Faith, truth and forgiveness: How your brain processes abstract thoughts

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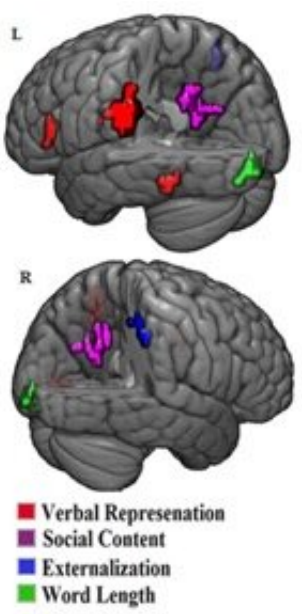

Voxel clusters with the highest loading for interpretable factors. Credit: Cerebral Cortex

Researchers at Carnegie Mellon University have leveraged machine learning to interpret human brain scans, allowing the team to uncover the regions of the brain behind how abstract concepts, like justice, ethics and consciousness, form. The results of this study are available online in the October 29 issue of *Cerebral Cortex*.

"Humans have the unique ability to construct abstract concepts that have no anchor in the physical world, but we often take this ability for granted," said Marcel Just, the D.O. Hebb University Professor of Psychology at CMU's Dietrich College of Humanities and Social Sciences and senior author on the paper. "In this study, we have shown that newly identified components of meaning used by the human brain that acts like an indexing system, similar to a library's card catalog, to compose the meaning of abstract concepts."

The ability of humans to think abstractly plays a central role in scientific and intellectual progress. Unlike concrete concepts, like hammer, abstract concepts, like ethics, have no obvious home in the parts of the brain that deal with perception or control of our bodies.

"Most of our understanding of how the brain processes objects and concepts is based on how our five senses take in information," said Robert Vargas, a CMU graduate student in Just's lab and first author on the paper. "It becomes difficult to describe the neural environment of abstract thoughts because many of the brain's mental tools to process them are themselves abstract."

In this study, Just and his team scanned the brains of nine participants using a functional MRI. The team sifted through the data using machine learning tools to identify patterns for each of the 28 abstract concepts. They applied the machine learning algorithm to correctly identified each concept (with a mean rank accuracy of 0.82, where chance level is 0.50).

Just said these abstract concepts are constructed by three dimensions of meaning in the brain. The first dimension corresponds to regions associated with language. For example, the concept of ethics might be linked to other words like rules and morals. A person must first understand the words to construct the additional meaning of ethics. The second dimension defines abstract concepts in terms of reference, either to self or an external source. For example, spirituality refers to self, while causality is external to the self. The final dimension is rooted in social constructs. There is an inherent social component to the concepts of pride and gossip.

"For me, the most exciting result of this study was that we were able to predict the neural activation patterns for individual abstract concepts across people," Vargas said. "It is wild to think that my

concept of probability and spirituality is neurally similar to the next person's, even if their experience of spirituality is different."

During the scan, each concept was presented visually and the participant was allowed to think about this idea for three seconds. The participants saw the set of words six times.

The 28 concepts covered in the study span seven categories: mathematics (subtraction, equality, probability and multiplication); scientific (gravity, force, heat and acceleration); social (gossip, intimidation, forgiveness and compliment); emotion (happiness, sadness, anger and pride); law (contract, ethics, crime and exoneration); metaphysical (causality, consciousness, truth and necessity) and religiosity (deity, spirituality, sacrilege and faith).

The work is based on nine adult brain scans from a culturally homogenous community on the CMU campus.

"It's flashy to call this work mind reading," Just said. "For me, it is proof that we have identified some of the elements of the brain's indexing system—verbal representation, externality/internality and the social dimension—that our brains use to code concepts that have no physical manifestation in the world."

Just and Vargas published the article, titled "Neural representations of Abstract Concepts: Identifying Underlying Neurosemantic Dimensions" in the October issue of *Cerebral Cortex*.

Provided by Carnegie Mellon University