

Learning of novel semantic relationships by sudden comprehension is associated with a hippocampus-independent network

Jasmin M. Kizilirmak¹, Björn H. Schott^{2,3}, Hannes Thuerich², Kristian Folta-Schoofs¹, Alan Richardson-Klavehn⁴

¹University of Hildesheim, Institute for Psychology, Hildesheim, Germany

²Leibniz Institute for Neurobiology, Magdeburg, Germany

³Department of Psychiatry and Psychotherapy, University Medicine Göttingen, Göttingen, Germany

⁴Memory and Consciousness Research Group, Departments of Neurology and Stereotactic Neurosurgery, Otto-von-Guericke-University, Magdeburg, Germany

Sudden comprehension—or insight—during problem-solving can enhance later memory, but the underlying neural processes are largely unknown. We investigated neural correlates of learning from insight using functional magnetic resonance imaging (fMRI) during induced sudden comprehension compared with continued incomprehension. The task employed was a modified German version of the Compound Remotes Associates Task, during which three words are presented for which a fourth solution word needs to be found, so that compound words can be built with each of the other three (e.g., *gown, club, mare*; solution word: *night*). The key feature of this task is that associations between the three problem words are at first remote or latent. Only when the solution is found or presented, does the association between the words become stronger or more direct.

To experimentally induce sudden comprehension or continued incomprehension, either solvable or unsolvable problems, and their solutions or pseudo-solutions respectively, were presented while participants were being scanned (encoding session). They were instructed to search for a solution during the presentation of a triad without its solution. When presented with the correct solution (sudden comprehension) or pseudo-solution (continued incomprehension) shortly afterwards, participants were asked to decide via button press whether the solution was plausible or implausible. Later memory of the problems and their solutions was tested after 24 hours by means of a test in which participants solved old and new sudden comprehension items themselves. To investigate neural correlates of learning from sudden comprehension, fMRI activity in the encoding session for later solved and later unsolved problems was compared.

Irrespective of later memory, we found highly increased activation of the hippocampus bilaterally, the medial prefrontal cortex (mPFC), amygdala, and striatum for sudden comprehension compared with continued incomprehension, despite the novelty and emotional salience of individual words being matched across conditions. Adding to its role in associative novelty, the hippocampus likely responds to a form of conceptual novelty, a novel meaningful relationship between familiar items. Notably, however, mPFC rather than hippocampal fMRI responses were associated with later learning of sudden comprehension solutions. We propose that learning from sudden comprehension may constitute one of the special cases when novel information is directly encoded into semantic memory (mPFC-mediated), similarly to previous accounts of schema- or prior-knowledge-dependent memory. Furthermore, more difficult problems were associated both with activations of the dopaminergic midbrain and greater learning in the memory test, suggesting that comprehending solutions to more difficult problems was intrinsically more rewarding.