Summary of the Dissertation

**Balancing Act:**

**On Modulators and Mechanisms of Cognitive Stability and Flexibility**

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Cognitive control is crucial for adaptive, goal-directed behavior. It enables us to adjust information processing and behavior in order to meet various demands. The present work examined cognitive stability and flexibility as two modes or functions of cognitive control. Cognitive stability, on the one hand, promotes a stable task focus and thereby enables us to shield a current goal from distractions or interference. This is, for instance, helpful when trying to concentrate on writing an important email in a noisy environment. Cognitive flexibility, on the other hand, is crucial to adjust to changes. For instance, when maneuvering a bike through a crowded street, flexibility allows us to quickly react and brake if a pedestrian suddenly steps in our way.

Gaining insight into factors that modulate these control functions is not only of theoretical interest but also bears practical potential for supporting individuals in adopting optimal control configurations in clinical, occupational, or safety-related contexts in the future. One of the main aims of this dissertation was therefore to investigate potential modulators of cognitive stability and flexibility. Previous research has yielded inconclusive findings on whether modulations in cognitive stability and flexibility levels are subject to voluntary control. The present work therefore tested whether individuals can deliberately adjust cognitive stability and flexibility levels according to explicit strategy instructions. Furthermore, in line with the proposed notion that cognitive control is grounded in basic learning principles, previous research demonstrated that control states can be modulated by learning experiences. Here, I extended these findings by investigating whether cognitive stability and flexibility would be enhanced through learning when adjustments in these control functions are selectively reinforced. Finally, the processes underlying cognitive stability and flexibility remain unclear. Increases in stability have often been observed to be related to decreases in flexibility, and vice versa. Cognitive stability and flexibility have therefore been suggested to represent opposing endpoints on a single dimension. However, recent evidence for independent regulations of cognitive stability and flexibility challenges this notion. This discrepancy sparked a debate on whether these two control functions are governed

by the same or distinct processes and whether there is an inherent tradeoff between the costs and benefits of cognitive stability and flexibility. In this work, I contributed a novel perspective to this debate. Specifically, using a multilevel approach, I examined the relationship between individual shifts in these control functions to test for a stability-flexibility tradeoff.

I addressed my research aims in three pre-registered task-switching studies. In these studies, I assessed participants' susceptibility to interference from the competing task set and their task-switch costs as inverse indicators of their cognitive stability and flexibility levels, respectively.

Study 1 tested deliberate control adjustments in two experiments. Participants received explicit strategy instructions that either promoted a more stable task focus or fostered more flexible task-switching. These instructions were further combined with feedback in the form of a performance-contingent bonus. Furthermore, the task-relevance of the presented distractors was manipulated between experiments. Participants switched faster between tasks when instructed to do so, providing evidence for voluntary adjustments in cognitive flexibility levels. However, results suggested that participants were equally susceptible to interference from the competing task set in both conditions, indicating no deliberate modulation in their cognitive stability levels. Moreover, the results did not indicate that instruction-based flexibility enhancements were facilitated when distractors were made task relevant. Lastly, I investigated the correlation between individual shifts in cognitive stability and flexibility levels. However, results yielded no evidence that these shifts were inversely related, contrasting the notion of a tradeoff between cognitive stability and flexibility.

Study 2 aimed to test learning-based control modulations and investigated whether selectively reinforcing more stable or flexible behavior would lead to control adjustments. Moreover, it aimed to replicate instruction-based control adjustments as observed in Study 1. The results indicated no coherent evidence for reinforcement- or instruction-based adjustments of cognitive control states. However, analyses of participant-specific shifts in stability and flexibility between conditions indicated that fluctuations in the two control functions were inversely related across both experiments. While consistent with the notion of a stability-flexibility tradeoff, this finding contrasted with the results of Study 1.

Finally, Study 3 employed explicit strategy instructions to investigate the processes underlying voluntary control adjustments. Specifically, I examined whether control adjustments were associated with modulations in theta power as a neural indicator of cognitive control and effort mobilization. However, although participants exhibited instruction-based shifts in behavioral indicators of both stability and flexibility levels, these performance shifts were not reflected in modulations of theta levels. Shielding and shifting of goals were thus not associated with reduced effort mobilization in more stable and flexible control states, respectively. Furthermore, the results did not support the hypothesis that overall control mobilization differed between control states.

The results of the three studies can be summarized as follows: First, findings of instruction-based adjustments in cognitive flexibility, and partly also in stability levels, largely suggest that individuals can deliberately modulate their cognitive control states to some extent. Second, the results did not consistently indicate learned control adjustments when more stable or flexible control states were reinforced. Third, the mixed findings on the relationship between individual stability and flexibility shifts did not consistently, but partly, support the notion of a stability-flexibility tradeoff. Lastly, the results did not indicate that deliberately enhanced stability and flexibility differed in the associated level of sustained or phasic effort or control mobilization. This raises the question of which processes enable a more efficient use of the invested effort.

Taken together, this work provided novel insights into instruction- and learning-based control modulations, thereby advancing our understanding of determinants of cognitive control states. Moreover, the nuanced insights into the relationship between individual shifts in cognitive stability and flexibility levels underscore the need to elucidate the mechanisms underlying these control functions and the conditions giving rise to a potential tradeoff in the future.