Understanding the Role of Preparatory Brain States in Processing Speed and Executive Function with a Network-based EEG Connectivity Approach

Why does the same person respond in 200ms on one trial but 600ms on the next? Traditional cognitive research averages hundreds of trials, treating this threefold variation as noise. We propose this variability reflects meaningful fluctuations in how the brain prepares before information appears—and these preparatory states fundamentally determine processing speed. Processing speed predicts outcomes ranging from academic achievement to driving safety, yet mechanisms generating speed differences remain unclear. Current theories focus on what happens after a stimulus appears, assuming faster processors have more efficient neural transmission or decision-making. This overlooks a critical question: what if speed is determined before processing begins? Our pilot analysis of public EEG datasets provides compelling initial evidence. We found that prestimulus connectivity between the Salience Network (detecting important information) and Dorsal Attention Network (directing focus) correlates with reaction time ($r=0.47$, $p<.001$). This suggests that when these networks communicate effectively before stimulus onset, rapid responses follow. This proof-of-concept study tests whether processing speed differences—both between and within individuals—arise from preparatory brain states rather than processing efficiency. Using high-density EEG, we will record 80 participants performing three validated tasks that measure sustained attention (GradCPT), processing speed (Arrow Task), and inhibitory control (Stop-Signal Task). This streamlined single-session design generates six performance conditions while minimising participant burden. Crucially, we employ trial-by-trial analysis rather than averaging. For each response, we examine brain activity during preparation (500 ms before stimulus), perception (0-200ms after stimulus), and decision-making (300-500ms after stimulus). We predict that optimal preparatory states—characterised by alpha oscillations in the Salience Network that enhance readiness—cascade through processing stages, enabling fast responses. Poor preparation necessitates compensatory executive control, producing slow responses. Our approach reveals why processing speed and executive function appear correlated in traditional studies: both are impaired when attention fluctuates. By classifying each trial's attention state based on neural markers, we can test whether these represent distinct capacities when preparation is optimal. Post-session questionnaires (ASRS, CFQ, MAAS) will validate whether neural instability predicts real-world attention difficulties. If validated, this framework transforms understanding from "some people are slow processors" to "suboptimal brain preparation causes slow responses." Rather than training people to process faster—attempting to accelerate fixed hardware—interventions could optimise preparatory control. This paradigm shift has implications for intervention (neurofeedback / brain stimulation), clinical assessment (identifying specific preparatory deficits), and lifespan cognitive health (maintaining preparation abilities).