How Our Brains Create Categories: A Look Inside the Mind

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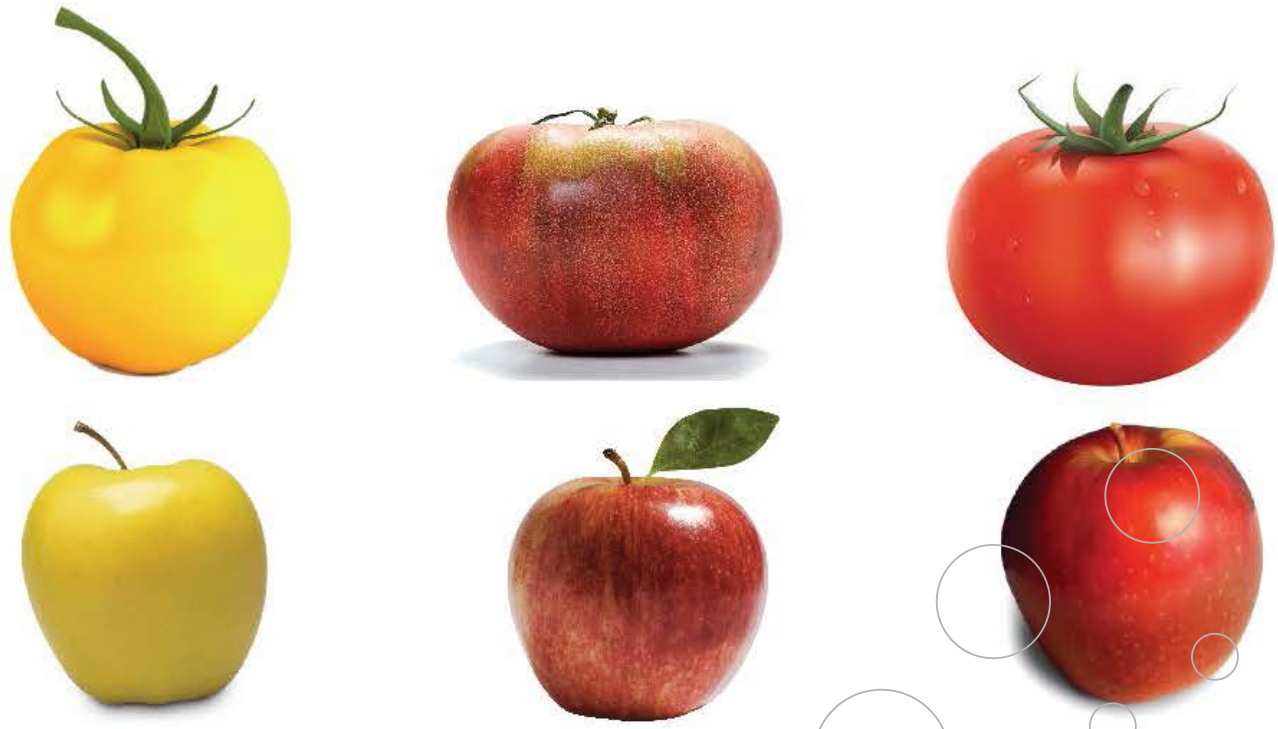
What is more similar to the yellow tomato, the yellow apple or the red tomato?



How Our Brains Create Categories: A Look Inside the Mind

Our brains have an incredible ability to organise information into meaningful categories, allowing us to make sense of the world around us. However, this categorisation process can also bias how we perceive and remember this world. Dr Dagmar Zeithamova and her team at the University of Oregon are uncovering how our brains form category-biased representations, even when we're focused on learning about individual examples. Their work sheds new light on the neural mechanisms underlying concept formation and how categories shape our perceptions.

The Power of Categories

From the moment we wake up, our brains are constantly sorting the flood of sensory information we encounter into meaningful categories. This ability to organise our experiences allows us to navigate the world efficiently, make quick decisions, and draw on past knowledge to interpret new situations. However, our inclination to categorise can also lead to biases in how we perceive and remember individual items.

Previous research has shown that after learning to sort items into categories, we tend to perceive examples from the same category as more similar to each other than they actually are. At the same time, we perceive more significant differences between items from different categories. This 'perceptual magnet effect' can occur even for arbitrary categories created in laboratory settings.

While this categorical perception can be helpful in many situations, allowing us to focus on relevant similarities and differences, it can also lead us to overlook individual variations within a category. This tendency toward categorical thinking may contribute to harmful social biases like stereotyping. Understanding the cognitive and neural mechanisms behind category formation could provide insights into how such biases develop and potentially how to counteract them.

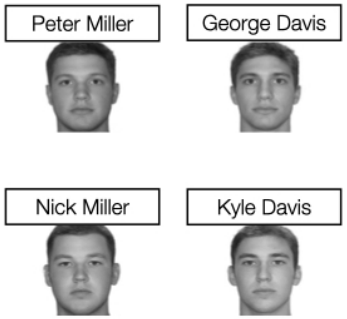
But how and when do these category-biased perceptions form in the brain? Do they only arise when we are explicitly trying to learn about categories? Or can simply learning category labels lead to spontaneous changes in how our brains represent individual examples? These are some of the key questions Dr Dagmar Zeithamova and her colleagues at the University of Oregon set out to investigate.

Unveiling Category Bias in the Brain

Dr Zeithamova, an associate professor of psychology, has long been fascinated by how the brain integrates information across experiences to form new knowledge. Her work combines behavioural experiments with advanced brain imaging techniques to peer into the neural mechanisms of learning and memory.

In a recent study, Dr Zeithamova and her team used an innovative experimental design to track how category learning shapes neural representations. They wanted to see if category-biased neural patterns would form even when people were focused on learning about individuating details rather than categories. The researchers created a set of face stimuli by blending photographs of different individuals. Some faces shared visual features because they were created by blending the same 'parent' faces. Crucially, some pairs of visually similar faces were assigned to the same category by giving them the same family name, while other similar pairs were assigned to different categories with different family names. This allowed the team to separate the effects of visual similarity from learned category membership.

Participants in the study were asked to learn the full names (both first and family names) for each face. Importantly, they were not told to focus on the categories or family names – their task was simply to memorise the individual name-face pairs.



< Illustration of the category learning task.

Grouping the faces in family categories was not really helpful for the task at hand as participants needed to differentiate 'Peter Miller' from 'George Miller' and 'John Miller'. This meant any effects of categorisation would occur spontaneously rather than through explicit category learning.

As the participants studied the face-name pairs, their brain activity was recorded using functional magnetic resonance imaging (fMRI). This allowed the researchers to examine the patterns of neural activity associated with viewing each individual face. After learning, participants also completed perceptual similarity ratings and a surprise categorisation test with new face examples.

Tracking Category Information in the Brain

To analyse the fMRI data, Dr Zeithamova's team used advanced pattern analysis techniques that can detect subtle differences in how information is represented across populations of neurons. They looked for evidence that the brain was encoding category-relevant information about the faces, even though participants weren't explicitly trying to learn categories.

The results were striking. Even during initial learning, when participants were focused on memorising individual face-name pairs, their brains were spontaneously extracting and representing category information. The researchers could reliably decode which category (family name) a face belonged to based on the pattern of brain activity it evoked, particularly in regions involved in concept representation and generalisation like the middle temporal gyrus and ventromedial prefrontal cortex. Dr Zeithamova notes that this spontaneous formation of category-biased neural representations may help explain why we so readily generalise our experiences. Our brains seem primed to extract category-relevant patterns from our experiences, allowing us to apply knowledge to new situations. However, it may also contribute to over-generalisation and stereotyping in some cases.

From Neural Patterns to Behaviour

After the learning phase, participants were asked to rate the visual similarity of different face pairs. They also completed a surprise categorisation test where they had to assign new face examples to the correct family name categories. Interestingly, while the group as a whole did not show a significant behavioural category bias in their similarity ratings, there were individual differences. Participants who showed a stronger neural category bias were more likely to rate faces from the same category as more similar. They also performed better on the surprise categorisation test with new face examples.

This suggests that the strength of category representations formed during learning, even when not explicitly focused on categories, can influence later perception and the ability to generalise category knowledge to new examples. Dr Zeithamova points out that the neural measures may be more sensitive early indicators of categorical thinking compared to explicit behavioural measures.

Widespread Category Effects in the Brain

One surprising aspect of the results was how widespread the category effects were in the brain. While the researchers had predicted category-biased representations would form in regions

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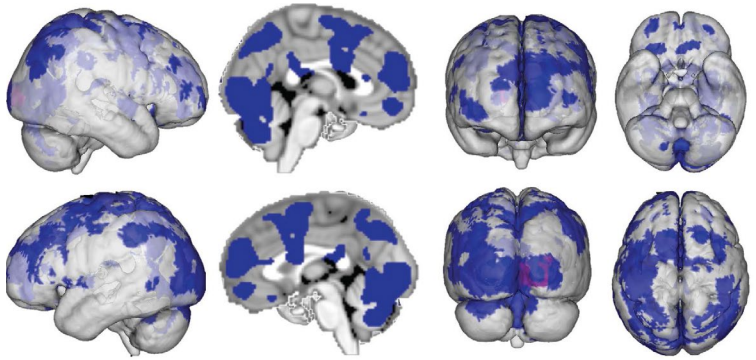
Credit: Dr Dagman Zeithamove Demircan.



previously implicated in concept learning and memory generalisation, like the ventromedial prefrontal cortex, they found category information distributed across many areas of the cortex. Even early visual processing regions showed some evidence of emphasising category-relevant visual features. This aligns with other research suggesting that conceptual knowledge can influence visual processing through top-down attentional effects.

Dr Zeithamova speculates that the widespread nature of the category representations may reflect attentional biasing toward category-relevant features across multiple levels of processing. Rather than being confined to high-level conceptual regions, category learning may alter how information is processed and represented throughout much of the cortex.

Practical Applications and Societal Impact

This research provides important insights into how our brains spontaneously organise information into meaningful categories, even when we're not explicitly trying to learn or create categories. It demonstrates that simply being exposed to category labels can bias how our brains represent individual items, highlighting features relevant to category membership.

These findings have potential implications for understanding how stereotypes and social biases might form. Even without intentionally trying to create categories, our brains may extract and emphasise similarities among individuals assigned to the same group. This could contribute to overlooking individual differences and overgeneralising based on group membership.

Dr Zeithamova emphasises that categories themselves are not inherently problematic – they are a crucial tool for efficiently organising knowledge. The key is being aware of when categorical thinking may lead us astray and developing strategies to look beyond category labels when needed. As we navigate an increasingly complex world, understanding the cognitive mechanisms behind categorisation and generalisation is more crucial than ever. Dr Zeithamova and her colleagues are shedding new light on how our brains make sense of the world around us, one category at a time.

MEET THE RESEARCHER

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Dr Dagmar (Dasa) Zeithamova Demircan is an associate professor at the Department of Psychology and Institute of Neuroscience at the University of Oregon. Her research focuses on the formation of knowledge and flexible use of experience, with particular emphasis on mechanisms supporting memory specificity and generalisation. Dr Zeithamova employs a combination of functional MRI, computational modelling, and behavioural methods to investigate how the brain builds conceptual knowledge from individual experiences. She has made significant contributions to understanding the roles of the prefrontal cortex and hippocampus in category learning and memory integration. Dr Zeithamova's work has been supported by grants from the National Institutes of Health, and she has received recognition for her research and mentorship, including the 2024 Faculty Research Mentor Award from the University of Oregon and a Humboldt Research Fellowship for Experienced Researchers in 2022.

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FURTHER READING

CR Bowman, T Iwashita, D Zeithamova, Tracking prototype and exemplar representations in the brain across learning, *eLife*, 2020, 9, e59360. DOI: https://doi.org/10.7554/eLife.59360

L Frank, CR Bowman, D Zeithamova, Differential functional connectivity along the long axis of the hippocampus aligns with differential role in memory specificity and generalization, Journal of *Cognitive Neuroscience*, 2019, 31(12), 1958–1975. DOI: https://doi.org/10.1162/jocn_a_01457

D Zeithamova, ML Mack, K Braunlich, *et al.*, Brain mechanisms of concept learning, *Journal of Neuroscience*, 2019, 39(42), 8259–8266. DOI: https://doi.org/10.1523/JNEUROSCI.1166-19.2019