INCOGNIZANT COLLECTIVE DECISION MAKING IN ANT COLONIES
Jake R. Hanson1, Sara I. Walker1,2, Gabriele Valentini1, Theodore P. Pavlic3, and Stephen C. Pratt4
1School of Earth and Space Exploration, Arizona State University
2Beyond Center for Fundamental Concepts, Arizona State University
3School of Computing, Informatics, and Decision Systems Engineering, Arizona State University
4School of Life Sciences, Arizona State University

Overview
Temnothorax rugatulus is a house hunting ant capable of collectively selecting a nest from a myriad of potential nest sites. Like many other emergent decision-making systems, the colony makes the correct decision in absence of centralized control and with limited information at the individual level. Usually, this is taken to imply the existence of information aggregation at the colony level, whereby information about each nest spreads throughout the colony via ant-to-ant interactions. Here, however, we provide a completely different explanation for how the decision is reached that does not involve aggregating opinions among ants. Instead, each ant executes a random walk incognizant of the opinion of other ants, and the environment dictates the outcome of the decision-making process.

Background
Preference experiments have been carried out that show, in absence of external pressure, Temnothorax rugatulus prefer small nests with small entrances [1]. Assuming that this preference is indicative of nest quality, ants consistently are able to choose the better of two candidate nests when forced to emigrate during a time of crisis. The bulk of the work done throughout the emigration is performed by only a small subset of ants known as transporters [2]. Transporters are responsible for finding new candidate nests as well as relocating the colony from the old nest to the new nest. There are two behaviorally distinct means of transport exhibited throughout the emigration: tandem running and active transport. Tandem running is a slow process by which a transporter leads a follower to the candidate nest. In contrast, active transport is a fast process by which a transporter picks up a fellow nest mate and carries her to the candidate nest. Generally, it is thought that tandem running represents a phase of deliberation that is ended in favor of active transport only after a quorum has been met at a candidate nest.

Incognizant Decision Making
The mechanism by which transporters perceive quorum in a candidate nest is encounter rate [3]. Since encounter rate is a proxy for nest density, it is believed that higher quality nests reach quorum through preferential recruitment during the deliberation phase (e.g. [4]). This hypothesis implies that transporter behavior changes based on nest quality, which in turn implies they have the cognitive capacity to assess and internalize nest quality in order to react accordingly. As an alternative hypothesis, we propose a cognitively simple deliberation algorithm in which transporters execute a random walk at all times inside a nest regardless of its quality. Since there is a geometric aspect to nest quality, i.e. surface area and entrance size, the higher quality nest is able to hold ants inside longer and effectively build up to quorum. This algorithm can also answer an important open question, namely, the reason for a peak in time spent inside the nest at a specific encounter rate, as Figure 1 shows.

Discussion
The random walk serves the purpose of sensing the global density through encounter rate, and has been shown to be an accurate algorithm for this task [5]. Thus, it is likely that ants are already using a random walk to sense quorum, and this model shows that the same algorithm can accurately choose the best possible nest, without the need to invoke transporters cognizant of nest geometry. This is because the behavioral algorithm relies on information about nest quality stored in the environment rather than internally. This viewpoint deprioritizes individual level cognition in favor of evolutionary tuning of a simple behavioral algorithm. In addition, it allows us to model the dynamics of the collective decision in terms of observable parameters that exist outside the black box of ant psychology and are easily amenable to experiment.

References