



The Thoughtful Animal

Desert Ants Are Better Than Most High School Students At Trigonometry

By Jason G. Goldman on February 20, 2012



*This marks the 500th post in the history of **The Thoughtful Animal**! To mark the occasion, I thought I'd revise and repost the post that started it all. This wasn't the first post I ever wrote, but it was the first post I wrote (back when I was blogging at Wordpress) that got any sort of wider attention, thanks to Dave Munger.*

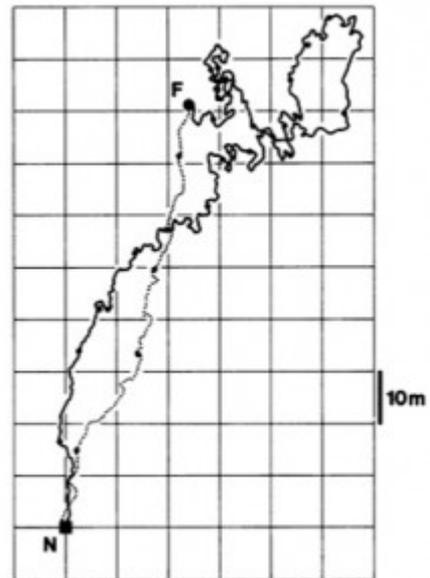
Let's say you're an ant, and the place you call home is the desert-like salt pans of Tunisia. You leave your nest one morning in search of food. You don't know where

you will find food, so you set out from the nest in a random direction, walking around in a twisted circuitous journey until you find something to eat. Now you must return to the nest with the food. How do you get back home?

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Scientists observed that instead of retracing their winding route back home, they head straight back to the nest. How does the ant keep track of its current location relative to home? Path integration is the name given to the process thought to be used by animals (human and non-human alike) for what some might call dead reckoning.

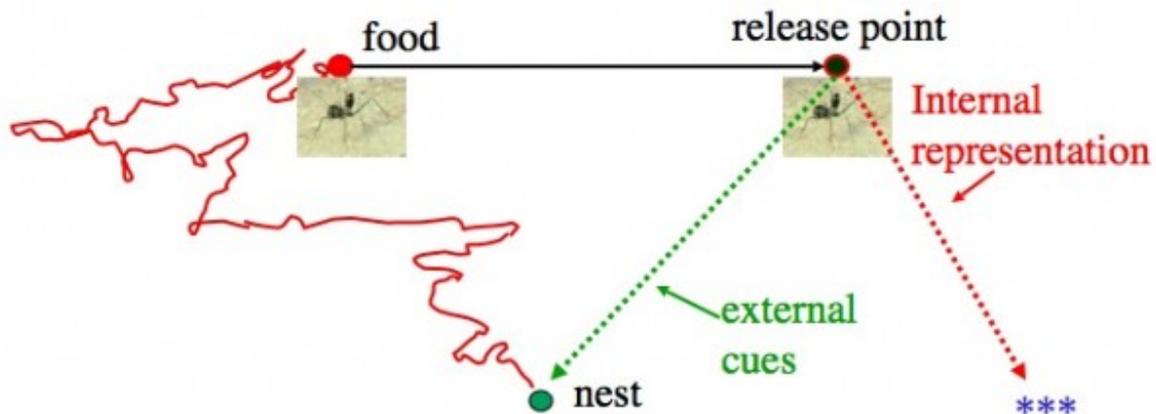
Jungle ants or forest ants might rely on external cues, such as scent trails or visual landmarks, to find their way back home. But the desert generally lacks such visual landmarks, and the strong winds prevent using scent-related cues. It stands to reason that desert ants must have evolved some other cognitive mechanism to find their way back home. On the other hand, it's still possible that the ant makes use of some sort of external cues that are otherwise invisible to humans.



To investigate this question, researchers conducted an ingenious series of experiments out under the hot Tunisian sun. These researchers wake up really early before it gets too hot, drive out to the desert, and find an ant nest. Then, they draw a white grid on the ground, so that they can track the ants movements on a coordinate system.

Eventually, an ant leaves the nest in search of food and finds some bait that has been placed there by one of the researchers. The ant is then picked up, moved some distance away, and placed back on the ground. If ants rely on some sort of

external cues for navigation - even ones invisible to humans -, they should take a path that will lead them back to the nest. However, if they rely on some sort of internal *mental* representation of their location relative to the nest, then they should take a route that they would have taken had they not been picked up and moved. In other words, they should attempt to get home by walking a parallel path to the route they would have taken from the food source. They should actually walk away from the nest.



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And that's exactly what happens. When released, the ants walk on a path that should have taken them back home, had they not been moved. Somehow, the few neurons of the nervous system of the desert ant, maintain a continuous internal representation of the nest's location relative to the ant's current position. Not only that, but they are also extremely accurate. For a five hundred meter outbound journey, their inbound route sends them towards home with an error of only 2 degrees in direction and 10 percent of distance. Even more impressive is that the ant's navigation program accounts for the error: just before they think they've reached home, they switch strategies and walk back and forth in parallel lines until they come across the nest again.

What this means is that each ant must represent the distance and direction to the nest at each point in their journeys, since they don't know when or where they will find food. We know that ants maintain an internal representation of their location relative to home. But how?

The first problem to investigate is how these ants were able to determine the *direction* to get home. Perhaps they use the location of the sun in the sky as a tool in representing the direction back to the nest. In another deceptively simple experiment, scientists used a set of mirrors to alter the perceived location of the sun in the sky. And almost immediately, as soon as the mirrors were in place, the ants altered their paths, using the new location of the sun as their guide. This raised a new problem though: the sun moves across the sky. In another experiment, the researchers waited for an ant leave the nest, find the bait, and then trapped it under a box for a few hours. In that time, the sun would have moved across the sky, and wouldn't have been a reliable tool to use to calculate the return trajectory.

The key to this experiment was that while trapped under the box, the ants would not have been able to continuously update their representation of the nest's direction based on the sun's motion. If they rely on the sun as an external cue, then they would make systematic errors when attempting to navigate back to the nest after being released from their temporary prisons. On the other hand, if they simply use the sun's location as a way to calibrate their own internal clocks, then they would have no trouble getting back home. In another impressive win for the ants, they indeed accurately found their way home. This means that these desert ants maintain a mental representation of the passage of time, even when the movement of the sun is hidden from them!

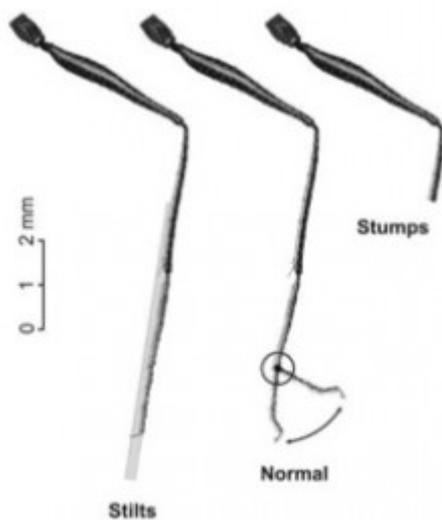
Taken together, this tells us something about how ants determine the *direction* home: they use the sun's motion across the sky in order to calibrate an internal mental clock. Turning their attention to the question of the ants' ability to represent the *distance* home, researchers developed and tested three hypotheses.

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The energy hypothesis proposed that ants keep track of how much energy gets expended during the trip from nest to food, and therefore they know how much energy they should use for the return trip. To test this, once an ant had found a food source, the researchers strapped tiny little backpacks on the ants, therefore changing the weight of the load that their bodies must carry. This change in weight would mean that the energy required to get back home would be greater than it should have been. It turned out that regardless of the weight of the load they were carrying, the desert ants were able to assess their distance home just fine.

The optic-flow hypothesis offered that perhaps the ants have a way of tracking how much "stuff" has passed through their visual field, and assume that after an equivalent amount of visual "stuff" has occurred on the return trip, they must be home. The tireless researcher again follows an ant from nest to food source, and then blindfolds the ant, thus depriving the ant of the optic flow information. Even blindfolded, the ants were able to get back home.

Converging evidence comes from a second type of experiment. This time, scientists put the ant on a very long TV screen on which a video was played, simulating the optic flow of an ant traveling across the desert. By varying the rate at which the video appeared to pass by the ant, researchers were able to manipulate the rate of optic flow. Even this sort of virtual reality manipulation had no influence on the ants' ability to accurately estimate the distance home.



Finally, researchers proposed the pedometer hypothesis: perhaps ants simply count the number of steps that they take. How could you test whether or not the ant counts its steps, using this as a basis for determining the distance back home? Once again you follow a ant to a food source, and once there, you glue pig bristles to the ant's legs, creating ants on stilts. For other ants, rather than making them taller, you make them shorter by amputating their legs below the knee. By varying the length of the stride (longer for

stilts, shorter for stumps), and measuring the distance the ant walks to get back home, you can see if it was counting the steps that it takes. If ants count their

steps, than those on stilts should overestimate the distance home, and those with stumps should underestimate the distance home.

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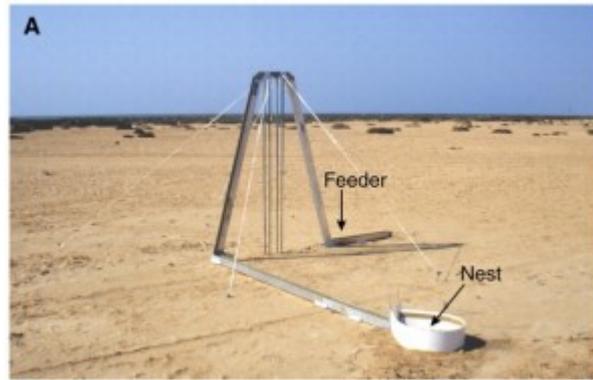


Ant on stilts

It turned out that they did indeed count their steps. The stumpy ants underestimated the distance home, and the stilt-walkers overestimated the distance home. More evidence comes from some ants who were given stilts or stumps prior to leaving the nest: these ants had no problem getting back home, since their legs were of equivalent length for both the outbound and return parts of their journey.

Sometimes, though, there are hills in the desert. And you might wonder: do ants represent their location in 2D space or in 3D space? And so you might be tempted, as some scientists were, to build an elaborate contraption to test this question. A sort-of obstacle course for ants that requires a lot of steps in order to move a relatively small distance in two-dimensional space.

If ants count their steps assuming 2D topography, then when they are moved from the feeder to a location on flat ground, they should considerably overestimate the distance to the nest. If they are counting their steps in relation to 3D space, then they should head home in the accurate direction.



Again the ants were undeterred from finding their way home: ants represent their location in three dimensions!

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Taken together: ants represent the direction home by using the sun as a compass in combination with a mental clock to correct for the changing position of the sun. And they represent distance by counting their steps in 3D space.

It turns out, by the way, that humans use some of the very same mechanisms, subject to the same sorts of limits, to guide our own navigation. These mental navigation systems are likely very, very old.



Research
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Images: internal vs. external representation diagram courtesy Justin Wood. Ant on stilts origin unknown. Other images and diagrams from above-referenced papers.

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Jason G. Goldman is a science journalist based in Los Angeles. He has written about animal behavior, wildlife biology, conservation, and ecology for *Scientific American*, *Los Angeles* magazine, *The Washington Post*, *The Guardian*, the BBC, *Conservation* magazine, and elsewhere. He contributes to *Scientific American's* "60-Second Science" podcast, and is co-editor of *Science Blogging: The Essential Guide* (Yale University Press). He enjoys sharing his wildlife knowledge on television and on the radio, and often speaks to the public about wildlife and science communication.

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