Research Award Brief

Quantifying individual differences in network dynamics for abstract information learning (2015-2017)

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Research Question: How does the brain control the processing of different kinds of information that sometimes need to cooperate and sometimes need to compete, such as sensory information from the outside world versus abstract ideas and relationships?

Interdisciplinary Approach: Bridging computational engineering methods, brain imaging techniques, and cognitive neuroscience, this study will test whether the strength of different interactions among multiple brain areas is related to how well an individual person is able to learn different kinds of information.

Potential Implications of Research: Results will inform our understanding of the mechanisms behind how different parts of the brain communicate with each other. The results also may have implications for treating ADHD, autism, and other disorders with altered interactions between brain areas, and for designing educational methods tailored to the learning strengths and weaknesses of a broad range of typically developing individuals.

Our ability to succeed in everyday life is often driven by concrete, learned relationships between particular sights or sounds and particular responses, such as seeing a red light and pressing the brake pedal. We also bring to mind specific sights and sounds when we explicitly recollect past events. However, the most profound human abilities of science, art, and philosophy also depend on being able to extract abstract information from sensory experience and apply those learned ideas, rules or relationships to novel sensory experiences, or to imagine worlds beyond our sensory experience. For example, when we have a conversation, we have to be able to hear what the other person is saying, and plan what words we want to speak, but an effective conversation also requires that we keep in mind abstract information about our own and other people's goals and intentions. In the educational setting, one often observes differences in how students are able, or unable, to learn these different types of information, such as a student who excels in memorizing multiplication tables or procedures to solve arithmetic problems, but who struggles with the abstract concepts of algebra and calculus. Others may excel with understanding the complex, abstract motivations underlying international political history, but struggle to remember the specific people, dates and locations of historical events. This research study aims to understand the neural mechanisms behind these individual differences in the hope of being able to devise educational approaches that help all learners to be able to balance and transition between these two different modes of thinking and learning.

Recent research suggests that these two modes of thinking and learning depend on different sets of regions in the brain. The regions that cooperate to process one kind of information appear to be strongly connected to each other to form functional networks. Interactions between the two networks, however, are less clear. Sometimes the two networks appear to cooperate and even be dependent on one another, but other times each network appears to suppress the other. We will test whether the strength of this cooperation and competition between brain networks is related to an individual person's ability to process and learn about sensory versus abstract information. We believe that how much these two networks cooperate or compete in an individual's brain is related to how easily they are able to learn about concrete information, such as memorizing particular sights, sounds or facts, and how easily they are able to learn about abstract rules and relationships, such as a person's goals and intentions. We will measure brain activity with functional magnetic resonance imaging during tasks that are expected to require either cooperative or competitive interactions between these brain networks. We will develop new ways of analyzing this data to figure out what aspect of these brain networks best predicts how well a particular person will perform on different tasks that involve paying attention to or learning about either concrete or abstract information.

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