Research Statement

Timely and flexible responding to changing demands is a hallmark of adaptive behavior. To support such behavior, neural activity must be efficiently coordinated across distributed networks that arise and dissolve within fractions of a second. Thus, coordination of neural information processing is both computationally complex and evolutionarily significant, and represents a compelling possible source of cognitive variability both within and across individuals. From that basis, my research aims to understand how variation in neural coordination relates to intra-individual performance variability, as well as to individual differences in higher-order cognitive functions. I pursue these questions through three related research lines that aim to clarify: 1) dynamic neural mechanisms of intra-individual variability, 2) spontaneous activity features that influence task-related activation and performance, and 3) disrupted coordination in mild executive dysfunction. I investigate these questions through the combined application of electrophysiological (EEG/MEG) recordings, experimental cognitive tasks, and conventional neuropsychological assessments.

Intra-individual variability and Fluid Intelligence

A large body of chronometric research has established the inverse relation between choice reaction-time variability and intelligence, such that higher ability individuals exhibit less variation and skew in their individual reaction-time distributions. Although mathematical models can readily account for these findings, a corresponding mechanistic account is lacking. The related line of my research aims to identify which aspects of neural coordination account for cross-trial variability, the task features most critical to such variation, and the relations therein with fluid intelligence. In one study currently under review, my colleagues and I demonstrated that individuals with higher fluid intelligence exhibit greater consistency in the timing of their early visual responses to novel stimuli across trials, despite the fact that novel stimuli elicit less consistency overall relative to familiar stimuli (Euler, Weisend, Jung, Thoma, & Yeo, under review). Thus, higher ability individuals exhibit consistent perceptual responses in spite of changing inputs, and importantly, this effect was only detectable using measures that emphasize the functional coordination of local neural processing. Hence, by testing a coordination-based framework for neural variability, this study generated the novel hypothesis that greater flexibility in configuring early perceptual processing is actually the operative mechanism underlying individual differences. We are currently testing a replication of this finding in a separate paradigm, as well as its implications for higher-order neural processing.

This spring I will seek funding via a University of Utah Seed Grant as well as matching funds from the Mind Research Network, to support an MEG and diffusion tensor imaging study on elementary task performance and fluid intelligence. Based on the above findings and preliminary results from separate projects, the study will test a larger neural oscillatory
framework of intellectual variation, with the goal of integrating chronometric accounts with the major neuroanatomical and metabolic theories of biological mechanisms of intelligence (i.e., the Parieto-Frontal Integration theory, Jung & Haier, 2007; and the Neural Efficiency Hypothesis, Neubauer & Fink, 2009). In support of that submission, we are currently analyzing our incoming data investigating EEG correlates of simple and choice reaction-time variation.

**Influence of Ongoing Activity Features on Task-related Activity and Performance**

In addition to studying task-related neural activity, it is also important to identify the features of ongoing activity that enable fluid transitions to task-related processing and effective performance. Although several features of resting alpha oscillations (8-12 Hz) have been linked to intellectual ability, like much of the intelligence literature, the neural mechanisms underlying these effects tend to be poorly specified. To address this limitation, this line of my research explores the influence of “resting-state” and pre-stimulus activity features on task-related activation and cognitive performance.

For example, recent research has demonstrated the presence of long-range temporal correlations in the human EEG, indicating positive dependence between activity fluctuations over time, and thus temporal structure in the ongoing oscillations. Although this phenomenon is intriguing, little work has been done to assess its functional significance. In a large sample of neuropsychological and resting EEG data collected since coming to Utah (n < 75), we have recently observed that greater long-range correlations in frontal theta-band activity (4-8 Hz) actually predicts poorer overall working memory ability in healthy college students, suggesting less moment-to-moment flexibility in the underlying neural system (Euler, Butner, & Niermeyer, in preparation). Given the established role of theta activity during working memory task performance, and the link between resting alpha and broader intellectual skills (as well as hypothesized theta/alpha interactions), several other projects are exploring the implications of this finding for broader neurocognitive functioning, as well as for theta-band activation during working memory tasks.

**Dynamic Neural Causes of Subtle Executive Dysfunction**

The third line of my research extends our basic science work on neural coordination to help inform an emerging issue in clinical neuropsychological assessment. In particular, neuropsychology is increasingly challenged by the need to identify subtle cognitive dysfunction that may herald incipient neurodegenerative illnesses or might go undetected in other sub-clinical conditions. As demonstrated by the work of my colleague, Dr. Yana Suchy, computerized complex motor sequencing tasks have shown superior sensitivity to mild executive dysfunction relative to conventional measures, and have promising clinical utility (e.g., Suchy, Euler, & Eastvold, 2014). This sensitivity likely results in part from their ability to capture minute behavioral effects that manifest at millisecond timescales. Given this timescale, and the
absence of identifiable structural lesions in subclinical conditions, electrophysiology provides the optimal method for elucidating the neural basis of these effects.

To that end, Dr. Suchy and I have begun collaborating on a program of behavioral and electrophysiological research that aims to clarify which features of complex sequencing best account for its predictive utility, and their associated neural correlates. In light of both of our prior work establishing the relevance of perceptual novelty to behavioral and neural variability, the current primary aim of this research is to identify individual differences in neural coordination in response to novelty. The results of our initial project demonstrated a strong general link between executive functioning and preparatory activity during motor planning, and further suggested that novel contexts invoke executive resources due to capacity limitations within the action planning system (Euler, Niermeyer, & Suchy, in preparation). Altogether, these results provide important physiological support for the clinically consequential hypothesis that motor planning represents a rudimentary substrate for more complex behavioral control (Suchy & Kraybill, 2007). Separate preliminary analyses from the larger project also appear to extend my lab’s prior findings of more consistent neural responding following repeat stimulus exposure, which will form the basis of a second manuscript exploring effects on subsequent regional coordination during action planning. In the near-term, we also plan to adapt the task paradigm to isolate effects of context vs. sequence novelty, and to extend the research to select clinical samples.

**Future Directions**

There is considerable convergence between these three lines of research. Each shares the overarching oscillatory framework and each bears on our understanding of how dynamic neural mechanisms support complex behavioral control. In addition, the complex sequencing and elementary task paradigms I employ implicate highly overlapping neural substrates involved in orienting, visual perception, and response planning, with quite diverse projects providing evidence for the importance of perceptual novelty and neural flexibility to individual differences. Given this convergence, a longer-term goal of my work is to better understand the task parameters and neural processes that define the boundaries between reaction time versus more complex action planning, and the basis of their respective relations to intelligence and executive functions. Elucidating (or challenging) those boundaries will ultimately entail developing an account of how coordination processes interact over multiple scales to eventually determine single-trial performance, and in turn which aspects of neurobehavioral variability are important to broader cognitive skills. As part of that larger endeavor, I hope that my own work can incrementally advance that basic science, while also clarifying its implications for contemporary neuropsychological assessment.