Knocking on a honeybee hive: quantitative analysis of a colony's reaction to an artificial vibrational knock

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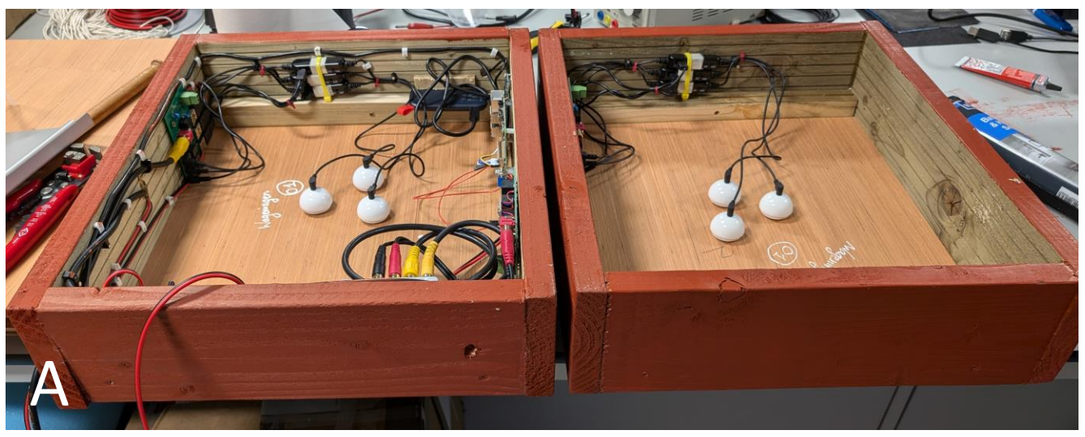
Introduction

In the past many beekeepers have been simply knocking on their hives, with their hand, to check and listen for a positive buzzing response, indicating the liveliness of the colony.
In this work we aim to provide a quantitative method allowing the probing of the physiological status of honeybee colonies by providing them with a gentle, short, external artificial vibrational shockwave, and recording their response.
In order to do so, we measure the response of bees when knocking on their hive, for (i) established Darwinian survivors, (ii) control colonies, (iii) colony under low stress, (iv) colony undergoing high stress.

Methods

In order to deliver the required knock automatically, a dedicated wooden box is built (see photo A and B), with its floor made of thin plywood, onto which three separate mighty boom ball electromagnetic shakers (Focus Multimedia Limited, Rugeley, UK) are glued, centrally. These are connected to the output of a sound card, controlled by a "Raspberry Pi" computer in charge of running the experiment. An accelerometer (805M1-0020, TE Connectivity, CH) residing in the centre of the central frame of the brood box is connected to the input of the same sound card, in order to capture the colony's reaction. The same "Raspberry Pi" can comfortably run two boxes/hives (a 'master system', A, and a 'slave system', B) as most sound cards are stereo. In case the hive's roof is heavily metallic, an external WiFi areal can be installed (black item protruding from box in photo B) in order to access the computer remotely. The wooden box sits under the hive's roof (see photo B), totally protected from the weather, it is powered by a single external wire and requires 4 Watts of power. A sinusoidal pulse, shaped by a Gaussian envelop with Full Width Half Maximum of 30 ms, is driven into the shakers to simulate a vibrational 'knock', approximately every hour, at randomized times to avoid bees' habituation to the stimulus. The computer reboots itself every four days, at which time it also sweeps the frequency of the stimulus pulse, in order to find the one providing the maximum vibration into the accelerometer residing at the heart of the colony. This optimal frequency is then kept for the next four days.



These systems were designed, tested, built and set up at Nottingham Trent University, UK, then installed on 8 colonies in Wageningen, NL (Plant Pathology & Bees Business Unit Biointeractions and Plant Health), on 8 more in Norway (Norwegian Beekeepers Association), on 8 more in Cluj-Napoca, RO (Apiculture and Sericulture Unit, Faculty of Animal Science and Biotechnologies), and on 6 more in Ghent, BE (Laboratory of Molecular Entomology and Bee Pathology (L-MEB)& Honeybee Valley). They are presently running on "established Darwinian" colonies (bees that survive varroa infestation without any treatment) and "control colonies" (bees that are treated for varroa) and bees subjected to various level of stressors (Asian Hornet presence).

Preliminary Results

- The affordable hardware was found appropriate to stimulate and record high-quality instances of three independent colony reactions. The system will run, uninterrupted, for many months. The results presently do not permit measurements of the bee mobility as demonstrated previously[1] with accelerometers ten times more sensitive than those used here, probably due to the strength of the vibrational knock being still insufficient.
- With this hardware, we have found that bees respond mostly for a stimulus frequency between 50 and 200 Hz. We therefore restricted the optimization to this range of frequencies.
- We have found that the strength of the vibration that we are delivering to the colony is stronger that in our last study[1], in particular we are able to often pick up 'whooping signals'[2] as a response to the stimulus ***even in the active season*** of the summertime.
- The bees reactions provide a wealth of information: they are of four types, (i) none, (ii) short lived (0.1 s) whooping signals[2] ~200 ms after the stimulus, (iii) long-lived (several seconds) overall buzzing response, and (iv) purring bee. The long-lived buzzing, in particular, is characterised by three independent parameters (magnitude, ramp-up and decay times) which further enhances the quantitative assessment of the colony's reaction.

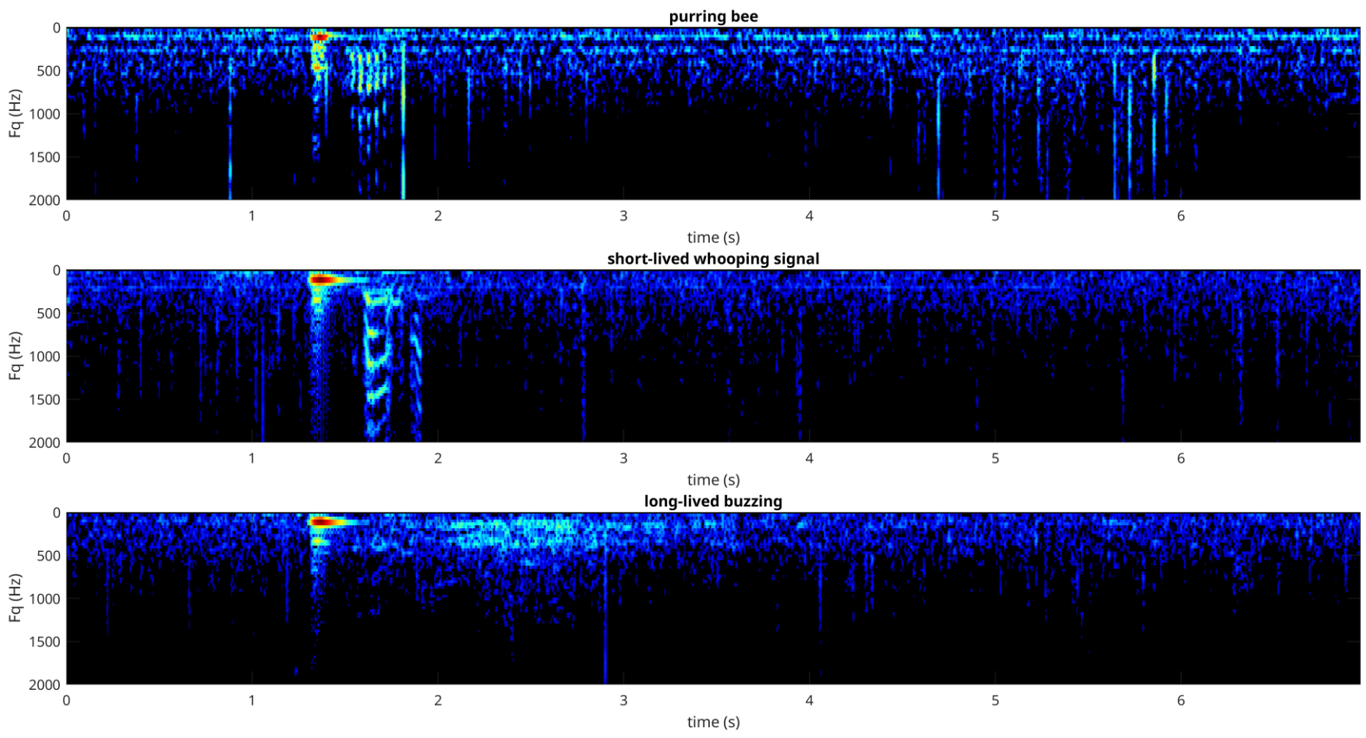


Figure 1: Spectrograms of three different bee reactions:
Top: a 'purring bee' signal (seen between 1.5 and 1.7 s) is occasionally taking place as a reaction to the stimulus. The vibration is a train of pulses, 30 of them in a second, lasts approximately 0.5 s, and is seen 200 ms after the stimulus (red trace taking place at 1.3 s). The vibration is coming from one or few bees, is never detected as a 'colony response', either because the signal does not convey to the accelerometer from any substantial distance, or because very few bees react in this way. **Middle**: a 'whooping signal' response (seen between 1.5 and 1.7 s) is occasionally taking place, usually only for a strong enough vibrational stimulus. The vibration is a single pulse, around 340 Hz, lasts approximately 0.2 s, and is seen 200 ms after the stimulus. The vibration is coming from one or few bees, is never detected as a 'colony response', either because the signal does not convey to the accelerometer from any substantial distance, or because very few bees react in this way. **Bottom**: a 'buzzing' response is occasionally taking place. The long-lived vibration is coming from numerous bees buzzing, lasts several seconds, and is seen 500 ms after the stimulus. The vibration is coming from numerous bees, and is detected as an 'entire colony response', as it has been shown that this kind of buzzing is representative of the entire colony[3]. This reaction can be triggered with a much weaker vibrational stimulus, but only when the colony fails to engage with normal activities, either when in the winter cluster or when irremediably queenless.
On all spectrograms, note that the trace of the artificial vibration is asymmetrical, as the stimulus has been applied on one resonant frequency of the wooden plate, which keeps vibrating 100 to 200 ms after the end of the application of the pulse. However, the overlap with the start of the vibrational response of the bees is negligible, so it is possible to extract it.

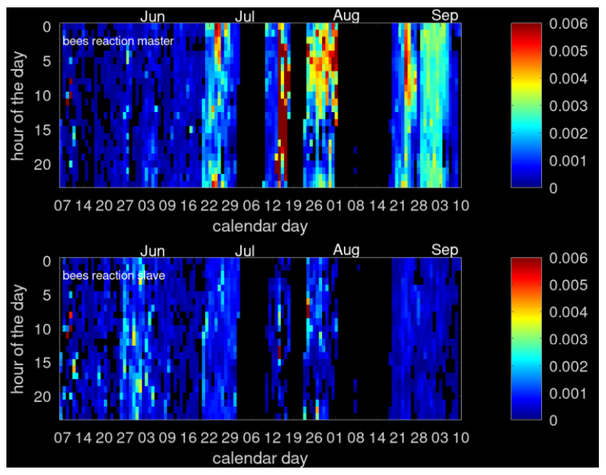


Figure 2: Long term evolution of the response of two neighbour colonies:
Top: a Belgian colony found queenless in late July, unsuccessfully requeened on July 30th, successfully requeened on Aug 27th, is exhibiting a reaction substantially higher than **Bottom:** an immediately neighbour colony situated 3 m away from the first one, found queenright all through the season that is shown. Both hives were stimulated at exactly the same times (approximately every hour) to avoid artefacts coming from the picking up of spurious vibrations coming from the neighbour colony. The horizontal axis indicates the day of the month, the vertical axis the hour of the day, the colour is coding an indication of the magnitude of the bees reaction (in arbitrary units), by calculating the difference between the mean signal found (see Figure 1) on the spectrogram (i) between 1.4 and 3 seconds (AFTER the stimulus), and (ii) between 0 and 1 second (BEFORE the stimulus). Pixels that are black in May indicate an absence of reaction, but in early July, mid July and August, longer lasting black rectangles originate from missing data, from moving the colonies to different apiaries or from power cuts or technical issues. The enhanced reaction measured on a queenless colony in the summer has also been reported in our pilot study[1], where one queenless colony is compared to seven queen right colonies in the same apiary. In both cases, the queenlessness-related enhanced reaction is essentially made of the 'long-lived buzzing' type (Figure 1) and is mostly enhanced in the morning. Here the signal is also seen to gradually fade away as the colony becomes queenright.

Present endeavours

- Machine Learning code is presently being written, to allow the discrimination of the three independent bee responses, so each can be plotted separately.
- Data is presently being acquired in Romania, Norway, Holland, and Belgium on hives (i) with known differences (resilient/non-resilient, high/low stress) and (ii) inspected monthly, to establish new sensitivities of the measurement, using a phenomenological approach, on the three different responses extracted by machine learning.
- We already have evidence[1] that the method can sense the appearance and disappearance of the winter cluster, and the colony's queenlessness. We are presently gathering further data to (i) confirm these and (ii) extend, quantitate the range of, and provide the specificities of the sensitivities.

References
[1] Quantitative assessments of honeybee colony's response to an artificial vibrational pulse resulting in non-invasive measurements of colony's overall mobility and restfulness, Martin Bencsik, Adam McVeigh, David Claeys Bouuaert, Nuno Capela, Frederick Penny, Michael Ian Newton, José Paulo Sousa & Dirk C. de Graaf, Scientific Reports, 14, Article number: 3827 (2024).
[2] Long-term trends in the honeybee 'whooping signal' revealed by automated detection, Michael Ramsey, Martin Bencsik, Michael I. Newton, PLOS ONE, 12(7): e0181736 (2017).
[3] Honeybee Colony Vibrational Measurements to Highlight the Brood Cycle, Martin Bencsik, Yves Le Conte, Maritza Reyes, Maryline Pioz, David Whittaker, Didier Crauser, Noa Simon Delso, Michael I. Newton, PLOS ONE, 10(11): e0141926 (2015).

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