Neural Correlates of Cognitive Control and Goal-Directed Behavior: The Impact of Impulsivity and Compulsivity

Abstract to the dissertation submitted by Kerstin Dück

Adaptive, goal-directed behavior shapes our daily life and, at a higher level, life outcomes such as relationships, career and academic success, and health. Individuals vary in their capacity to behave in a goal-directed manner, depending on their cognitive control functioning. Key aspects of cognitive control include response inhibition, i.e., refraining from prepotent or ongoing, yet inappropriate actions, and model-based (MB) control, i.e., decision-making based on a mental model of action-outcome associations. Both cognitive control mechanisms show alterations in their neural correlates, such as psychophysiological signals of inhibition or feedback processing, in relation to various mental disorders, highlighting their potential role as transdiagnostic markers for psychopathology. Neural dysfunction is often observed in disorders marked by high levels of impulsivity, compulsivity, or overlapping impulsive-compulsive symptoms, e.g., substance use disorder and obsessive-compulsive disorder. Impulsivity and compulsivity are both related to maladaptive behavior as well as self-control impairments, suggesting a mediating role for the personality dimensions. Despite their considerable overlap in neurobiological substrates and clinical impairments, impulsivity and compulsivity are mostly studied separately, disregarding potential interactions. Moreover, findings outside clinical samples are rare, limiting the use of impulsivity and compulsivity as influential characteristics within the general population. Transdiagnostic approaches are warranted to understand how behavioral regulation is shaped by cognitive control functions in the context of personality. Furthermore, intact MB control functioning might enable individuals to weigh goals against immediate desires or automatic responses by strengthening goal representation and the mapping of different actions to wanted or unwanted outcomes. Investigating the association of MB control with self-control may be crucial for bridging the gap between the controlled laboratory setting and daily life and allow us to assess the role of cognitive control for everyday behavior.

The goal of this thesis was to evaluate the role of cognitive control, specifically response inhibition and MB control, for goal-directed behavior, observed in impulsive and compulsive behavioral patterns as well as failures of self-control. First, we set out to examine the associations between impulsivity and compulsivity with response inhibition (study 1) and MB control (study 2). We then aimed to assess how MB control, impulsivity and compulsivity impact self-control as a measure of everyday behavior (study 3). For all three studies, we used data from a large general-population sample examining electroencephalographic (EEG) correlates of different cognitive control functions.

In study 1, we aimed to investigate the link between response inhibition and self-reported impulsivity and compulsivity, with particular interest in potential interactions as well as non-linear effects of the personality dimensions. A Go/Nogo task yielded EEG (Nogo-N2, -P3a and -P3b amplitudes) and behavioral correlates of inhibitory control (*N* = 250). Neither robust linear regression nor non-linear regression-tree analyses uncovered significant associations between impulsivity or compulsivity and neural or behavioral measures of response inhibition. Possibly, inhibitory performance was unimpaired in a non-clinical sample, suggesting that the effect of these personality traits on inhibition and cognitive control may only emerge in clinical populations or under more demanding task conditions.

In study 2, we set out to unravel the neural mechanisms underlying MB control and their link to impulsivity and compulsivity. MB control was assessed using single-trial regression analysis of feedback-locked EEG data (modulation of the feedback-related negativity [FRN] and P3 components) during a two-step decision-making task (*N* = 238). High impulsivity appeared to impair the link between neural and behavioral signs of MB control. Crucially, high compulsivity was related to a reduced modulation of the P3 signal, pointing to a deficient mental action-outcome model in highly compulsive individuals.

Subsequently, in study 3, we aimed to investigate how MB control deficits as seen in the previous study would manifest in everyday behavior and how this association is interwoven with impulsivity and compulsivity. Ecological momentary assessment of self-control was combined with single-trial EEG data modeling MB control (modulation of the FRN and P3 components; *N* = 236). We showed that while MB control alone did not predict self-control, its effect varied with the personality context: in highly compulsive individuals, robust MB control was linked to more failures of self-control, suggesting an enhanced awareness of desire-goal conflicts but a reduced capacity to adapt behavior accordingly. High impulsivity may counterbalance this moderation effect, such that MB control was consistently linked to improved self-control across compulsivity levels, potentially allowing the protective influence of MB control on behavioral regulation to unfold.

These findings provide evidence for a link between cognitive control and goal-directed behavior. Impulsivity and compulsivity may mediate the influence of cognitive control functions and potentially contribute to the emergence of maladaptive behavior or even clinical impairments. To disentangle the true effects on goal-directed behavior, further research is needed to elucidate the role of response inhibition, explore the nature of MB control deficits, and examine transdiagnostic effects. This may offer valuable insights into the mechanisms underlying adaptive behavior and the emergence and treatment of mental disorders.