Can Electromagnetic Exposure Cause a Change in Behaviour?

Studying Possible Non-Thermal Influences on Honey Bees – An Approach within the Framework of Educational Informatics

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Abstract
In recent years the public discussion has been focused increasingly on possible unhealthy effects of high-frequency electromagnetic fields (particularly of mobile-phones) on human beings. Whereas thermal effects of this radiation could be explained very well, non-thermal effects could hardly be clarified. In our last works, we pointed out that – from view of Educational Informatics – honey bees are suitable bioindicators to serve as a model of a living being to study learning processes especially in this aspect.
In this paper, we describe a first pilot study, which explores the non-thermal influence of high-frequency electromagnetic fields. Therefore we observe the behaviour of honey bees (*apis mellifera carnica*) by exposing them to the radiation of DECT-phones. In this study four respectively eight bee-colonies were used as experimental group and were irradiated, whereas the same numbers of comparable bee-colonies was field-free. The observed parameters were the building behaviour of the bees within the beehive, its weight and especially the bees' returning behaviour.

Key words
Electromagnetic exposure, non-thermal, bioindicator, honey bees, learning process, changing behaviour

Introduction
The modern media together with the increasing use of mobile computing in education produce, among other things, an increasing public debate about possible side effects of electromagnetic exposition on human beings. In recent years further studies were initiated to examine the effect of high-frequency electromagnetic radiation on living organisms and cells. But up to now there exists no adequate model of effect with specific relation to learning processes to explain the different, especially non-thermal effects. In this context we only want to mention the resonant stimulus of living organisms, especially of their brain, by high-frequency electromagnetic fields of mobile phones. This could be observed as alterations in the learning behaviour of the organism.
Because studies using human beings are banned in this field, adequate bioindicators should be used to evaluate a possible model. Therefore it is necessary that the brainstructure of the bioindicator is similar in important aspects to that of human beings and that it could be resonantly stimulated by the frequency of mobile phones because of its size. Consequently it is necessary to find a

suitable bioindicator to verify a respective model of explanation of the effect of high-frequency electromagnetic fields on human beings, especially on the human brainstructure.
To determine a possible bioindicator for an experimental physical interpretation of the model, we use topical studies about the learning process of honey bees (in a first step). In our model we assume that the knowledge of the honey bees' surrounding determine their actions. Thereby we suppose that this knowledge is caused by the information processing in the way described by the process of superation (Stever, 2002). This interpretation is supported by results of neurobiological research. It shows that the alterations of the honey bees' actions are combined with modifications in certain areas of their brain, especially in such areas called mushroom bodies (Withers et al, 1993; Faber & Menzel, 2001). Therefore we want to consider these mushroom bodies as representations of internal models, which were the results of honey bees' learning processes. These internal models represent parts of the surrounding. In addition, Menzel points out, that the associative brainstructure of bees is similar to the brainstructure of human beings: The memory of both passes through sequences, which differ in their susceptibility of problems and in the amount of participating brain areas (Menzel, 1993).
Summing up, these results show that honey bees are suitable for studying the neuronal basics of learning and memory. Furthermore honey bees turn out to be permissible and suitable bioindicators to develop adequate models of explanation for the effect of high-frequency electromagnetic fields on human beings, especially on the structure of their brain. Observations of honey bees also make it possible to develop corresponding theoretically guided models of effect, which are based on the theory of supersigns.

Methods

Physical design.

To study non-thermal influences of high-frequency radiation on the learning behaviour of honeybees, these insects (resp. their brains) had to be stimulated non-thermally (Stever & Kuhn, 2004). For that, we used the basis stations of cordless DECT mobile phones (Digital European Cordless Telecommunications). These stations send out continually electromagnetic radiation with a sending frequency $f_S \approx 1900$ MHz. So they also irradiate when the mobile phone is out of order or is not in use. The average transmitting power P_S amounts to 10 mW, the peak power is 250 mW. The sending signal is frequency modulated and pulsed with a pulsing frequency f_p of 100 Hz. The station was put at the bottom of a beehive, right under the honeycombs (Fig. 1).
The station was placed within the beehive, so the honey bees have been able to touch the sending aerial all the time.

Subjects and location.

The experiment was carried out on the premises of the "DLR Fachzentrum für Bienen und Imkerei" in Mayen by students of Environmental Sciences at the University of Koblenz-Landau/Campus Landau.
Subject was to study the behaviour of exposed and non-exposed honey bees concerning finding back home to the beehive and building honeycombs.

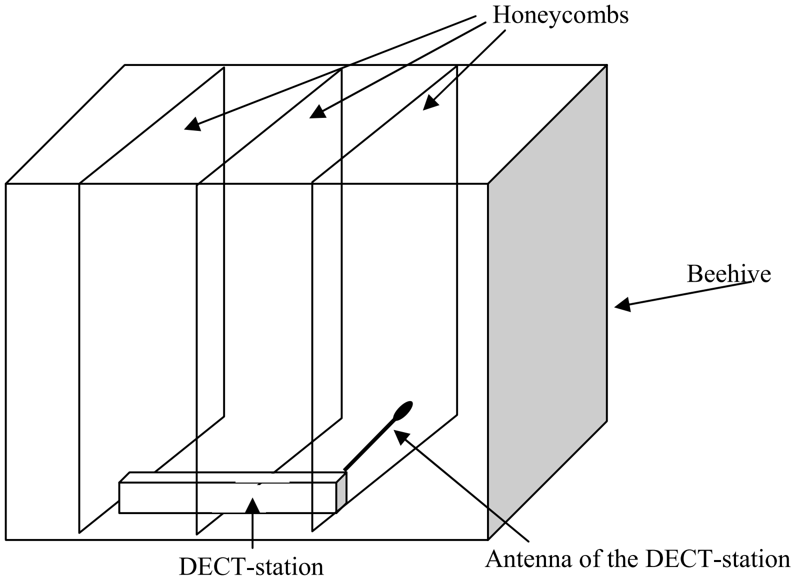

Fig. 1: Position of the DECT-station within a beehive.

Procedure.
Sight registration of returning behaviour to the beehive*:*
To study the returning behaviour eight mini-hives – each with colonies of about 8.000 individuals – were set up in a row. A block of four colonies were equipped with DECT-stations on the bottom of their hive. At the entrance of each hive a transparent 10 cm plastic tube with a diameter of 4 cm was mounted to gather single bees and watching them later entering the hive. At the beginning of each study-sequence 25 bees of one colony were gathered in their tubes, stunned in a cooling box and got marked with a marker dot on the thorax. At a distance of about 800 m to the hive all marked bees were set free simultaneously and got timed from that moment. The returning bees were intercepted at the bee hive's entrance and the returning time was noted down. The observation time lasted 45 minutes, bees that came back afterwards were disregarded. Within every study-sequence the groups of exposed and non-exposed honeybees were paired (at least one group of exposed and non-exposed colonies) and observed simultaneously.
Building behaviour:
To study the building behaviour of the bees, two variables were examined: the change of the honeycomb area, which was documented by photographs, and the development of the honeycomb weight. Sixteen mini-hive colonies, eight neighbouring hives with DECT-stations, were set up in a row. At the beginning of the experiment the empty frames for the honeycombs were weighed, then the hives got filled with bees (400 g) and 250 ml food. The bees were fed two times moreover while running the experiment. The front- and backside of the frames, six in each hive, with the developing honeycombs were photographed every day at the same time, also the frames got weighed.
Other data:
To register the returning behaviour of the bees automatically four standard hives, two of them with DECT-stations, were equipped with beescan-units. Because of technical problems and in-

completeness, the data couldn't be taken into account. The collected weather data were incomplete, too.

Results

Because of the explorative character of this study we refrain from a differentiated statistical analysis, but exemplary the most obvious differences between exposed and non-exposed colonies about honeycomb weight and returning times will be represented graphically.
The development of honeycomb area and weight will be compared by averages of exposed and non-exposed colonies and shown in two diagrams, too.
The first two diagrams (Fig. 2 and Fig. 3) show the distribution of the averaged entire weight to single honeycombs of the respective experimental group. In the course of the experiment three exposed colonies and one non-exposed colony broke down. To compute the average weight of the honeycombs over all analyzed colonies their weight was used at the time of the breakdown.
While the weight of the frames for the honeycombs was similar at the beginning, the average total weights of the honeycombs, which were built by non-exposed bees, came to 1326 g while the average honeycomb weight of the exposed bees amount 1045 g. The difference of 281 g corresponds to 21.1%.

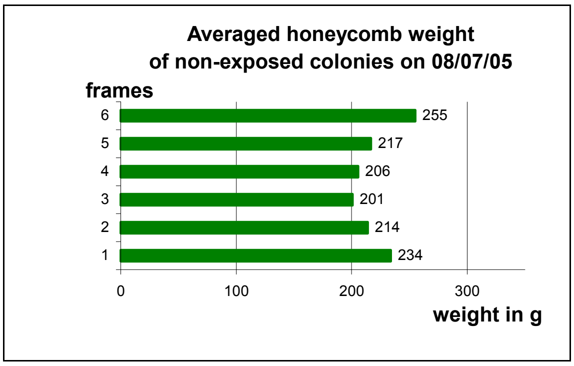

Fig. 2: Honeycomb Weight of non-exposed bees

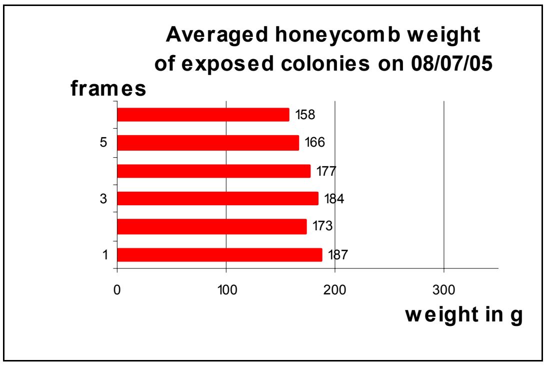

Fig. 3: Honeycomb Weight of exposed bees

Fig. 4 and Fig. 5 show the progression of honeycomb weight and area during the experiment. Right after the moment of the breakdown the data of the collapsed colonies were taken into account as constants. The area of the honeycombs couldn't be measured directly, so the photographs were analyzed with the graphic tool "ImageJ" (Rasband, 2005). With this software the area of the honeycombs could be marked by framing the section on the photos. Then the mean for front- and backside could be calculated to minimize errors determining the areas.
During the process of the experiment it became clear that both weight and area were developed better by non-exposed honey bees. Although this has to be interpreted as a tendency or a trend, a Mann-Whitney U-Test, which was done for descriptive reasons, never showed a difference (5%-level) between exposed and non-exposed colonies.
Fig. 6 - Fig. 9 depict the returning behaviour of a specific sequence of the experiment on 07/07/05, 12:10 to 12:55. All observed honey bees had the same weather conditions. These figures show that the quantity of returning bees of the non-exposed honey bees was bigger as well as the returning time of the few returning exposed honey bees was distinctly longer.

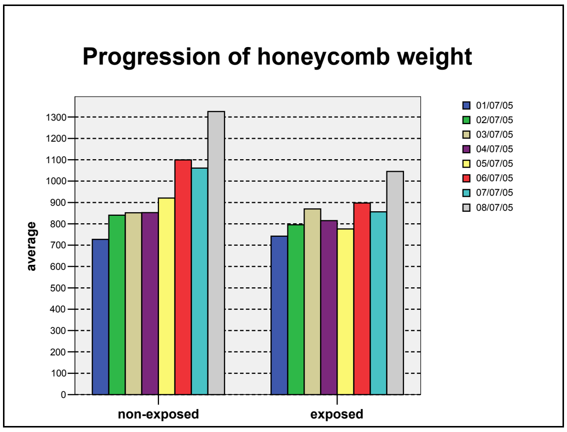

Fig. 4: Honeycomb Weight

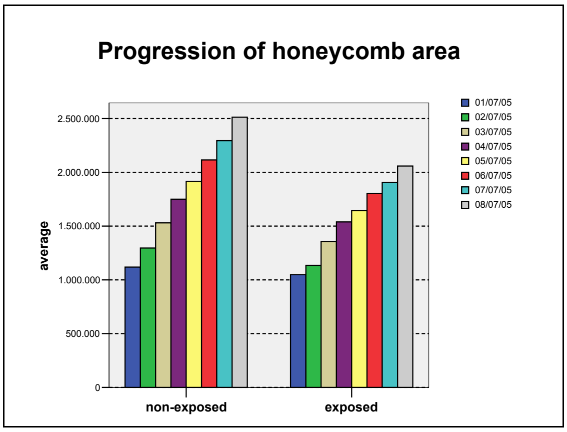

Fig. 5: Honeycomb Area

This observation was done during a sequence of the experiment with the maximum of returning bees of both exposed and non-exposed colonies. At no time of the experiment more than six exposed bees arrived, several times none came back to the hive within 45 minutes, whereas at every sequence of the experiment returning non-exposed honey bees could be observed. So the depict sequence shows even the best-case!

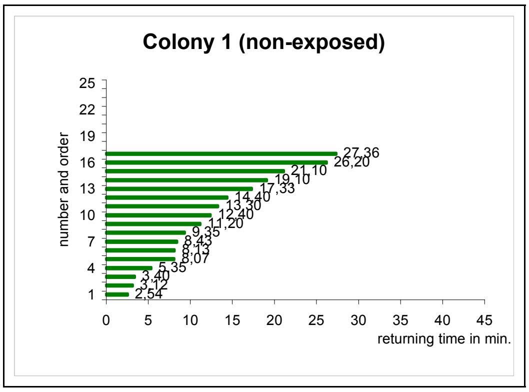

Fig. 6: Returning Time, Colony 1

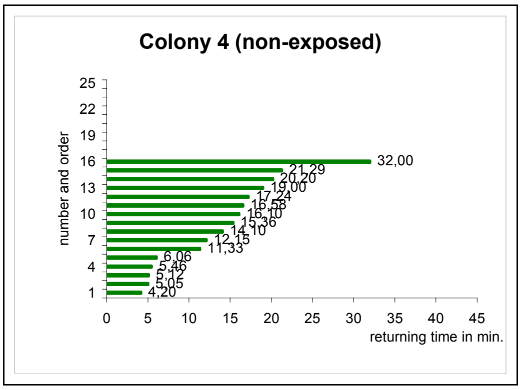

Fig. 7: Returning Time, Colony 4

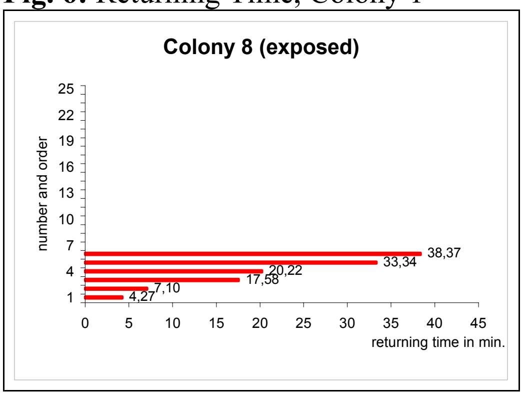

Fig. 8: Returning Time, Colony 8

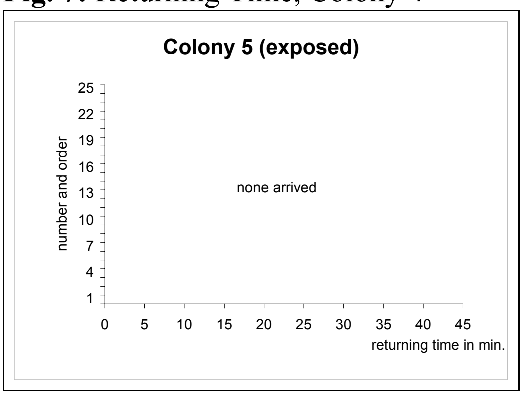

Fig. 9: Returning Time, Colony 5

Outlook

The physical design of this study could be modified in different ways concerning the used power and frequency. Therefore mostly frequency- and power-ranges of daily life should be interesting. So the following physical modifications are conceivable:

1. Increasing power:
   In a worst-case-study the DECT-station should run in active state with maximum sending power.
2. Frequency-modification:
   Besides cordless DECT phones, which are mostly used within buildings, other mobile phones could be used. For example the GSM mobile phones (Global System for Mobile Communication) send their information with sending frequencies of 900 MHz and 1800 MHz as well as with a pulsing frequency of 217 Hz. So GSM mobile phones differ from DECT-phones in their physical characteristics, these phones can also be used in buildings as well as outdoors. Because GSM technology works with power adjustment depending on the distance between mobile phone and station, the phone should be used in active process for worst-case-situation.

Further modifications could be done regarding to the position of the beehives and the periods of exposition. To reduce location-effects the control- and experimental beehives should be positioned alternately. Furthermore the period of exposition and studying the honeybees' behaviour could be modified or extended. In order to that different stages of bee development (not only the adult level) and the influence of exposition in each stage could be observed.

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