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DYNAMIC METACONTROL: NEUROPHYSIOLOGICAL SIGNATURES OF PERSISTENCE AND FLEXIBILITY

Abstract

Adaptive behavior requires a balance between stable goal maintenance and flexible adjustment to changing demands. The Metacontrol State Model proposes that cognitive control is regulated through such a balance between persistence and flexibility. Persistence supports focused processing, goal shielding, and resistance to distraction, whereas flexibility supports openness to alternative information, wider attentional allocation, and adaptive switching. Although this framework provides a useful account of how control states may be configured, the neurophysiological mechanisms through which metacontrol states are induced, expressed, transferred, and maintained over time remain insufficiently understood. The present dissertation addressed this issue across four empirical studies combining behavioral measures with electroencephalography. Study 1 examined how metacontrol states influence conflict regulation in a modified Flanker task. Conflict frequency was manipulated to bias participants toward persistence or flexibility. Behavioral results confirmed the effectiveness of the manipulation. At the neurophysiological level, theta band activity closely followed the behavioral pattern and was especially sensitive to mismatches between expected control state and current task demand. Alpha and beta band activity showed additional post response modulations, suggesting a role in resetting the system for upcoming demands. Directed connectivity analyses further indicated stronger interregional communication during persistence biased states. Study 2 tested whether metacontrol is reflected in tonic or phasic changes in aperiodic EEG activity. The aperiodic exponent showed post stimulus increases during incongruent trials, while no corresponding pre stimulus differences were observed. Cross task correlations between creativity based metacontrol measures and Flanker based measures were absent. These findings support a phasic, task specific account of metacontrol expression. Study 3 extended this question by asking whether metacontrol states induced through convergent and divergent thinking transfer to visual attentional selection. Remote Associates Task and Alternate Uses Task contexts were used to bias persistence and flexibility, followed by Global or Local processing demands. Behavioral results showed a global advantage across sessions, while aperiodic exponent differences between Global and Local trials emerged only after stimulus onset. This suggests that metacontrol adjustments were recruited in response to current task demands, with limited cross domain transfer. Study 4 examined the temporal carryover of conflict induced control adjustments using a prime probe Flanker task with blank or NoGo intervals. Behavioral results showed that conflict induced adjustments were detectable beyond the immediate prime to probe transition. Neural results were more selective. Midfrontal theta reflected local control implementation and its relation to behavior depended on the intervening interval. Together, the findings indicate that metacontrol is best understood as a dynamic and context sensitive regulatory process. Periodic and aperiodic EEG measures captured complementary aspects of this process. Theta activity reflected local implementation of control and mismatch processing, whereas the aperiodic exponent reflected phasic changes in neural processing state after task relevant events. Thus, metacontrol cannot be reduced to a single neural marker, but is expressed through interacting behavioral and neurophysiological dynamics that depend on current demands, prior context, and temporal structure.