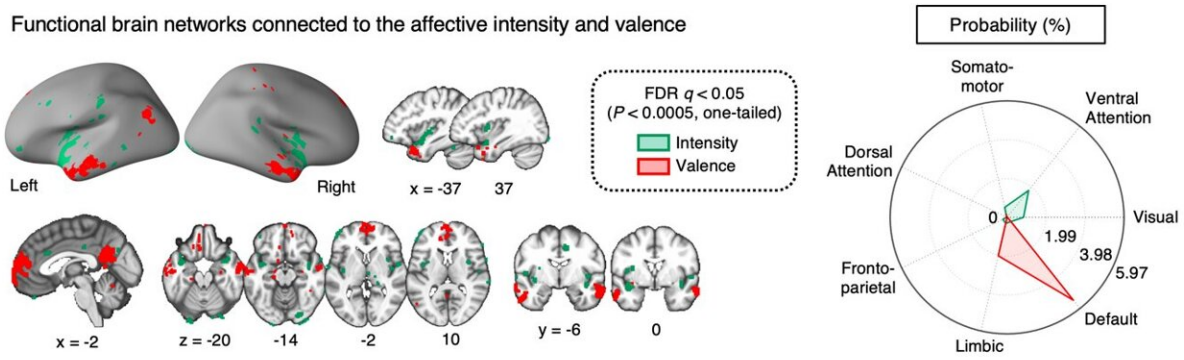
Machine learning and fMRI reveal brain activity patterns for sustained pain and pleasure

June 11 2024



Functional brain networks that are connected to the affective intensity and valence information. Left: The affective valence information is connected to the limbic and default mode networks, and the affective intensity information is connected to the ventral attention network. Right: The probability that the affective intensity and valence is connected to each of seven functional brain networks. Credit: *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2310433121

A team of researchers has revealed how the brain processes emotional

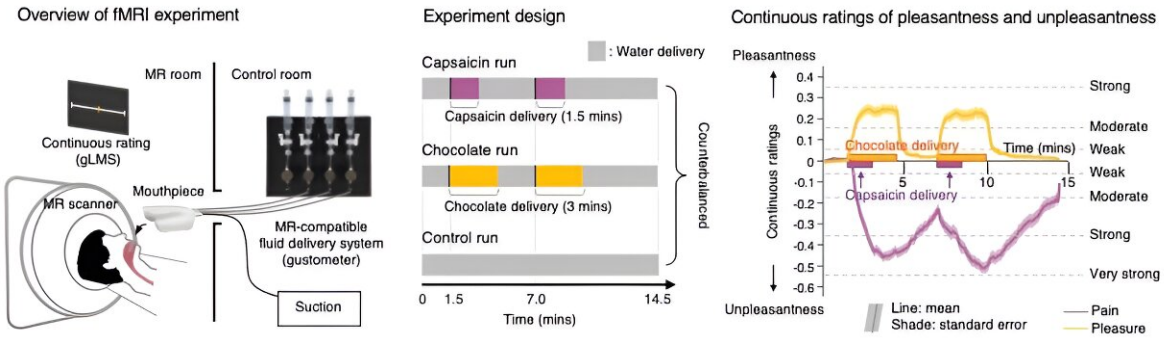
information of sustained pain and pleasure. Using functional Magnetic Resonance Imaging (fMRI), the team recorded brain activity while participants experienced sustained pain and pleasure induced by capsaicin and chocolate fluids. The study is published in the journal *Proceedings of the National Academy of Sciences*.

Through sophisticated machine learning techniques, they unraveled the brain activity patterns that encode pleasant or unpleasant emotions and the magnitude of sustained pain and pleasure.

Although pain and pleasure are opposite experiences, they are intricately connected. Previous studies have suggested a set of brain regions that respond to both pain and pleasure. However, most previous studies have been conducted on animals rather than humans, and studies that directly compared the brain representations of pain and pleasure within the same individuals are still lacking.

In this study, the research team led by Lee Soo Ahn and Woo Choong-Wan at the Center for Neuroscience Imaging Research (CNIR) within the Institute for Basic Science (IBS), in collaboration with Choi Myunghwan at Seoul National University and Tor D. Wager at Dartmouth College, conducted an experiment that induced sustained pain and pleasure to participants in the MR scanner, by delivering capsaicin and chocolate fluids.

While experiencing sustained pain and pleasure, participants reported moment-by-moment changes in subjective pleasantness and unpleasantness.



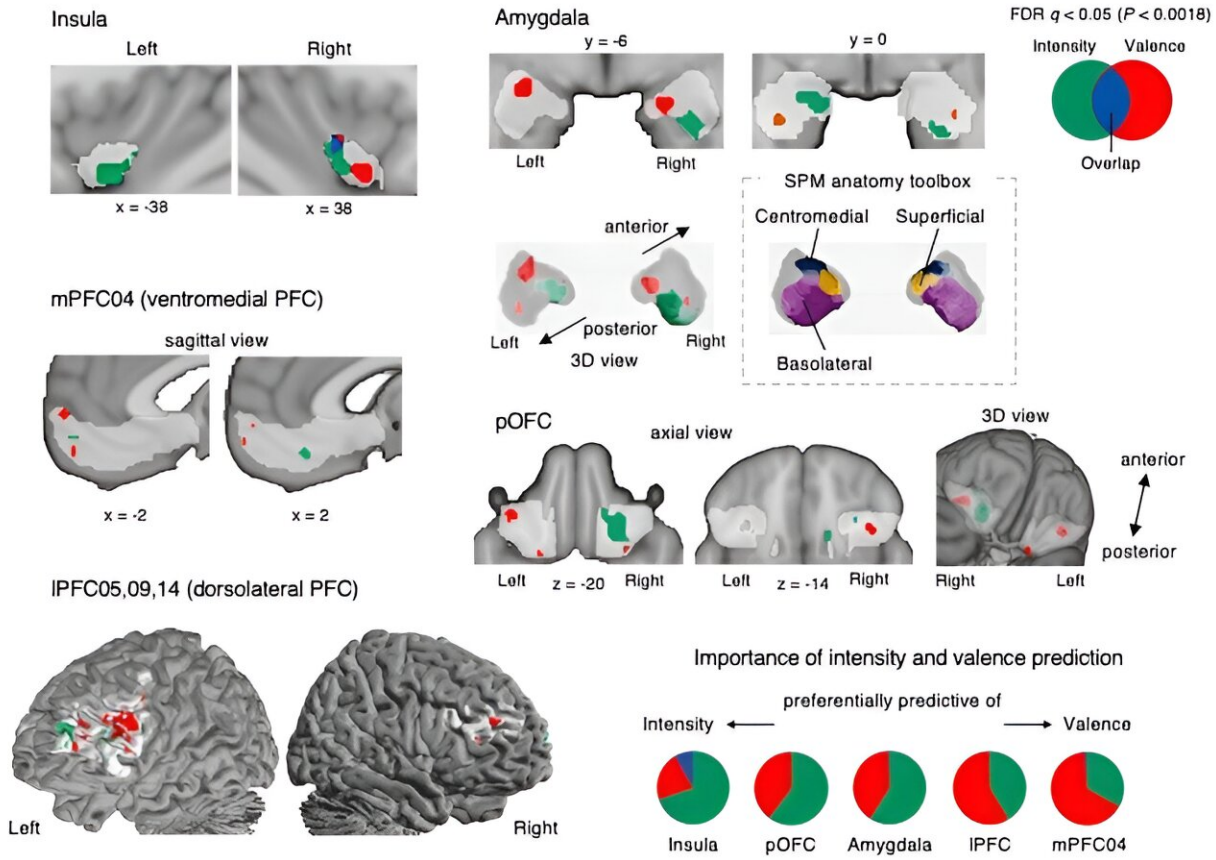
Overview of the fMRI experimentLeft: Fluids were delivered using an MR-compatible fluid delivery system (gustometer) and removed from participants' mouths during the experiment using a suction device.Middle: Capsaicin or chocolate fluid was delivered twice during the scan, with a duration of 1.5 minutes each for capsaicin fluid and a duration of 3 minutes each for chocolate fluid. The entire run lasted 14.5 minutes.Right: Participants continuously rated pleasantness or unpleasantness (purple: pain, yellow: pleasure) while receiving capsaicin and chocolate (n = 58). Credit: *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2310433121

The participants' subjective reports of pleasantness and unpleasantness gradually increased and persisted during the capsaicin and chocolate fluids deliveries and decreased after the deliveries ended. By inducing dynamic changes in sustained pain and pleasure, the team aimed to identify the brain regions activated by both experiences.

The research team collected the brain imaging data and moment-by-moment changes in pleasantness or unpleasantness ratings from 58 participants. The team utilized machine learning techniques to analyze the brain data, and they identified a set of brain regions that responded to both sustained pain and pleasure.

Based on the brain activity patterns of these common brain regions, the team developed two predictive models to capture 1) the magnitude of affective experiences regardless of how pleasant or unpleasant they are (i.e., 'affective intensity') and 2) the magnitude of pleasantness or unpleasantness (i.e., 'affective valence').

The researchers found that these models successfully predicted the affective intensity and valence information of sustained pleasure and pain, from both the 58 individuals in the training dataset and 61 new individuals in the independent test dataset.



Important brain regions for predicting affective information related to pleasure and painThese brain regions include groups of subregions contributing to

predicting pleasantness or unpleasantness scores (affective valence) and their intensity (affective intensity). In predicting the affective intensity, the ventral anterior insula and right ventral and left dorsal amygdala were involved. In predicting the affective valence, the left centromedial and right superficial amygdala and the ventromedial prefrontal cortex were involved. Credit: *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2310433121

The activity patterns predictive of the affective intensity and valence were spatially distinguishable, and these patterns were connected to distinct functional brain networks. This suggests that the affective intensity and valence information represent multiple aspects of brain mechanisms underlying pain-pleasure interaction.

"While there have been separate lines of studies on pain and pleasure, research comparing the experiences of both pain and pleasure within the same individuals has been rarely conducted," stated Dr. Woo Choong-Wan, associate director of IBS, who led the study.

"The brain activity patterns for affective valence and intensity can contribute to the understanding of how pain and pleasure interact, as well as the brain mechanisms underlying depression commonly observed in chronic pain patients."

Lee Soo Ahn, a doctoral candidate and the first author of this study, emphasized, "These results demonstrate that pain and pleasure share the same underlying emotional information on pleasantness and unpleasantness," adding, "We should focus on the fact that affective valence and intensity information can be represented across multiple brain regions."

More information: Soo Ahn Lee et al, Brain representations of

affective valence and intensity in sustained pleasure and pain, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2310433121