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ABSTRACT

To achieve the goal of maintaining human cognitive effectiveness and emotional resilience, it is essential to understand the neural basis of the emotions and their interactions with cognition. Yet these processes have remained largely elusive. Emotions are complex integrative functions with links to the sensory, motor, and cognitive domains, but are primarily internal, often free-floating states that are difficult to control experimentally, and they are supported by many different and distributed brain structures, exacerbating the difficulty to determine their neural basis. The objectives of this project are to conduct basic research to increase fundamental knowledge and understanding of the neural mechanisms of the emotions in a way that provides the basis for technological progress in artificial intelligence, and to create new interdisciplinary training opportunities in a field of high relevance to long-term national security needs. To achieve these objectives, the project will develop a new experimental paradigm for the emotions, adopted from the one the principal investigator pioneered for other domains of complex information processing and cognition, and integrate this experimental paradigm with advanced computational neuroscience approaches. We conceptualize emotions as fast, (initially) sub-conscious, automatic neural processes that compute approximate solutions to the problem of selecting the best behavioral response in complex environments. We hypothesize that the three main qualities fundamental theories of the emotions propose, categories, decision making, and internal states, are means towards these computational ends. Our approach to assess these properties, comprises a novel conceptual framework, a novel behavioral paradigm, and a novel experimental paradigm for affective neuroscience. The behavioral paradigm includes a spectrum of settings ranging from simple stimulus presentation to real-world social communication settings in which dynamic faces are perceived which, in the appropriate social context, elicit facial expressions. We will use functional magnetic resonance imaging to localize areas of the brain selectively engaged by different task components and will characterize the network character of these areas of a core emotion circuit and their coupling with sensory, motor, and cognitive control areas. We will then target these nodes of the emotional processing circuit for massively parallel long-term electrophysiological recordings of single neuron activity and local field potentials, allowing us to uncover population codes in each node as well as local and global dynamics. This approach will allow us to understand how neural circuits implement emotions as computations. We will determine how these systems create categories from the sensory to the motor level and how categories at different levels of processing relate to each other. We will test whether categories pre-exist explicit processing, and how explicit training and voluntary processing can modify them. We will determine how the system makes decisions and uncover whether and how motor and emotional processes feed back onto emotional and sensory processes. And we will characterize the dynamics of the system and determine whether emotional states exist and what they are in neural terms. The results, together with the creation of neural computation models to explain them, will allow us to identify the computational organization of this distributed system. We expect that we will uncover a novel probabilistic graphical model architecture that will inspire new concepts for artificial intelligence and neuromorphic computing. We will propose a new theory of the emotions as computations and establish a new paradigm for the affective and cognitive neurosciences. We expect that these insights into the neural circuits of emotion processing and their malleability by cognitive control, will be foundational for the understanding of emotional resilience.