To support adaptive behavior, the brain must possess mechanisms for rapidly and flexibly allocating the cognitive resources needed to address momentary challenges, as well as for anticipating the organism's longer-term needs and upcoming demands. As such, the nature and resilience of these dynamic capacities are apt to be key sources of cognitive variability both within and across people. With these premises in mind, my research aims to help clarify how variation in neural dynamics relates to higher-order cognition, and how that information could ultimately be used to improve cognitive assessment. Finding the answers to these questions has implications for both basic science and clinical problems, ranging from better understanding the nature of intelligence, to improving the diagnosis and treatment of numerous cognitive disorders. In turn, these goals inform three related lines of research, which I pursue through studies that combine standardized cognitive assessments, experimental tasks, and electrophysiological (EEG) measures of neural activity.

Neural Dynamics, Uncertainty, and Adaptive Performance: Most of my empirical work to date has focused on identifying EEG and event-related potential (ERP) correlates of adaptive performance, and their relation to higher-order cognition. A series of studies in my lab has particularly highlighted the role of uncertainty in driving these effects. For example, we have found that while lower stimulus familiarity undermines the reliability with which early perceptual networks are recruited, resilience to these effects predicts higher fluid intelligence (Euler, Weisend, Jung, Thoma, & Yeo, 2015). These effects also extend to the motor domain, where uncertainty about task demands (e.g., the specific movements to-be-performed in an upcoming motor sequence) impede motor preparatory activity, such that greater neural resilience to these effects predicts higher executive functioning (Euler, Niermeyer, & Suchy, 2016). Further, we have recently shown that uncertainty effects not only emerge in a reactive, post-stimulus fashion, but are also evident in anticipatory processing. For example, we have found that higher-ability individuals are not only more sensitive to highly subtle, implicit cues about impending stimulus onsets (and seem to alter their perceptual and motor planning systems accordingly; McKinney & Euler, 2019), but they in turn leverage this sensitivity to facilitate post-stimulus processing (Euler, McKinney, Schryver, & Okabe, 2017).

In trying to identify general principles that support adaptive performance I have also sought to take a broader view of neural dynamics, by incorporating the perspectives and methods of dynamical systems theory. Of particular interest is the notion of "soft assembly," which describes a crucial feature of complex systems like the brain, which is their capacity to flexibly re-organize in response to changing demands. Although this clearly evokes intuitive notions of intelligence and neural efficiency, dynamic systems theory provides methods for explicitly testing this idea. In our first study in this area, we observed that stronger long-range correlations (a dynamical systems measure relevant to soft assembly) in the low frequency EEG (2-7 Hz) predicted poorer working memory in healthy adults (Euler, Wiltshire, Niermeyer, & Butner, 2016). Interestingly, greater long-range correlations in this context indicate a more-ordered signal (greater dependence between fluctuations over time, as opposed to randomness), potentially suggesting a less flexible neural system. A second study in this vein extended our earlier experimental work, and examined how stimulus familiarity altered neural markers of soft assembly. Although that study did not examine individual differences, results supported predictions derived from soft-assembly, that as the brain transitioned from a resting-state, to pre-stimulus anticipation, to post-stimulus processing, neural activity became increasingly ordered (Wiltshire, Euler, McKinney, & Butner, 2017). Altogether, these and our other recent findings support our contention that variability in neural dynamics, and especially in response to uncertainty, is key to understanding how the brain supports adaptive performance.

Theoretical Issues in the Neuroscience of Intelligence: My efforts to clarify dynamic neural correlates of cognitive ability have also caused me to consider several broader issues in the neuroscience of intelligence—an area that still faces several important gaps and conceptual challenges. These include, a lack of clear principles governing the expected direction of brain activity-intelligence correlations (e.g., should ERP amplitudes correlate positively or negatively with intelligence, and under what conditions, and why?), and similarly, few principles that inform the size of those relationships, or the effects of various moderators (e.g., task difficulty, unique effects of particular networks).

In my view, these and other questions in this literature highlight the need for additional theory development in the neuroscience of intelligence, and especially for *integrative* accounts that could inform directional, *a priori* hypotheses about brain-ability relationships, across the different modalities and physiological scales involved (e.g., early ERP amplitudes, fMRI functional connectivity, etc.). In an attempt to make progress in this area, I recently published a narrative review of the physiological intelligence literature, which aims to unify the various subfields under an uncertainty-based framework (Euler, 2018). In brief, I argue that by recasting intelligence as the capacity to respond appropriately despite cognitive uncertainty, this enables a shift in focus away from specific cognitive processes in neuroscientific accounts of intelligence, and more towards examining the precise types of uncertainty that are relevant to any given task-ability correlation. That is, from a dynamic perspective, although intelligence is a latent construct, *intelligent behavior* is of course expressed on a momentary basis, as mediated by particular networks. In turn, any attempt to understand why instantaneous neural activity should relate to intelligence ultimately requires a conceptual mapping from the discrete physiological events on the one hand, to the aggregate, latent construct on the other.

Overall, the main goal of this approach is to provide a more principled basis for hypothesizing about which task parameters and neural circuits should relate to intelligence under various conditions, and to what degree and why. In addition, because this framework takes an inherently task-specific view of brain-ability relationships, it enables anatomically-specific, directional predictions regarding the effects of uncertainty on neural activity in particular networks. This in turn gives it potential for helping to integrate the currently disparate neuroanatomical and activation-based accounts of intelligence (i.e., the Neural Efficiency Hypothesis and Parieto-Frontal Integration Theory), as well as for potentially clarifying aspects of the ERP-IQ literature. Recently, I was also fortunate for the opportunity to extend this theoretical line of work through an invited contribution to an upcoming book on the cognitive neuroscience of intelligence (Euler, & McKinney 2019), and I am currently collecting a large-n (200 participant) sample related to this research program.

Applications to Neuropsychological Assessment: The empirical and theoretical research described above has also begun to support a more applied research program with relevance to neuropsychological assessment. In the first instance, in collaboration with my colleague Dr. Yana Suchy, I have contributed to studies examining how sensitivity to uncertainty (in the form of task novelty) can inform identification of sub-clinical cognitive problems. Those studies have focused on complex motor sequencing, and have shown that greater behavioral sensitivity to novelty can predict the presence and number of past mild traumatic brain injuries (Suchy, Euler, & Eastvold, 2014), while resilience to novelty predicts higher executive functioning (Euler, Niermeyer, et al., 2016).

Second, inspired by our work on activity-ability relations, we have recently undertaken a series of studies seeking to identify EEG correlates of mental exertion and fatigue. In brief, several key challenges in neuropsychological assessment relate to mental exertion, but unfortunately, current behavioral methods are somewhat insensitive in detecting these scenarios. For example, if a patient is performing more poorly than expected due to legitimate fatigue, this is difficult to distinguish from intentional malingering. Similarly, we are currently unable to detect whether an individual is exerting greater effort than expected (relative to their overall ability), which could prove decisive in improving early detection of incipient dementias, or in predicting recovery following brain injuries.

In an effort to help address these issues, I have begun a series of studies aiming to validate EEG markers of mental effort and fatigue. In several recent presentations and one published article, my collaborators and I described evidence that changes in EEG mid-frontal theta (4-8 Hz) and posterior alpha (8-13 Hz) activity track distinct aspects of task performance and engagement over time. Specifically, whereas mid-frontal theta power is linked to cognitive control, and increases with higher task difficulty (Pathania, Leiker, Euler, Miller, & Lohse, 2019)—thereby possibly indicating mental exertion—alpha power increases with greater time-on-task, making it a plausible index of mind-wandering and fatigue. These findings recently supported a successful application to the National Institute on Aging (1 R03 AG063044-01), which will examine mid-frontal theta power as an index of mental exertion during early Alzheimer's disease stages. Specifically, the project will compare task-related mid-frontal theta power across cognitively-intact older adults, and individuals who meet criteria for Amnestic Mild Cognitive Impairment or early Alzheimer's disease, with the goal of establishing whether theta power is abnormally elevated under conditions where affected individuals perform simple tasks at levels comparable to healthy controls. If successful, the results will provide important support for the possibility of eventually validating EEG mid-frontal theta power as a marker of real-time mental exertion for this and other neuropsychological applications.

Broader Impacts and Long-term Directions: Finally, because my account of intelligence emphasizes subjective uncertainty over particular processes, it supports several other hypotheses with broader implications for research on cognitive functioning. These include the idea that different people may leverage different cognitive strengths in solving the same tasks—implying that intelligence might be organized differently in the brains of different individuals—as well as the idea that individuals who have had more limited educational opportunities may face differential uncertainty in approaching cognitive tasks. Crucially however, my framework also suggests means of testing these ideas (Euler, 2018). Thus, while I will test these and the other emerging directions in the next phase of my research, they nevertheless speak to the generativity and scope of the laboratory's overall framework, and its potential to improve understanding and assessment of human cognitive functioning.

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