames before the focus bee started shimmering, the trigger neighborhood was the closest to the focus bee; whose near neighborhood was not made up of more that 5-7 agents (to exclude daughter waves).
Stimulus was a dummy wasp.
RESULTS
53.06±3.05% of identified agent bees were found to participate actively in shimmering

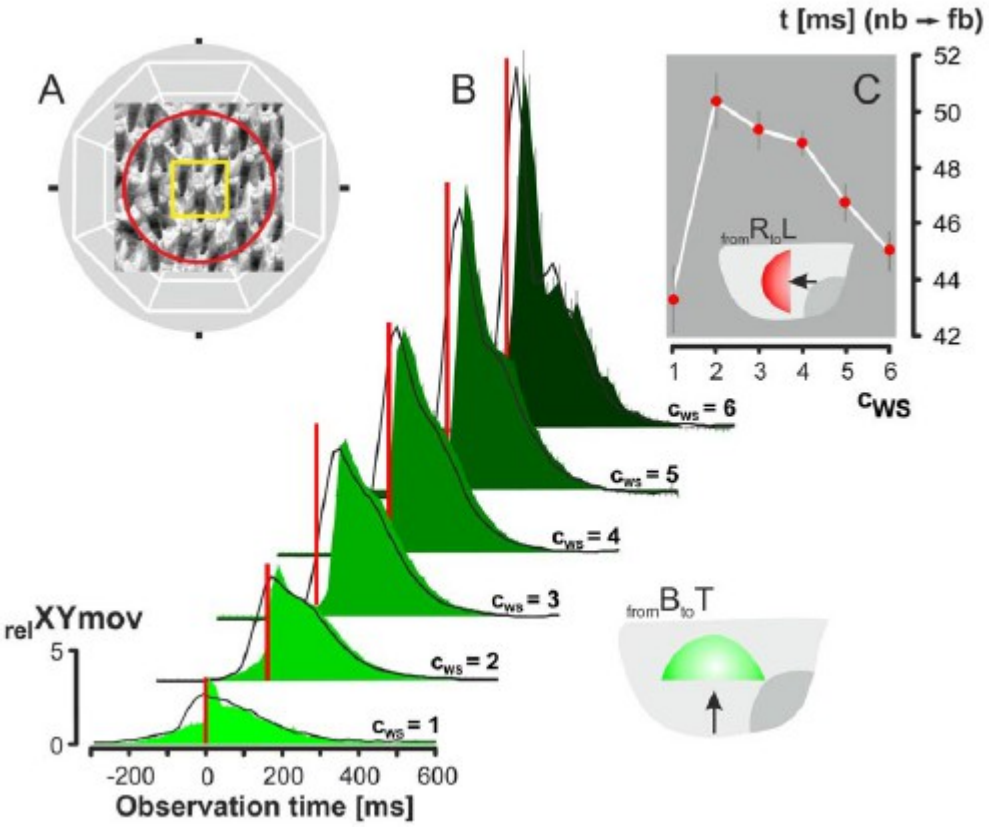


Generally interesting chart, if you look at Column A you will see that there is a weird correlation between vertical waves and higher wave strength categories for individual focus bees. Note that for the third column, C, 0° is due right, then progressing clockwise.



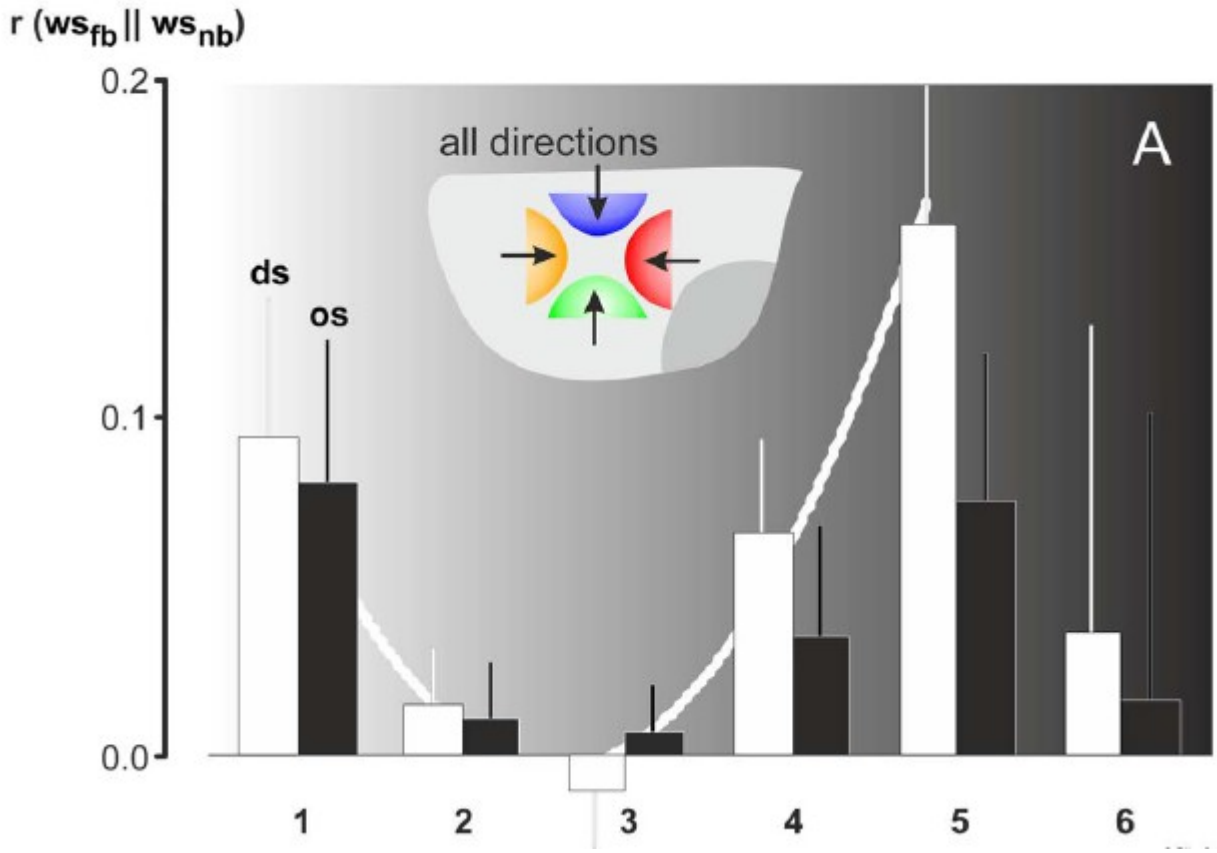
And here is another useful chart, as you can observe the trigger angle's effect of the triggering of the bee dissipates after about 45°-90° away from the waves primary direction.
The other column is the number of bees in the far neighborhood with a wave strength 1-5.

About 24.28% of bees were found to be “flipped their abdomens without having received a mechanical cue from their immediate neighbours” Thus were likely to be part of an alternate spreading mechanism.



The gray square is again just the near neighborhood.
The relative XYmov is just that change in light from earlier; with the c's being wave strengths.
C is the time it takes to transfer information from the near neighborhood to the focus bee, based on wave strength. Which is 47.296±1.12ms.
Given the average distance from a focus bee to one in its far neighborhood being 62mm (remember that there are more bees closer to the edge of the circle) The author calculates that neighbors in the far neighborhood bucket-bridging achieve a speed of 1.3116±0.030 m/s.

The author then goes into arguing linearity, the argument for which is itself not particularly valuable; but comes to the conclusion that 93.85% of focus bees where triggered from a random direction, regardless of the wave's direction.
Then an argument for continuity follows. Though honestly I don't get how on earth it proves continuity.



ds is the sectors of the trigger direction, os is of the opposite direction.

$$r_{ds} = k * r_{os} (\text{proportional}: k>0;\ \text{antagonistic}: k<0) \quad (4a)$$

The following equation was then proposed.
In general under 184 test cases r_{ds} =0.059460.0174; r_{os}= 0.038160.0175;
k is significantly positive for low and high wave strengths, for example if c_{ws} = 5 then r_{ds} = 0.16006±0.0426)
If all the wave strength are considered together then 0.36% of the total pop are controlled by graduality.
If they are considered separately, particularly for the low and high wave strength such as c_{ws} = 5, then this number goes up to 2.56%.
However bees participating at a 2-3 level, which makes up about 85% of all agents, did not seem to exhibit this behavior.
It is also important to note that shimmering is different from the flickering of fireflies, which is their attempt to synchronize.
The active-neighbor hypothesis proved continuity at a level of 27% of all wave incidents.
At early stages of the wave bees are more likely to participate at a higher level then their predecessors.
Thus early on, 200-500ms after waves start, the wave behaves like a positive feedback loop.
But in the phase before wave death, the the information transfer is weaker.
“These results confirm graduality and positive feedback in propagation for maximal 15% of the identified wave incident”
The main result is that only a small minority transmit information through bucket-bridging.
75.72% of active bees were triggered by their immediate neighbors. Out of which 85% responded at medium, 2-3, wave strength. 5% responded weakly, and 10% strongly.
Only 6.15% conform to linearity.

28.03% conform to continuity.
refractory phase of around 800 ms.