SPECIFIC AIMS

A substantial portion of human experience consists of engaging in one task (e.g., driving to the grocery store) while thinking about another (e.g., remembering which groceries to buy). *Near-goal off-task thinking*—or thinking about a near-term task while performing another task—may be an adaptive way to balance progress across tasks that share goals (e.g., getting groceries). Conversely, *goal-unrelated off-task thinking*, or task-unrelated thinking that lacks a clear goal and task focus, can either be adaptive (e.g., creativity), unproductive (e.g., daydreaming), or harmful (e.g., rumination). Given the prevalence of off-task thinking estimated at ~30-50% of daily life[1–4] and its capacity to exacerbate mental illness through rumination,[5–7] understanding the processes that lead off-task thinking to be beneficial or harmful is of paramount importance.[8] Understanding different forms of off-task thinking could also be vital for distinguishing various subclinical symptoms associated with deteriorating frontal and executive brain circuits.[9–11]

We propose that near-goal off-task thinking draws on representations of task hierarchies[12–15] to adaptively balance control across tasks that share goals. We further propose that this adaptive balancing is absent during goal-unrelated off-task thinking, such as rumination. During off-task thinking generally, the mind is less perceptually sensitive to the environment[16–18] and the brain more poorly coordinates task-relevant activity.[19–22] However, how different types of off-task thinking impact this perceptual sensitivity and the broader dynamics of brain networks is unclear.

We test the novel hypotheses that—during near-goal off-task thinking—the mind balances control across tasks that share goals by (i) enhancing perceptual sensitivity to the environment and (ii) better coordinating task-relevant neural activity. Across two aims, we will evoke near-goal off-task thinking by having participants perform well-validated continuous performance tasks in between a memory encoding and recognition task. We will measure perceptual sensitivity with well-established features of electroencephalography (EEG) and task-relevant neural activity with functional magnetic resonance imaging (fMRI). Neural and behavioral data will be related to one another through innovative joint computational models,[23] providing rigorous and precise estimations of latent cognitive variables of interest. Evidence in favor of our hypothesis would have broad implications for identifying the underpinnings of potentially adaptive and maladaptive off-task thinking and could highlight potential interventions for clinically dysregulated off-task patterns such as rumination.

<u>Specific Aim 1.</u> Determine whether the mind maintains more perceptual sensitivity to the sensory environment during near-goal vs. goal-unrelated off-task thinking. While undergoing EEG recording, participants will first be instructed to remember the location of images presented in a grid (memory task). They will then perform a continuous performance task, making a fast button press in response to a common stimulus and withholding a button press for a rare stimulus. Well validated experience sampling probes[24] will assess whether participants are having thoughts related to (i) the ongoing task, (ii) the memory task, or (iii) something unrelated to the experiment. We will fit a previously validated computational model[25,26] that can estimate sensitivity to the rare stimulus, which is the aspect of task processing most negatively impacted by off-task thinking. We predict that—if control is balanced between ongoing and near-future tasks during near-goal off-task thinking—then, when having more thoughts about the memory task than experiment-unrelated thoughts, performance on the continuous performance task should be better ($H1_A$), EEG measures should suggest greater perceptual sensitivity to the environment ($H1_B$, $H1_C$), and model-based estimates should suggest greater sensitivity to task stimuli ($H1_D$). Such results would suggest that the mind balances control across tasks that share goals by maintaining more perceptual sensitivity to the environment.

<u>Specific Aim 2.</u> Determine whether task-relevant neural activity is stronger and better coordinated during near-goal vs. goal-unrelated off-task thinking. In an fMRI scanner, participants will perform the same memory task as in Aim 1 and a modified continuous performance task. The default mode and dorsal attention networks (DMN and DAN) coordinate in opposition (i.e., are "anticorrelated") during higher task focus and are less related to one another during lower task focus.[19–22,27] Additionally, visual regions more strongly encode task stimuli during high vs. low task focus.[22] We therefore predict that—when having more thoughts about the memory task than experiment-unrelated thoughts—visual regions will exhibit stronger task stimuli encoding ($H2_A$), and DMN and DAN will exhibit higher anticorrelation ($H2_B$). Such results would offer neural correlates suggesting more balanced control across tasks that share goals during near-goal off-task thinking, a major adaptive process that is absent during goal-unrelated off-task thinking, such as rumination.

The proposed work and the Sponsor and Co-Sponsor's expertise will provide two major and novel training experiences for the Applicant: (1) methodological training in EEG and fMRI, and (2) conceptual training in integrating across cognitive and neuroscience levels of investigation to study control and off-task thought.