The influence of group size on cooperative decision making in honeybees
Martina Szopek, Gerald Radspieler, Ronald Thenius, Thomas Schmickl & Karl Crailsheim

Introduction
In a temperature organ young honeybees show thermotaxis and move to their preferred temperature (approx. 36°C) [1]. In contrast to this, only a few single bees do stop at the optimum in a two dimensional temperature gradient, whereas groups of bees aggregate collaboratively at the optimum. We tested different group sizes of young honeybees in a complex gradient with two different optima. We examined if groups of bees are able to distinguish between two optima of different attractiveness and the influence of different group sizes on this cooperative thermostactic behaviour.

Material and Methods
We used a circular arena for our experiments (see Fig. 1). We generated the temperature gradient with ceramic heat lamps. We equipped the ground with temperature sensors and covered it with beeswax honeycomb sheets. We filmed the bees under infrared light which is invisible for them. For the experiments we used honeybees aged 2 to 30 hours. We generated a gradient with a local and a global optimum (see Fig. 2a). Groups consisting of 6, 24, 64 and 128 bees were released in the center of the arena (N = 8/group size). For control purpose we performed the experiment with single bees (N = 10). We defined a target zone for each optimum. Thirty minutes after releasing we counted the bees in the predefined zones (see Fig. 2b).

Results
The median fractions of bees in the 36°C-zone and the 32°C-zone are significantly different within each group size (Kruskal-Wallis test p<0.01). As shown in Fig. 3a and 3b there is no difference in the median fraction of bees between the different group sizes in the respective zones (Kruskal-Wallis test p>0.05). At each group size the median fraction of bees in the 36°C-zone is above the expected fraction of bees at uniform distribution (Fig.3a; dashed line). There are less than 50% of the bees of each group size located outside of the target zones (Fig.3b). The median fraction of bees of each group size in this zone is below the expected fraction of bees at uniform distribution (Fig.3b; dashed line). The median fraction of bees in the 32°C-zone increases with increasing group size (Fig.3c; Kendall’s Tau 0.3995, p=0.0068). At group sizes from 6 to 64 bees the median fraction is below the expected fraction of bees at uniform distribution, and above at group size of 128 bees (Fig. 3c; dashed line). 40% of the single bees are located in the 36°C-zone and outside of the target zones, and 20% are located in the 32°C zone (Fig.3a,b,c; orange line).

Discussion
Groups of young honeybees are able to discriminate the local optimum from the global optimum and aggregate successfully in the 36°C-zone, independently of the group size. In contrast to this, only 40% of the single bees stopped at the optimum. The nearly equivalent median fraction of bees aggregating in the optimal zone (36°C) at all group sizes indicates that cooperative thermostactic behaviour is little influenced by the group size. Increasing median fractions of bees in the 32°C-zone with increasing group size could be a result of overcrowding in the 36°C-zone with the effect that some bees switch to the 32°C-zone. In overcrowded brood nests this effect could ensure that young bees move to the cooler edges or into other brood nest areas to take over other tasks or tasks in another area.

Acknowledgements
This work was granted by: FWF – P 19478-B16