Résumé de la thèse :

Acute cognitive fatigue is a temporary decline in cognitive function resulting from prolonged mental effort engagement in an effortful task. As the consequence, cognitive fatigue might result in performance decline and a decrease in the capacity or motivation to deploy further mental effort. According to André et al. (2019), engaging effort activates the Salience Network (specifically the ACC and AI), which exerts control through the effort signal over other task-related brain regions to optimize information processing. However, the SN’s capacity is assumed to be limited (André et al., 2019). Therefore, engagement in a long and demanding task may lead to a reduction in the SN's capacity to exert effort signal ultimately resulting in performance decline and the feeling of cognitive fatigue (André et al., 2019). Furthermore, the decline in an individual's capacity and motivation to exert mental effort can be attributed to willpower, defined as the ability to resist temptation through self-control (Baumeister et al., 1998). In other words, willpower is the capacity to exert effortful control even when there are high costs (Baumeister & Tierney, 2011). Mental fatigue is one of these high costs involved in effort-based decision making, which can be referred to a temporary reduction in the ability to exert effortful control necessitates an additional investment in effortful control to sustain performance (André et al., 2019). In this perspective, Audiffren et al. (2022) suggested that willpower is trainable and training programs, such as regular aerobic workouts and/or mindfulness practices, can be effective in improving the capacity to exert effortful control in order to resist in difficult situations (e.g., mental fatigue).

This thesis, comprising three studies, aimed to investigate the three following main hypotheses proposed by André et al. (2019) and Audiffren et al. (2022): (1) the role of SN in effort exertion; (2) the idea that the SN has a limited capacity to exert effort and acute mental fatigue may influence its function in effort exertion (3) the hypothesis that endurance athletes develop an advanced willpower capacity therefore they can show higher resistance against mental fatigue.

In all of the three studies, we used a suitable sequential protocol proposed by Mangin et al. (2021, 2022) to assess various aspects of cognitive fatigue: a 30-min modified computerized incongruent Stroop task (depleting condition) and a 30-min documentary watching task (control condition), followed by a time-to-exhaustion (TTE) handgrip task at 13% of their maximal voluntary contraction (dependent task).

The main objective of the first study, was to evaluate the electrophysiological changes in effort signal by analyzing mid-frontal theta and cardiac reactivity through EEG and ECG (Cavanagh & Frank, 2014; Mukherjee et al., 2011). In a between-subjects design, the sequential protocol mentioned above was administered to a total of 32 participants. We assumed to observe an increase in the electrophysiological correlates of mental effort during the depleting task and a performance decrement in the subsequent dependent task. For the depleting condition, the behavioral results showed worse performance in the subsequent dependent task and the EEG results showed higher mid-frontal theta power. Heart-rate variability results showed an increase in parasympathetic activity over time during the depleting task, probably due to a habituation effect. In conclusion, this study confirms that the depleting task required more mental effort compared to the control task, despite a slight decrease in effort engagement over time. Furthermore, we observed a subsequent performance decline in the TTE handgrip task as the result of prolonged effort engagement.

The second study aimed to demonstrate that endurance athletes, who engage in regular aerobic exercises, exhibit reduced sensitivity to the negative impact of acute mental fatigue compared to nonathletes. 50 athletes and 50 nonathletes participated in a mixed-design study, both groups underwent the two conditions in the sequential task protocol. Participants' Pre-Ejection Period and Heart Rate Variability were assessed. The behavioral results showed worse performance in the TTE handgrip task after performing the Stroop task only for the nonathletes, but not for the endurance athletes. Performance of both groups was similarly impacted by mental fatigue during the Stroop task and all the participants reported higher subjective fatigue after the Stroop task. The results of the psychophysiological data suggest that sympathetic activity decreased over time during the two cognitive tasks, certainly because of a habituation phenomenon. All together, these results provide arguments for a lower susceptibility of endurance athletes to the negative effects of acute mental fatigue and the idea that willpower is trainable (Audiffren et al., 2022).

Finally, the main objective of the third study was to investigate the role of the SN in effort exertion and acute cognitive fatigue. In a within-subject design, 16 healthy participants underwent the same sequential task protocol, while their resting-state connectivity changes were assessed using fMRI before and after the depleting task in comparison to the control task. According to the results, after the Stroop task, the SN-DAN connectivity increased, indicating effort exertion. However, the increase in error rate during the Stroop task was negatively correlated with the SN-DAN connectivity decrease, indicating a weakening of the SN's capacity to generate effort signal. Additionally, the increase in reaction time was positively correlated with the DAN-DMN connectivity increase, suggesting effort disengagement. In conclusion, our findings support the crucial role of SN in generating effort signal and exerting control over other brain regions to achieve the goal-directed behavior. Moreover, our results confirm that the capacity of SN is limited and engaging in prolonged effortful task may lead to performance decline and feelings of fatigue (André et al., 2019).

Key words: Acute mental fatigue, Effortful control, Salience network, Executive function