Waggle to Win:
The Evolution of Dance Communication in European Honey Bees

(Apis mellifera)

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Writing 101: *Monkey Mindreading*
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Due to schedule constraints and curiosity, I decided to take Dr. Lindsey Smith's Writing 101: *Monkey Mindreading* knowing virtually nothing about the topic. Dr. Smith introduced me to the study of animal cognition, focusing mainly on primates, and I learned exactly what cognitive abilities are truly possessed by our distant relatives. Not only was I exposed to the intellectual abilities necessary for survival in all species, but I became aware of the building blocks to my own cognition.

I discovered the unique abilities of European honey bees (*Apis mellifera*) after an extensive search for my final essay topic. I was immediately drawn to their communication style, and the intricacies of the dance language as it is used today. Growing up a competitive dancer, I was well versed in the expressive power of dance, but I was not aware of its practical uses. Researching and reporting on honey bees opened my eyes to the power of dance, and how a seemingly simple species has intellectual complexities far greater than I ever imagined.

I would like to thank Dr. Smith for opening my eyes to the wonders of animal cognition and pushing me to my fullest potential as a writer. This essay would not be complete without Dr. Sheryl Welte Emch and the *Deliberations* editorial board, who have worked diligently and patiently with me throughout the editing process, so I would like to extend a thank you to them as well. A final thanks to my mother, who preaches that the best way to learn is by teaching someone else, for being the best student in my exploration of honey bees.

Background

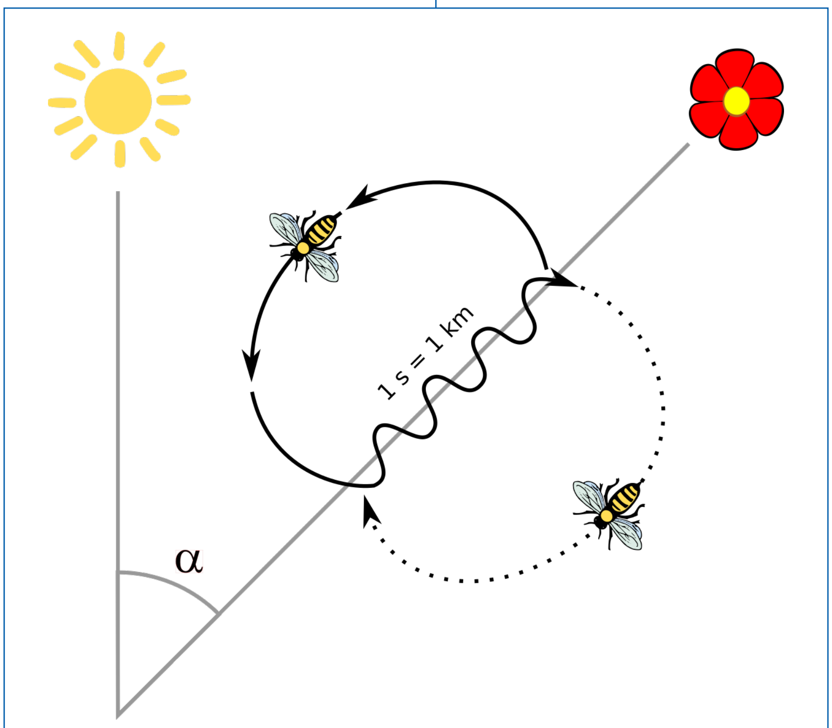
Communication is a central element in human life; it allows us to share information, express feelings, and build relationships with others. Especially in an environment that requires cooperation—e.g., within our homes or workplaces—all parties must have the ability to communicate, as well as receive communication from others. We communicate in a variety of ways, using verbal languages, non-verbal cues, written communication, and many other modes of passing on our ideas. We have also developed symbolic communication, which is the intentional exchange of information regarding objects that are not present (Buck & VanLear 2006). An example of symbolic communication in humans is sign language, which is used predominantly by people with hearing difficulties. To allow for sign language and other types of symbolic communication, there must be a shared system of signals that can be understood by all parties involved (Buck & VanLear 2006).

Humans' ability to communicate effectively has been an integral part of our evolutionary success, so it is no surprise that this ability has evolved in other species as well. European honey bees (*Apis mellifera*) have developed one of the most impressive systems of symbolic communication using movement, which is affectionately known as the "waggle dance" (Barron & Plath 2017). The dance language provides important information about the distance and direction of prominent food sources, based on the specific movements, duration, and location of the dance (Barron & Plath 2017). I'Anson Price and Grüter (2015), as well as Dornhaus and Chittka (2004), have provided various explanations as to why this communicative ability has evolved in *A. mellifera*, which may further our understanding of honey bee cognition and how the dance language may change in the future.

In this essay, I draw on these studies to explain why dance communication evolved in *A. mellifera* and why European honey bees use communication during foraging. In addition, I explore the extent to which honey bees possess the cognitive ability of communication through their renowned dance language.

An Overview of Honey Bee Communication

In a colony of European honey bees, a successful forager will perform a specific dance on the hive when it has scouted an abundant food resource, which recruits additional bee foragers to the intended resources (Barron & Plath 2017). Visually, the dance is a series of repeating figure-eight movements, but the dancer vibrates its wings and waggles its abdomen between the loops of the figure-eight (Barron & Plath 2017). This waggling movement has given rise to the characterization of honey bee communication as the "waggle dance" (Barron & Plath 2017). Key features of the waggle dance change based on the direction and distance of the food source, which categorizes the dance as a form of symbolic communication (Barron & Plath 2017).



Own work - File:Bee dance.png File:Sun01.svg File:Abeille-bee.svg by Emmanuel Boutet File:RosendeutschschweizerBlatt.svg by Kilom691

A honey bee dancer expresses the direction of the food source through the orientation of the dance and the distance of the food source in the duration of the waggle run (I'Anson Price & Grüter 2015). For example, if food resources are closer to the hive, the waggle phase of the dance will be shorter, and the figure-eight pattern will be more of a rounded shape (Barron & Plath 2017). Recruited bees can receive information from the dancer through a combination of touch and recognition of air flows from the wing vibrations of the dance (Michelsen 2003).

Ancestral honey bees first communicated with a simple waggle dance that involved body shaking in the direction of the foraging site with the honey bee dancer performing on the horizontal surface on top of the comb. As the dance developed, the setting of the performance change to the vertical surface of the hive, and the incorporation of the figure-eight pattern allowed the bee dancer to maintain its position on the comb for multiple repetitions of the dance (Barron & Plath 2017).

The Effectiveness of the Waggle Dance

Observational studies (Riley *et al.* 2005) have shown that it can take several iterations of the dance or a necessary search flight before recruits arrive at the indicated food source, or recruits may not find the food source at all. Generally, recruited bees follow at least five waggle runs before they can successfully locate the intended food source. The dance can only give general information about the direction and distance of the food source, so it is the responsibility of the recruited forager to use odor and other senses to trace its exact location (Riley *et al.* 2005).

An experimental study by Riley *et al.* (2005) examined how effectively recruits could use the information contained in the waggle dance to accurately locate a food source. The study used an odorless artificial feeder as the primary food source located near a hive of honey bees. The foraging bees communicated the position of this food source using the waggle dance, and most recruited bees took a flight path almost directly to the food source. However, very few recruited bees actually found the feeder due to its lack of scent.

This experiment also sheds light on the effect of orientation on foraging success. A sample of recruited bees was taken 200 to 250 meters away from the hive after receiving information from the waggle dance, and their flight paths followed the vector that would have taken them to the feeder if their release point had not been altered. These bees strictly followed the directions given during the dance, regardless of where they were released to find the food source because the information in the dance is intended to have a starting point at the hive (Riley *et al.* 2005). The researchers concluded that recruits directly translate the information provided during the waggle dance into real flight paths to a food source. Without a sense of smell or the ability to assess orientation, most recruits would not reach the intended food source; however, by combining dance communication with individual senses, honey bees become very successful at finding plentiful food sources (Riley *et al.* 2005).

In a recent experimental study by Hasenjager *et al.* (2020), researchers found that when finding an intended food source for the first time, recruited bees rely most heavily on information received from dance communication rather than from olfactory and other senses. However, dances that include information about new foraging sites only account for 12-25% of all honey bee dance interactions at the hive; the remaining 75-88% of dances relay information about a known food source. Hasenjager *et al.* (2020) found that foraging bees who are recruited to known food sites rely on not only the waggle dance, but also odor-based searching.

Ecological Circumstances That Favored the Evolution of Dance Communication

For European honey bees to relay information via the waggle dance requires them to have sophisticated cognitive abilities, including spatial memory and cooperation. These abilities likely arose from environmental challenges, such as the variability in food quality and distribution (Van Horik *et al.* 2012). I'Anson Price and Grüter (2015) assessed the seasonal differences in honey bee dance communication, concluding that the waggle dance was beneficial to foraging success in the winter, but less so the rest of the year. Because resources are sparser in the winter, the spatial information provided during the waggle dance is essential for finding food sources for the colony.

Evidence from experimental and observational studies (Dornhaus & Chittka 2004; Donaldson-Matasci & Dornhaus 2012) suggests that dance communication in honey bees originally evolved in a tropical habitat due to the clustered and diverse food sources. In their experimental study, Dornhaus and Chittka (2004) measured the foraging success of colonies in which they obstructed direct communication and compared this to foraging success in a colony with normal communication. The experiment used artificial feeders to act as the food source to induce dance communication. The researchers used three different test sites to vary the habitat of the experiment: two temperate locations in Spain and Germany and one tropical location in India. The researchers made every effort to simulate the conditions of European honey bees in the wild (colony size, space inside the hive, etc.) and assessed foraging success by measuring the daily weight change of the hives, which is reflective of the nectar intake of the colony.

The researchers found a difference in the relation between communication and foraging success in the temperate and tropical locations. While there was no change in foraging success between the obstructed and unobstructed dance communication groups in the temperate climates, unobstructed dance communication was associated with significantly greater foraging success in tropical climates. In explaining this phenomenon, Dornhaus & Chittka (2004) describe that the "honey bee dance language is an adaptation to the tropical conditions under which the genus *Apis* diversified and may no longer be essential for efficient foraging in some temperate habitats" (p. 400). A similar study was conducted by Donaldson-Matasci and Dornhaus (2012) on the ecological situations where honey bee communication is most beneficial. However, they used testing sites near Tucson, Arizona to simulate different ecological conditions. The researchers measured the effect of dance communication on foraging success in different environments and found evidence to support that communication is most important in environments with clustered food resources that are variable in quality, which is a distinct characteristic of tropical habitats (Donaldson-Matasci & Dornhaus 2012). There is convincing evidence in both studies that the characteristics of tropical environments are conducive to the evolution and usage of dance communication in European honey bees.

Conclusions

European honey bees use specific movements during the waggle dance to express the location of valuable food resources to the colony (Barron & Plath 2017). Specifically, foraging bees manipulate the orientation and duration of the dance on the vertical surface of their hive, which signals to potential recruits the direction and distance of a food resource (Barron & Plath 2017). This dance language has proven beneficial in the survival of the species because this method of symbolic communication allows for efficient foraging in a colony of honey bees (Barron & Plath 2017). When the intended resources are at a known versus novel site, however, dance communication is not as essential to successful foraging (Hasenjager *et al.* 2020). The use of the waggle dance is less important in temperate habitats as well because food resources are more consistent in those locations (Dornhaus & Chittka 2004; Donaldson-Matasci & Dornhaus 2012).

There have already been great improvements to the honey bee dance language since its inception, and these advancements are an important part of honey bee foraging success in the wild. Recent evidence (Dornhaus & Chittka 2004; Donaldson-Matasci & Dornhaus 2012) suggests that the waggle dance evolved in an ancestral Apis species in the tropics in response to the high cost of foraging for patchy resources. As the genus diversified into more temperate habitats, the dance persisted, and it is still present in the modern-day species *A. mellifera.* In the more temperate environments, where high-quality resources are plentiful, the ability for European honey bees to communicate via the waggle dance may not be as important for their foraging success as other methods (odor-based searching, spatial memory, etc.). As the importance of dance communication wanes in these temperate locations, so will the frequency at which the waggle dance is used in those colonies.

European honey bees, as well as many species in the genus *Apis,* continue to possess an amazing form of symbolic communication that is scarcely found in invertebrates, but this impressive ability is at risk of dying out in honey bee populations where food resources can be found easily by other means. Examining exactly how this ability of communication is used in the honey bee population would enhance our understanding of how and why the dance language developed originally. In addition, future research could identify other ecological or behavioral conditions that are impacting the impressive dance language in *A. mellifera* today.

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