

# How does the word 'not' affect what we understand? Scientists find negation mitigates our interpretation of phrases

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When we're told "This coffee is hot" upon being served a familiar caffeinated beverage at our local diner or cafe, the message is clear. But what about when we're told "This coffee is not hot"? Does that mean we

think it's cold? Or room temperature? Or just warm?

A team of scientists has now identified how our brains work to process phrases that include negation (i.e., "not"), revealing that it mitigates rather than inverts meaning—in other words, in our minds, negation merely reduces the temperature of our coffee and does not make it "cold."

"We now have a firmer sense of how negation operates as we try to make sense of the phrases we process," explains Arianna Zuanazzi, a postdoctoral fellow in New York University's Department of Psychology at the time of the study and the lead author of the paper, which appears in the journal *PLOS Biology*.

"In identifying that negation serves as a mitigator of adjectives—bad or good, sad or happy, and cold or hot—we also have a better understanding of how the brain functions to interpret subtle changes in meaning."

In an array of communications, ranging from advertising to legal filings, negation is often used intentionally to mask a clear understanding of a phrase. In addition, [large language models](#) in AI tools have difficulty interpreting passages containing negation. The researchers say that their results show how humans process such phrases while also potentially pointing to ways to understand and improve AI functionality.

While the ability of human language to generate novel or complex meanings through the combination of words has long been known, how this process occurs is not well understood.

To address this, Zuanazzi and her colleagues conducted a series of experiments to measure how participants interpreted phrases and also monitored participants' brain activity during these tasks—in order to

precisely gauge related neurological function.

In the experiments, participants read—on a computer monitor—adjective phrases with and without negation (e.g., "really not good" and "really really good") and rated their meaning on a scale from 1 ("really really bad") to 10 ("really really good") using a mouse cursor. This scale was designed, in part, to determine if participants interpreted phrases with negation as the opposite of those without negation—in other words, did they interpret "really not good" as "bad"—or, instead, as something more measured?

Here, the researchers found that participants took longer to interpret phrases with negation than they did phrases without negation—indicating, not surprisingly given the greater complexity, that negation slows down our processing of meaning.

In addition, drawing from how the participants moved their cursors, negated phrases were first interpreted as affirmative (i.e., "not hot" was initially interpreted as closer to "hot" than to "cold"), but later shifted to a mitigated meaning, suggesting that, for instance, "not hot" is not interpreted as either "hot" or "cold," but, rather, as something between "hot" and "cold."

The scientists also used magnetoencephalography (MEG) to measure the magnetic fields generated by the electrical activity of participants' brains while they were performing these phrase-interpretation tasks. As with the behavioral experiments, neural representations of polar adjectives such as "cold" and "hot" were made more similar by negation, suggesting that the meaning of "not hot" is interpreted as "less hot" and the meaning of "not cold" as "less cold," becoming less distinguishable.

In sum, neural data matched what was observed for the mouse movements in the [behavioral experiments](#): negation does not invert the

meaning of "hot" to "cold," but rather weakens or mitigates its representation along the semantic continuum between "cold" and "hot."

"This research spotlights the complexity that goes into language comprehension, showing that this [cognitive process](#) goes above and beyond the sum of the processing of individual word meanings," observes Zuanazzi, now at the Child Mind Institute.

**More information:** Zuanazzi A, Ripollés P, Lin WM, Gwilliams L, King J-R, Poeppel D, Negation mitigates rather than inverts the neural representations of adjectives. *PLoS Biology* (2024). [DOI: 10.1371/journal.pbio.3002622](#)

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