

How the brain navigates cities: We seem to be wired to calculate not the shortest path but the 'pointiest' one

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An MIT study suggests our brains are not optimized to calculate the shortest possible route when navigating on foot. In this figure, pedestrian paths are shown in red while the shortest path is in blue. Credit: MIT



Everyone knows the shortest distance between two points is a straight line. However, when you're walking along city streets, a straight line may not be possible. How do you decide which way to go?

A new MIT study suggests that our brains are actually not optimized to calculate the so-called "shortest path" when navigating on foot. Based on a dataset of more than 14,000 people going about their daily lives, the MIT team found that instead, pedestrians appear to choose paths that seem to point most directly toward their destination, even if those routes end up being longer. They call this the "pointiest path."

This strategy, known as vector-based navigation, has also been seen in studies of animals, from insects to primates. The MIT team suggests vector-based navigation, which requires less brainpower than actually calculating the shortest <u>route</u>, may have evolved to let the brain devote more power to other tasks.

"There appears to be a tradeoff that allows <u>computational power</u> in our brain to be used for other things—30,000 years ago, to avoid a lion, or now, to avoid a perilious SUV," says Carlo Ratti, a professor of urban technologies in MIT's Department of Urban Studies and Planning and director of the Senseable City Laboratory. "Vector-based navigation does not produce the shortest path, but it's close enough to the shortest path, and it's very simple to compute it."

Ratti is the senior author of the study, which appears today in *Nature Computational Science*. Christian Bongiorno, an associate professor at Université Paris-Saclay and a member of MIT's Senseable City Laboratory, is the study's lead author. Joshua Tenenbaum, a professor of computational cognitive science at MIT and a member of the Center for Brains, Minds, and Machines and the Computer Science and Artificial Intelligence Laboratory (CSAIL), is also an author of the paper. A preprint version of this study was posted to <u>arXiv.org</u> earlier this year.



Vector-based navigation

Twenty years ago, while a <u>graduate student</u> at Cambridge University, Ratti walked the route between his residential college and his departmental office nearly every day. One day, he realized that he was actually taking two different routes—one on to the way to the office and a slightly different one on the way back.

"Surely one route was more efficient than the other, but I had drifted into adapting two, one for each direction," Ratti says. "I was consistently inconsistent, a small but frustrating realization for a student devoting his life to rational thinking."

At the Senseable City Laboratory, one of Ratti's research interests is using large datasets from mobile devices to study how people behave in urban environments. Several years ago, the lab acquired a dataset of anonymized GPS signals from cell phones of pedestrians as they walked through Boston and Cambridge, Massachusetts, over a period of one year. Ratti thought that these data, which included more than 550,000 paths taken by more than 14,000 people, could help to answer the question of how people choose their routes when navigating a city on foot.

The research team's analysis of the data showed that instead of choosing the shortest routes, pedestrians chose routes that were slightly longer but minimized their angular deviation from the destination. That is, they choose paths that allow them to more directly face their endpoint as they start the route, even if a path that began by heading more to the left or right might actually end up being shorter.

"Instead of calculating minimal distances, we found that the most predictive model was not one that found the <u>shortest path</u>, but instead one that tried to minimize angular displacement—pointing directly



toward the destination as much as possible, even if traveling at larger angles would actually be more efficient," says Paolo Santi, a principal research scientist in the Senseable City Lab and at the Italian National Research Council, and a corresponding author of the paper. "We have proposed to call this the pointiest path."

This was true for pedestrians in Boston and Cambridge, which have a convoluted network of streets, and in San Francisco, which has a gridstyle street layout. In both cities, the researchers also observed that people tended to choose different routes when making a round trip between two destinations, just as Ratti did back in his graduate school days.

"When we make decisions based on angle to destination, the street network will lead you to an asymmetrical <u>path</u>," Ratti says. "Based on thousands of walkers, it is very clear that I am not the only one: Human beings are not optimal navigators."

Moving around in the world

Studies of animal behavior and brain activity, particularly in the hippocampus, have also suggested that the brain's navigation strategies are based on calculating vectors. This type of navigation is very different from the computer algorithms used by your smartphone or GPS device, which can calculate the shortest route between any two points nearly flawlessly, based on the maps stored in their memory.

Without access to those kinds of maps, the animal brain has had to come up with alternative strategies to navigate between locations, Tenenbaum says.

"You can't have a detailed, distance-based map downloaded into the brain, so how else are you going to do it? The more natural thing might



be use information that's more available to us from our experience," he says. "Thinking in terms of points of reference, landmarks, and angles is a very natural way to build algorithms for mapping and navigating space based on what you learn from your own experience moving around in the world."

"As smartphone and portable electronics increasingly couple human and artificial intelligence, it is becoming increasingly important to better understand the computational mechanisms used by our brain and how they relate to those used by machines," Ratti says.

More information: Paolo Santi, Vector-based pedestrian navigation in cities, *Nature Computational Science* (2021). DOI: <u>10.1038/s43588-021-00130-y</u>. <u>www.nature.com/articles/s43588-021-00130-y</u>

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