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The Role of Self-Control in Anorexia Nervosa

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Abstract: Self-control, a key cognitive ability, facilitates the adjustment of behaviour to meet societal norms by overriding thoughts and emotions. Abnormal self-control can be detrimental, particularly in the context of Anorexia Nervosa (AN). AN is a disorder marked by extreme self-control, particularly in dietary intake, potentially leading to deficits in emotional regulation and cognitive abilities. The fear of weight gain can heighten anxiety levels, leading to more restrictive diets and potential comorbidity with other disorders when weight satisfaction is not achieved. However, the exact mechanism between self-control and AN is unclear. Therefore, this review aims to enhance understanding of AN and the role of self-control in its development and management from three perspectives: the cognitive aspects of self-control in AN, factors of social and emotion in AN and self-self, and effective interventions for AN. Through this examination, this review aims to deepen people's understanding of AN and the role of self-control in its manifestation and management. This review investigates the multifaceted interplay between AN, self-control, emotional regulation, and cognitive rigidity, characterized by restrictive dietary practices and exceedingly low body weights, and presented in two distinct subtypes: restricting and binge-eating/purging. AN individuals exhibit high self-regulation but are prone to negative affective states, underscoring the complexity of emotional regulation in this disorder. A comparison with Bulimia Nervosa illuminates that enhancing self-control can have divergent effects: potentially reducing restrictive eating in AN, while escalating excessive eating in Bulimia Nervosa. The review also highlights the escalated social-cognitive sensitivity and cognitive rigidity in AN individuals, which often trigger restrictive eating. Further, it points to the low mentalizing abilities and high alexithymia levels in AN individuals, leading to cognitive and behavioural inflexibility. Finally, it proposes that neuro-modulatory interventions, such as transcranial magnetic stimulation, may enhance cognitive flexibility in food choices, providing a novel perspective on AN treatment. This review can provide some guidance for prevention and intervention progroms in high schools and colleges.

Keywords: self-control, Anorexia Nervosa, emotion regulation, cognitive perspective

1. Introduction

Self-control, an aspect of self-regulation, is defined as an important cognitive control ability, enabling individuals to adjust their behaviors to conform to expected norms, and social rules via overriding thoughts and emotions. Appropriate self-control is important for occupational

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achievement, academic success, physical health, and mental well-being [1]. It is a product of evolutionary pressure that motivate individuals to equilibrate their desires between "want-to" (exploration) and "have-to" (exploitation) goals. This cognitive control operates along with three executive functions: inhibition, working memory, and task switching, to hinder primary response tendencies [1]. In contrast, excessive self-control is harmful and considered a main agent in Anorexia Nervosa (AN). There are three types of eating disorders: Bulimia Nervosa (BN), Binge Eating Disorder, and AN. BN is characterized by recurrent experiences of overeating and the use of extreme strategies to avoid weight-gaining like exercising excessively and purging [2]. Binge Eating Disorder is attributed to repeated episodes of binge eating, involving devouring large amounts of food that are greater than normal people would eat under similar circumstances. AN is marked by a fear of gaining weight and a distorted body image, accompanied by severe weight-control behaviors, such as caloric restriction via self-induced vomiting, and excessive exercises, leading to weight loss [3]. Individuals with AN are psychologically preoccupied with a fear of gaining weight or social influence (e.g., social exclusion of activities) relates to the idea of "motivated eating restraint". It has the greatest lethality of all psychiatric conditions and creates significant functional impairment.

Current research proposed two different ideas around self-control, the resource-dependent model (EDM) and the elaborated-processed model (EPM) [1]. EDM asserts that self-control is dependent on the limited availability of resources and energy. Intense self-control engagement consumes inner capacity which drives to a mental depletion state. Thus, following self-control attempts are likely failures. Nevertheless, this model lacks consideration of the differences between external reward and inherent rewarding leisure. EPM is derived from evolutionary considerations, deeming motivation as a pivotal factor in solving the deficiency from EDM. Regarding the aversiveness of cognitive control (i.e., inherent disutility), it argues that more extrinsic rewards are required to withstand the work aversiveness, otherwise desires for inherently rewarding leisure dominate people's inhibitory control. This motivated shifting supports self-control flexibility from an evolutionary perspective. It encourages organisms to disengage from exploitation tasks for more activities involving thrilling exploration. Therefore, regulating the extent to which the control system favors "have-to" tasks compared to other opportunities is particularly important in this model. "Want-to" tasks are personally joyful and meaningful, and easy to conduct and to sustain attention focally, instead "have-to" tasks are suppositionally a way of duty or obligation. Two tasks are either motivated extrinsically or intrinsically via external reward or demand, or inherent reward or joyfulness. However, depletion can shift motivational priorities that goals from "have-to" changes to "want-to" via orientating attendants' attention and emotion. Studies found that depletion results in attention lapses on "have-to" tasks and emotional-related negative affect with "have-to" goals in the dorsal anterior cingulate cortex with diminished brain potentials. Further premise regarding depletion is that it enhances cognitive effort for the future pursuing "want-to" goals [1].

Genetic studies suggest that AN is associated with a heritability ranging from 56-70% [3]. Its vulnerable genes are related to several personality traits, such as perfectionism. Food restriction behaviour is conditioning that disturbs opioidergic activity and further escalates self-starvation. Observations in rate suggest that long-term starvation contributes to sustaining restrictive eating behaviours due to delayed gastric emptying and gastric transit times. In addition, treatment refusal as the main psychopathology of AN in the population prevents early intervention and makes treatment more difficult and prolonged. Previous research proposed that AN individuals have abnormal neural systems regarding emotion regulation, and neurocognitive deficits in task-shifting, implicit learning, decision-making, and planning strategies in daily life [3].

Self-control postulates two main models: the EDM and the EPM. The EDM suggests that self-control relies on limited resources, and its intense engagement can lead to mental depletion and

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failure [1]. In contrast, the EPM emphasizes motivation, arguing that extrinsic rewards counteract cognitive control aversiveness, allowing flexibility and supporting the shift between obligatory tasks and inherently rewarding ones. AN is associated with high heritability and linked to personality traits like perfectionism. Restrictive eating behaviours, influenced by disturbed opioidergic activity and delayed gastric emptying, are exacerbated by treatment refusal and abnormal neural systems [3]. Regardless of physical health outcomes (i.e., weight) of individuals with AN, they display extreme weight-control behaviours, which suggests a possible conjecture about excessive self-control. Excessive self-control in dietary intake for individuals may have a negative impact on emotional regulation, cognitive ability, and thus interpersonal relationships, as they could isolate themselves from socializing parties to reduce caloric intake. The more eagerly AN individuals attempt to lose weight, the higher their anxiety levels can become, leading to increasingly restricted diets. Whenever they are not satisfied with their weight, they may feel dejected and depressed about themselves, further contributing to developing comorbidity with AN. However, the above assumption has not been validified, the underlying mechanism of excessive self-control in AN individuals remains unknown. Thus, this review aims to evaluate from four perspectives, the cognitive aspects of self-control in AN, factors of emotion regulation and social in AN and self-control, and effective intervention for AN, to better acknowledge the relationship between self-control and AN.

2. The Cognitive Aspects of Self-Control in AN

AN is an eating disorder, with two subtypes, which are restricting (ANR) or binge eating/purging (ANBP). Two subtypes have different manifestations of eating behaviors, but they all experience restrictive diets which resulted in extremely low body weights. ANBP has one exception is that individuals additionally experience recurrent binge-eating or purging behaviors. Thus, it is logical to predict that individuals with ANBP would likely experience uncontrolled behaviors and thoughts, whereas ANR individuals tend to exhibit extreme cognitive self-control manifestation. In the study by Uniacke et al. food-based decision-making and differences in the food choices between patients with ANR or ANBP were determined by applying Food Choice Task with fMRI (of 52 participants were tested with fMRI scanning) on 86 AN female participant (above 16 years) [4]. The result did not find any differences between ANR and ANBP on food choice. Both subtypes tended to choose low-caloric food and increase dietary restrictions (e.g., skipping a meal, avoiding eating high-fat food). This implies that regardless of which subtype of AN, self-control underpins the mechanisms of the food choices and avoidant behaviors of individuals with AN. Moreover, an internalized norm was formed in those individuals that they believe high-caloric food was less tasty and less healthy than low-caloric food. This feature is driven by food evaluation (i.e., judgments on the health and taste of food) and self-control. The cognitive processes related to self-control might give rise to internalized norms about the judgments of health and tasty. They were convinced by the internalized norm that high-caloric food is always linked to the label of less tasty and less healthy. This internalized norm inside them will in turn affect their food choices which consolidate the cycle of fear of gaining weight and distorted images, choosing food types, and losing weight. Together, though the two types of AN differed in psychopathology, they shared a similar pattern in food-based decision-making and avoidant behavior in high-fat food. Self-control as a cognitive aspect in both subtypes, regardless of the difference in psychopathology and etiology, potentially influence the development and the maintenance of the AN individuals. Consequently, by addressing these issues and drawing inferences from this study, people can better understand the role of self-control from the cognitive aspect of the psychopathological mechanism of AN, and its negative influence on food-based decision-making and avoidant behaviors in patients who have been diagnosed with ANR and ANBP subtypes of AN.

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Self-regulation competencies and action orientation are critical factors in mediating subclinical eating disorder symptoms, particularly in terms of managing body dissatisfaction and mood fluctuation. Key elements of these self-regulatory competencies, self-regulation, and self-motivation, play an important role in managing body dissatisfaction and mood fluctuations. Individuals who are diagnosed with AN may exhibit high levels of self-regulatory competencies but are still susceptible to mood fluctuations, particularly the negative affective effect. Blasczyk-Schiep et al. using questionnaires investigated the impact of self-regulation in subclinical eating disorder symptoms in 98 high school students (aged 17-18) [5]. To assess positive (i.e., competences) and negative (i.e., depressive personality) affect, the study utilized personality traits as a standard test to examine the differences. The result demonstrated that the eating disorder symptoms would fluctuate in mood which in turn led to intensifying negative affect in participants with depressive personalities. Alternatively, eating disorder symptoms were negatively associated with self-regulation competencies in positive affect leading. It means that participants who displayed eating disorder symptoms with body dissatisfaction solely experienced negative affect, but they can downregulate negative affect via self-motivation competencies. In addition, self-relaxation and self-motivation were two variables in the multiple mediation model, playing a role in partial mediators in effect, as suggested by the study. Combing the self-relaxation disposition and high level of self-motivation can enable individuals to experience emotional well-being and maintain positive affect within both self-regulatory competitions. Therefore, individuals with eating disorder symptoms can also receive benefits from two dispositions so that they can overcome negative affect when in the face of an eating disorder. The author also suggested that action orientation was a key determinant in inhibiting eating disorders that regulates oneself to leave an affective state regardless of positive or negative. Given the role of action orientation, developing self-regulation skills with action orientation may be helpful for individuals who are struggling with eating disorders, as this skill can help them mediate their emotions about eating disorder symptoms. This understanding allows people to understand the role of self-control and self-regulation in AN from the cognitive perspective and underscores the potential impact of self-regulation competencies on negative affect in the context of subclinical eating disorder symptoms so that researchers can generalize these findings to a general population.

In short, both ANR and ANBP of AN subtypes demonstrate analogous self-control mechanisms in their food selections and avoidance behaviors, regardless of their distinct psychopathologies. This commonality in food-choice decision-making underscores the crucial role of self-control in AN's onset and persistence. These self-control-related cognitive processes engender an internalized norm, slanting their perception of high-caloric food as less palatable and unhealthy, thereby perpetuating their restrictive eating patterns. Moreover, competencies such as self-motivation and action orientation are vital in mitigating body dissatisfaction and mood irregularities related to eating disorder symptoms. These skills help with curtailing negative emotions and fostering emotional stability. This accentuates the prospect of developing self-regulation abilities, especially those rooted in an action-oriented approach, as a supportive measure for individuals grappling with eating disorders.

3. Factors of Social and Emotion in AN and Self-Control

3.1. Emotional Regulation and AN

The emotional regulation in individuals with AN is perplexing, especially engaging with interplays of emotional deregulation, rumination, and maladaptive eating behaviors. The process of AN's emotional regulation undergoes wax and wane, wherein there will be a negative consequence including food-based excessive carving thoughts and binge eating behavior. Seidel and colleagues

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investigated the emotional regulation of AN with 70 female participants aged 12.1 to 29.5 years old (35 diagnosed with AN and 35 age-matched healthy controls) with momentary assessment and fMRI study [6]. It was found that elevated body-related or weight-related rumination, negative affect, and tension were significantly associated with neural regulation in the ventral striatum within AN patients, not found in the control participants. Additionally, this finding aligns with past studies that AN patients were reliant on suppression as a regulatory strategy, despite this strategy also intensified rumination about food, and increased possibilities of binge eating behaviors and food cravings. Also, intense downregulation of hunger and food intake indicated an avoidant thinking mode towards extreme emotion states. Thus, avoidance was related to negative affect and rumination about food. Given the evidence of suppression of escalated thoughts around food and binge eating behaviors, this validifies the previous speculation that how extreme suppression may not be efficient in regulating desires for body dissatisfaction, which instead result in an adverse consequence. This also suggests that new therapeutic interventions, such as cognitive behavior therapy, are needed to deal with deteriorating emotional regulation skills in these individuals. For instance, the use of exposure therapy and emotion regulation skills to reeducate them. However, the experimental paradigm that utilized Emotion Regulation Task with emotional picture sets cannot fully explain the phenomenon in real-life situations as it is much intricate and diverse in practice. Therefore, future studies can emphasize developing more precise assessment methods to capture the multifaceted nature of emotional experiences and corresponding regulatory strategies via sufficient interventions in daily life contexts. In addition, with the findings in the ventral striatum among AN patients, future research can compare the functioning of this brain region with controlled samples, and there will be great progress in regulating emotional-related eating disorder symptoms.

AN and BN are two types of eating disorders. The pattern of eating behaviors may differ in terms of various affective states and individuals' self-control levels. This means that increasing self-control for individuals with AN can improve restrictive eating conditions. For individuals with BN, enhancement of self-control mechanisms can increase excessive eating behaviours. The study by Meule et al. demonstrated useful insights into the relationship between emotional regulation, affective states, and binge eating behaviors in female individuals who were diagnosed with AN and BN [7]. The result demonstrates that participants with AN and BN had higher negative affective states and utilized dysfunctional emotion regulation strategies compared with the control group. This demonstrates that negative affective states and the utilization of dysfunctional emotional regulation are common in eating disorders to respond to upcoming eating behaviors, regardless of specific types of disorders. Furthermore, the different eating patterns in both AN and BN suggests that the occurrence of emotional response like negative affective states may influence eating behaviors differently depending on the type of eating disorder. For instance, the AN group demonstrated increased food intake when happy and decreased intake when upset. Conversely, the BN group increased eating during sadness, anger, and anxiety, but reduced food intake when happy. This pattern suggests a unique role of self-control in each disorder concerning emotion regulation strategies. The application of self-control for the AN group may be instrumental in mitigating under-eating linked to positive emotions, whereas, for the BN group, self-control is crucial in managing over-eating tendencies during negative emotional states. Furthermore, the study establishes a connection between binge eating and negative affect in BN individuals. Both undereating triggered by positive affect and overeating induced by negative affect represent dysfunctional eating behaviors. This insight is beneficial for BN patient recovery, as it is observed that they eat less when experiencing happiness during treatment. Therefore, due to the different eating behaviors in terms of specific eating disorders, future studies should conduct tailored interventions to aim specific needs and difficulties of each disorder, by focusing on improving self-control related to emotional responses.

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All in all, emotional regulation plays a critical role in AN, characterized by an interplay of emotional deregulation, rumination, and maladaptive eating behaviors. Research reveals that AN patients exhibit neural alterations in the ventral striatum, suggesting a reliance on suppression as a regulatory strategy, despite its escalation of food-related rumination and potential binge eating behaviours. Therefore, therapeutic interventions like cognitive behavioural therapy may be needed to improve these individuals' deteriorating emotional regulation skills. Furthermore, the study demonstrates unique self-control roles in AN and BN, with emotional states influencing eating behaviours differently depending on the disorder. Thus, tailored interventions targeting self-control related to emotional responses are required for each disorder.

3.2. Social and Emotional Aspects

Individuals with AN often exhibit heightened social-cognitive sensitivity, as evidenced by their acute concern about body satisfaction and susceptibility to distorted images, particularly in the context of modern social media. Their extreme self-control behaviors to manage body dissatisfaction stem from external opinions about ideal body shape. In addition, external sources may not convey such meaning, but those individuals interpret them inadequately and negatively and thus take extreme actions which show cognitive rigidity. Therefore, individuals with AN are likely to exhibit thinking rigidity and low levels of mentalizing ability compared to normal populations. Evidence from Rothschild-Yakar et al.'s study supports the hypothesis [8]. The study investigated the mentalizing processes and predictive ability of affective regulation in AN and depression. It found that the AN group reported lower mentalizing ability and higher alexithymia and emotional reactivity compared to controls. This suggests that individuals with AN may overreact emotionally, and behaviourally in terms of external cues. Interestingly, there was no significant difference in Theory of Mind (ToM) measures, suggesting the specificity of certain cognitive impairments in these disorders. Furthermore, the study found that precise emotion recognition (low alexithymia) and higher mentalizing ability were associated with lower severity of eating disorder symptoms. This means that greater severity of AN individuals is associated with higher mentalizing ability and inadequate emotion recognition. Therefore, they can recognize emotions falsely from surrounding environments, with biased mentalizing and over-thinking. Thus, they initiate extreme behaviours to manage their body dissatisfaction stems from external environments, which can lead to cognitive rigidity. High alexithymia and depressive symptoms, on the other hand, predicted more intense eating disorder symptoms. Taken together, mentalizing ability and alexithymia were significantly correlated with eating disorder symptoms and predicted a link to AN. According to these findings, enhancing emotional understanding and mentalizing skills may be beneficial for managing eating disorder symptoms, including AN. Furthermore, given the association of high alexithymia and depressive symptoms with more severe eating disorder, interventions addressing these conditions may be crucial in treating AN. The shared characteristic of alexithymia between AN and depression suggests a potential common underlying mechanism that could be targeted in therapeutic interventions. Moreover, the unique link between mentalizing ability and AN highlight the possibility of developing tailored interventions based on unique cognitive profiles of different disorders.

Previous studies suggest that individuals with AN are associated with low levels of mentalizing ability and high alexithymia. These two factors may also later contribute to cognitive rigidity and behavioral inflexibility. Therefore, regarding the task-shifting paradigm, individuals with AN may also show slower response time and inaccurate responses. King and colleagues using aberrant task, response-set switching, and the interaction between two tasks, investigate the relationship between cognitive over-control and AN symptom in weight-recovered female participants (recAN) in comparison to a controlled healthy group [9]. This study focuses on the notion of how excessive

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self-control may relate to cognitive rigidity and behavioral inflexibility in patients with AN. The result demonstrated that recAN compared to the controlled group show a slower response, but a higher accuracy. This is different from the hypothesis that these individuals would show lower accuracy. The study elaborated that this speed-accuracy trade-off indicated a cognitive rigidity amongst AN individuals as they have the predisposition to maintain greater control to avoid generating errors in performance responses, which led to a disequilibrium allocation of priority between a superordinate task and a subordinate response. The theory of dual mechanism supporting this trade-off suggests that excessive dependence on sustained control, as evidenced by the generally slower but more accurate response in recovered AN, may compromise transient (reactive) control processes [10]. In addition, the finding demonstrated a small difference in reaction time between the recAN and the controlled group, but also an additional alternation in motor responses was dissociated from superordinate changes in task-setting. This again confirms the result that adjusted set-shifting in recAN might be associated with over-control. By addressing these cognitive aspects, it may be possible to facilitate a more balanced approach to decision-making, which could in turn contribute to improved treatment outcomes and overall well-being for individuals with AN.

The heightened activation in the amygdala among individuals with AN, compared to the general population, could potentially explain their predisposition to experience affective states more frequently, particularly those associated with negative emotions. In a focused study by Pauligk et al., neural predictors of affective states in AN were investigated using both ecological momentary assessment and fMRI scans, specifically targeting the dorsolateral prefrontal cortex (DLPFC) in 72 female adolescents (i.e., half diagnosed with AN and half age-matched healthy controls) [11]. The investigative focus was whether the initial presentation of the stimuli can predict the following affecting states. The study used arousal ratings for data analysis. The result revealed that within the AN cohort, elevated DLPFC activation predicted stronger amygdala reactivity during emotional processing tasks, a pattern not observed in the control group. This increased amygdala reactivity was associated with higher momentary tension in everyday life, suggesting a possible correlation between heightened amygdala activation and a predisposition to negative affective states in individuals with AN. These findings underscore the nuanced interplay between self-control, mediated by the DLPFC, and emotional reactivity, indexed by amygdala activation, within the context of AN. Intriguingly, the overuse of self-control mechanisms, often observed in AN, may contribute to emotional dysregulation, enhancing susceptibility to negative affective states. The divergence of these patterns in the control group emphasizes the potential dysregulation of this balance in individuals with AN, illuminating potential pathways for targeted interventions focusing on the regulation of self-control and emotional reactivity.

To summarise, individuals with AN often show cognitive rigidity and low levels of mentalizing ability, indicating a potential benefit from interventions that enhance emotional understanding and mentalizing skills. Moreover, research has found cognitive over-control in AN, leading to cognitive rigidity and behavioural inflexibility. Notably, recovered AN individuals exhibited slower but more accurate responses, indicating a predisposition to maintain control to avoid errors. This finding can guide the development of interventions that promote balanced decision-making, potentially improving treatment outcomes. Finally, neuroimaging studies have identified abnormal amygdala activation in individuals with AN, suggesting a predisposition to negative affective states. This insight emphasizes the need for interventions focusing on the regulation of self-control and emotional reactivity. Ultimately, understanding the nuanced interplay between emotional regulation, self-control, social factors, and behavioural habits in AN can guide future research and inform targeted, effective interventions.

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4. An Effective Intervention for AN

Concerning possible neural modifications in AN patients as suggested by prior research, the use of neuroscience tools such as transcranial magnetic stimulation (TMS) might have made significant strides in advancing effective treatments for AN. The prospective alterations in neuronal action potential could aid those suffering from AN in enhancing their cognitive flexibility regarding food selections, including high-fat foods and low-calorie "healthy" foods, thus potentially challenging their restrictive dietary habits. Dalton and colleagues' study adds to the existing literature on the relationship between self-control and AN by investigating the impact of repetitive TMS on food-based decision-making tasks [12]. Specifically, they placed rTMS on the left DLPFC. The study recruiting 34 female AN patients and 30 baseline participants, found that the AN group showed a propensity for low-fat foods, and rated high-fat foods less tasty and healthy, indicating a high degree of self-control. Interestingly, the stimulation of rTMS on the left DLPFC - an area lined with cognitive control - was significantly associated with decreased self-control in food choices after the treatment. This suggests a potentiality of neuro-modulatory interventions, such as repetitive rTMS for the restrictive eating behaviours observed in AN individuals. In other words, applying repetitive rTMS is possible to change thinking rigidity about decision-making processes regarding food intake in AN patients by reversing maladaptive restrictive food choices. However, there was no difference in food choice by fat content or rTMS application. This emphasizes the complexity of food-based decision-making processes. In general, this study underlies the complex relationship between cognitive control, specifically self-control, and eating behaviour in individuals with AN. The role of the left DLPFC in AN and the potential effects of manipulating activities encourage further replication to confirm precise functioning. The effects of repetitive rTMS also challenge the traditional view of AN as a disorder of excessive self-control and propose a more delicate understanding, wherein altering brain function in the left DLPFC region may potentially alleviate restrictive eating behaviors. Therefore, future studies should elucidate the precise mechanisms underlying the observed effects and maximize the use of rTMS in treating AN. Regarding excessive exercise as another hallmark of AN manifestation, it will be also valuable for individuals to investigate whether long-term repetitive rTMS treatment in practice can improve thinking rigidity from this perspective.

The above study indicated the importance of biological factors in AN. Consideration of measure validity and reliability, particularly when assessing self-control and AN symptoms, is crucial. The investigation of specific cortical regions should account for natural brain development, warranting age-range control or preliminary investigation of brain development in neuroscientific research. The maturation and thinning of the dorsolateral prefrontal cortex, located in the amygdala during adolescence, could alter cognitive control and emotion regulation, potentially impacting research findings [13, 14, 15].

5. Conclusions

The current review, despite offering insightful findings, suffers from several limitations. There is a lack of gender diversity in the participant pool across the included studies, which narrows the demographic context of understanding AN. To enhance the efficacy of future treatments for AN, it is imperative to diversify gender representation and incorporate comprehensive demographic information, such as age, race, and socioeconomic status. The complex interplay between self-control and AN, underpinned by emotional regulation, cognitive aspects, and neuroscience findings, necessitates a multi-dimensional and comprehensive investigation. Future research should adopt an integrative approach that includes psychological, neurobiological, and socio-cultural perspectives, which will facilitate a more holistic understanding of the role of self-control in AN. Lastly, it would

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be beneficial for future research to consider longitudinal study designs. These designs would provide insights into the causal relationships between self-control and the development and progression of AN. Furthermore, research contexts, such as laboratory settings, may not accurately reflect the real-world practice in which individuals with AN make decision about food and exercise. Therefore, future research should strive to employ more ecologically valid methods, such as experience sampling or naturalistic observation, to generalize findings to daily-life contexts of individuals with AN.

In conclusion, this review unveils the nuanced construct of self-control in the context of eating disorders, highlighting its role in AN that extends beyond food intake. This includes cognitive rigidity, heightened social-cognitive sensitivity, and deficits in mentalizing abilities and emotional understanding, which collectively contribute to restrictive eating behaviors and behavioral inflexibility. Neuro-modulatory interventions, like TMS, could potentially restore self-control in AN, enhancing cognitive flexibility in food choices, thereby modulating thinking patterns and behaviors. Future studies are encouraged to extend or replicate these findings to elucidate self-control's underlying mechanism in AN, thereby improving treatment efficacy and overall well-being for individuals with AN. This review can contribute to the design of prevention and intervention programs of AN.

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