Human behaviour follows probabilistic inference patterns

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The researchers designed their experiments presenting hierarchical integration tasks using the plane task. Credit: UPF

How do human beings perceive their environment and make their decisions? To successfully interact with the immediate environment, for human beings it is not enough to have basic evidence of the world around them. This information by itself is insufficient because it is inherently ambiguous and requires integrating into a particular context to minimize the uncertainty of sensory perception. But, at the same time, the context is ambiguous. For example, am I in a safe or a dangerous place?

A study published on 28 November in *Nature Communications* by Philipp Schustek, Alexandre Hyafil and Rubén Moreno-Bote, researchers at the Center for Brain and Cognition (CBC) of the Department of Information and Communication Technologies (DTIC) at UPF, suggests that the brain has a refined form of representation of uncertainty at several hierarchical levels, including context. Hence, the brain has a very detailed, almost mathematical probabilistic representation of all that surrounds us we consider important.

"The notions of probability, though intuitive, are very difficult to quantify and use rigorously. For example, my statistics students often fail to solve some of the problems I pose in class. In our study, we find that a complicated mathematical problem involving the use of the most sophisticated rules of probability can be solved intuitively if it is presented simply and in a natural context," asserts Rubén Moreno-Bote, coordinator of the Research Group on Theoretical and Cognitive Neuroscience at the CBC.

Cognitive tasks of hierarchical integration

Let us suppose that a city airport is hosting a football final and we look at a few passengers who are leaving a plane. If we note that four of them are fans of the red team and two of the blue team, we could conclude that more fans of the red team are attending the final than of the blue team. This inference, based on incomplete sensory evidence, could be improved with contextual information.

For example, if worldwide there are more fans of the blue team than of the red team, despite our initial observation, we would review our inference counting how many supporters of each group are travelling on the plane to more accurately confirm whether more fans of the red team have really come to the city than of the blue team. Or, we could also do the opposite, basing ourselves on the context inferring whether the sample observed follows the more general context or not.

The researchers designed their experiments presenting hierarchical integration tasks using the plane task. "For the study, we told our participants that they are at an airport where planes can arrive carrying more of one type of person than of another, for example, more supporters of Barça than of Madrid. On seeing a handful of passengers leaving several aircraft, the participants can predict with mathematical precision the likelihood that the next plane will be carrying more passengers of a certain type," Moreno-Bote explains.

"In general, this structure of tasks creates hierarchical dependencies among the hidden variables to be solved bottom up (deducing the context of previous observations) and then passing the message top down (deducing the current status combining current observations with the inferred context)," the authors explain.

The results showed that the participants, based on their preliminary observations, built a probabilistic representation of the context. These results help to understand how people form mental representations of

what surrounds us and how we assign and perceive the uncertainty of this context.

More information: Philipp Schustek et al, Human confidence judgments reflect reliability-based hierarchical integration of contextual information, *Nature Communications* (2019). DOI: 10.1038/s41467-019-13472-z