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Neuroscience: The extraordinary ease of ordinal series

December 20 2012

Familiar categories whose members appear in orderly sequences are processed differently than others in the brain, according to new research published by David Eagleman in the open access journal *Frontiers in Neuroscience* on December 20th, 2012. The study suggests that ordinal sequences have a strong spatial quality and activate a region of the brain not thought to be directly involved in language acquisition and production. Also, sequences shown in the correct order stimulated less brain activity in comparison to sequences that were not in the correct order, implying that the brain could predict what was coming and needed less activity to understand it.

"When an event happens, the brain can use less energy in its response if it has already predicted that event," says Eagleman of the Baylor College of Medicine in Houston, Texas. "Fundamentally, its job is to make a good model of the world so that it can avoid being surprised. The better it predicts, the more energy it saves."

Previous research suggested that so-called ordinal categories have unique properties that are encoded differently from non-ordinal sequences.

In some forms of dementia, for example, memories for ordinal stimuli such as numbers are spared, while those for non-ordinal stimuli, such as the names of animals or fruits, are impaired. And in a neurological condition called synesthesia, sensory experiences such as colour are triggered by unrelated inputs, especially ordinal stimuli such as numbers, letters and months of the year.

Until now, however, little was known about the neural representation of ordinal sequences.

To investigate, David Eagleman and his team recruited 35 participants and used functional magnetic resonance imaging (fMRI) to measure their brain activity while they performed an "oddball" task.

The participants were presented with lists of five words that appeared one after the other for half a second each. In one condition, ordinal words were shown in their correct order (e.g. Monday, Tuesday, Wednesday, Thursday, Friday). The second condition involved ordinal words presented in a scrambled order, and the third contained words belonging to non-ordinal categories.

Each participant completed 20 practice trials before being placed into the scanner to perform 120 more. During half of the trials, the fifth word in the sequence was replaced with an oddball stimulus, such as four days of the week followed by the word "banana," or four fruits followed by a number.

After completing each trial, the participants were simply required to indicate whether or not it contained an oddball stimulus, by pressing one of two buttons.

The researchers compared the brain scans obtained during the different trials, to determine which brain regions responded to ordinal words, and how the predictability of the word sequences affected the patterns of brain activity. Scrambled sequences (such as Sunday, Wednesday, Tuesday, Friday) elicited greater activity than did sequences in their correct order.

In other words, the more predictable a sequence of ordinal words was, the less brain activity it evoked. This, the researchers say, is direct

evidence that long-term experience dampens neural activity. The brain pays little attention to stimuli that are familiar, but alarm bells start to ring when those that do not meet our expectations.

Further, the study revealed that the processing of ordinal words involves more activation of the right hemisphere than the left—a surprise finding given that language is typically a left hemisphere phenomenon.

"We are just beginning experiments in which we teach people with synesthesia a new alphabet of arbitrary symbols – what we call an 'alien' alphabet. Through the use of video games, we rigorously train them on this novel sequence. We predict that the arbitrary symbols will take on synesthetic colors, and that the representation of those symbols move from the left to the right hemisphere."

More information: Pariyadath, V., et al. (2012). Why Overlearned Sequences are Special: Distinct Neural Networks for Ordinal Sequences. *Frontiers in Human Neuroscience*, DOI: 10.3389/fnhum.2012.00328

Provided by Frontiers