Anorexia Nervosa: Striving for Control

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Your mind will be like its habitual thoughts; for the soul is dyed with the colour of its thoughts. Soak it then in such trains of thoughts as, for example:
Where life is possible at all, a right life is possible.

Marcus Aurelius

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Preface

The following chapters of this thesis have already been published in international peer reviewed journals:

Chapter 2 (referred to as Study 1):

Fürtjes, S., Seidel, M., King, J.A., Boehm, I., Jaite, C., Roessner, V., Ehrlich, S. (2019). A naturalistic investigation of cognitive-affective dysfunction in Anorexia nervosa: The role of inefficiency. *International Journal of Eating Disorders, 53 (2)*, 239-247.

S. Fürtjes developed the study concept under the supervision of S. Ehrlich. C. Jaite assisted with participant recruitment. S. Fürtjes, M. Seidel, and J.A. King collected the data. S. Fürtjes performed the data analysis and wrote the manuscript. M. Seidel, I. Boehm, J.A. King, V. Roessner, and S. Ehrlich provided critical feedback and revisions.

This publication is not used or planned to be used in any other dissertation.

Chapter 3 (referred to as Study 2):

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Chapter 4 (referred to as Study 3):

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This publication is not used or planned to be used in any other dissertation.

Abstract

Anorexia nervosa (AN) is an eating disorder characterized by severely low bodyweight, fear of weight-gain, and a subjective believe to be "fat". An elevated need for control and fear of losing control are considered core aspects in the development and maintenance of AN and restricting food intake is thought to function as a means to gain feelings of control (Fairburn, Shafran, & Cooper, 1999; Schmidt & Treasure, 2006). Feelings of inefficiency (i.e. lack of control regarding personal goals) have been found to predict longer duration of treatment and worse treatment outcome, underlining the relevance of the need for control in AN (Olatunji, Levinson, & Calebs, 2018; Pinto, Heinberg, Coughlin, Fava, & Guarda, 2008; Surgenor, Maguire, Russell, & Touyz, 2007). The constant striving for control could lead to rumination and negative affect – two further important symptoms associated with AN. The Goal Progress Theory of rumination (GPT; Carver & Scheier, 1990; Martin & Tesser, 1996) proposes that perceived discrepancies between desired goals (in the case of AN e.g. goals regarding lowest possible calorie intake, weight, etc.) and the current state (in the case of AN e.g. the subjective conviction of having eaten or weighing too much) trigger ruminative thoughts, which subsequently lead to negative affect. Following this theory, it could be suggested that gaining feelings of goal-progress and control could lessen the burdening repetitive thoughts and negative affect and that individuals with AN try to achieve this by restricting food intake. This dietary restriction requires self-control. However, previous research has shown that patients with AN typically not only show such elevated self-control, but also display rigid habitual behaviours and routines, struggle with set-shifting, and often display comorbid obsessive-compulsive symptoms (Treasure & Schmidt, 2013; Halmi et al., 2003). This raises the question of whether food restriction in AN is indeed an act of self-control or rather a habit. Recent scientific development has challenged the traditional dichotomy between controlled and automatic processes (Shiffrin & Schneider, 1977), instead suggesting that they are intertwined in such a way that often self-control works via the establishment of goal-serving habits and routines (Gillebaart & de Ridder, 2015; Galla & Duckworth, 2015).

These theoretical considerations can generally draw support from previous research, but have not been investigated explicitly in the context of AN. It was the main goal of this thesis to analyse associations between feelings of inefficiency, rumination and negative affect, controlled and habitual behaviour, and eating behaviour to establish an empirical foundation for the proposed relationships between these aspects of AN.

Study 1 (Fürtjes, Seidel, et al., 2020) employed ecological momentary assessment (EMA; data collection several times a day over a period of several days in the natural environment of the participants) to investigate associations between feelings of inefficiency, rumination, and affect

in a sample of individuals with a history of AN who had recovered from the disorder in terms of eating behaviour and bodyweight and age-matched healthy control participants (HC). AN participants displayed elevated rumination about bodyweight/figure (but not food) and negative affect compared to HC, suggesting that these cognitive-affective symptoms are persistent even after recovery. Analyses investigating associations with inefficiency showed that inefficiency was associated with heightened rumination and negative affect, which is in line with the GPT. Furthermore, AN participants showed higher levels of inefficiency than HC and stronger associations between rumination and negative affect. These findings indicate that feelings of lack of goal-progress and control are a central aspect of AN, likely contributing to maintenance of the disorder by triggering dysfunctional cognitive-affective processes. The fact that these associations were still present in a sample of recovered individuals underlines the persistence of these processes, suggesting that they might not only maintain the disorder but could also present a vulnerability factor or contribute to risk of relapse.

Study 2 (Fürtjes et al., 2018) made use of EMA and leptin, an endocrinological marker of undernutrition, to further investigate associations between rumination and affect in a sample of patients with acute AN, once at the beginning of treatment and again after weight-restoration. In line with Study 1, results confirmed that rumination about bodyweight/figure and negative affect are closely linked in AN and that this association persists even after weight-gain. Thoughts about food on the other hand were associated with leptin levels, declined with weight-gain, and showed weaker associations with affect. This suggests that thoughts about food may reflect a physiological symptom of the disorder, connected to undernourishment, whereas thoughts about bodyweight/figure might present a cognitive-affective symptom which could be involved in maintenance of the disorder (as suggested by Study 1).

To test supporting evidence for the interaction of self-control and habits in the regulation of eating behaviour, Study 3 (Fürtjes, King, et al., 2020) employed task-based measures of controlled and automatic processing as well as self-report measures of self-control, habitual behaviour, and eating behaviour in a large female sample representative of the general population through an online study design. Results obtained via structural equation modelling (SEM) revealed that eating behaviour appears to be largely guided by habits and automatic behavioural tendencies, whereas controlled aspects have an indirect influence via this association. These findings could be interpreted as support for the proposal that self-control might work via the establishment of goal-serving habits and routines, which outlines the possibility that the restrictive eating behaviour in AN might be achieved and maintained via a combination of self-control and rigid routines and habits.

Taken together, the research presented in this thesis was able to demonstrate how striving for control as a core aspect of AN might play a role in triggering dysfunctional cognitive-affective processes, likely contributing to development and maintenance of the disorder, and that self-control and habitual behaviour interact in guiding human eating behaviour, carrying implications for the mechanisms behind restrictive eating in AN. Clinical implications that can be derived from this research include addressing need for control and feelings of inefficiency in therapy to enable improvement of dysfunctional cognitive-affective processes as well as eating behaviour.

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List of Abbreviations

AN	**A**norexia **N**ervosa
BDI-II	**B**eck **D**epression **I**nventory II
BMI	**B**ody **M**ass **I**ndex
BMI-SDS	**B**ody **M**ass **I**ndex **S**tandard **D**eviation **S**core
CPM	**C**onceptual **P**rocess **M**odelling
EDI-2	**E**ating **D**isorder **I**nventory 2
EMA	**E**cological **M**omentary **A**ssessment
GPT	**G**oal **P**rogress **T**heory
HC	**H**ealthy **C**ontrol Participant
HLM	**H**ierarchical **L**inear **M**odelling
IMC	**I**nstructional **M**anipulation **C**heck
RST	**R**esponse **S**tyles **T**heory
SEM	**S**tructural **E**quation **M**odelling
SIAB-EX	**S**tructured **I**nterview for **A**norectic and **B**ulimic **E**ating Disorders
TP	**T**ime**p**oint

1 General Introduction

1.1 Need for Control in Anorexia Nervosa

Self-control is the ability to override and change responses or behaviour to correspond with personal goals, including inhibition of undesired impulses or behavioural tendencies (Nigg, 2017). Heightened self-control is considered a core aspect of Anorexia nervosa (AN) (Bruch, 1978; Casper, 1998; Fairburn et al., 1999). Patients with AN typically set themselves extremely low weight-goals and – in striving towards those goals – exhibit restrictive eating behaviour that requires extreme amounts of control to resist food intake and inhibit hunger. Not only control of eating behaviour plays an important role in the disorder, but general need for control and fear of losing control are considered central maintenance factors of the disorder (Cooper, 2005; Fairburn et al., 1999; Schmidt & Treasure, 2006; Surgenor, Horn, Plumridge, & Hudson, 2002): Patients with AN use control over eating as a means to stabilize their feeling of self-worth (Fairburn et al., 1999) and report that being able to feel in control via typical AN behaviour (food restriction, excessive exercise, body-checking etc.) is experienced as an ego-syntonic aspect of their illness which they perceive as a benefit (Serpell, Treasure, Teasdale, & Sullivan, 1999). This is supported by findings that (subjective) loss of control leads to negative affect in the everyday life of patients with AN (Engel et al., 2013). Fear of losing control has not only been established as an important aspect of AN, but was also found to predict symptoms of eating disorders in the general population (Froreich, Vartanian, Grisham, & Touyz, 2016), suggesting that it might not just function as maintenance factor but could also represent a vulnerability. Subjective feelings of inadequacy and lack of control regarding personal goals have also been labelled as “inefficiency”, a factor that has also long been considered an important aspect of AN (Bruch, 1978; Froreich et al., 2016). In fact, higher inefficiency was found to predict longer duration of treatment as well as poorer treatment outcome (in terms of aspects such as body-dissatisfaction, comorbid depressive symptoms etc.) in AN – and be especially reliable in this prediction, even when controlling for the extent of symptoms at the beginning of treatment or severity of the disorder (i.e. weight status/body mass index (BMI)) (Olatunji et al., 2018; Pinto et al., 2008; Surgenor et al., 2007). Heightened control and need for control as central aspects of AN present the cornerstone upon which the further theoretical considerations and consequently the empirical research presented in the current dissertation were developed.

1.2 Rumination in Anorexia Nervosa

Need for control and fear of losing control in AN as discussed above are associated with further cognitive and affective aspects of the disorder such as rumination and depressed mood. Rumination (defined as repetitive thoughts about causes and consequences of distress and negative affect (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Smith & Alloy, 2009)) is highly prevalent in AN (Rawal, Park, & Williams, 2010) and has been proposed to play an important role in the maintenance of the disorder (Fairburn et al., 1999; Treasure & Schmidt, 2013). Patients with AN are constantly preoccupied with thoughts about food, bodyweight, and figure (Cooper, 2005; Treasure & Schmidt, 2013). Similar to analogue associations in depression (Nolen-Hoeksema et al., 2008; Segerstrom, Tsao, Alden, & Craske, 2000), these ruminative thoughts are linked to negative affect (Seidel et al., 2016; Smith, Mason, & Lavender, 2018) – but show a specific relation to eating disordered pathology exceeding shared associations with comorbid symptoms of depression or anxiety (Cowdrey & Park, 2011; Rawal et al., 2010; Startup et al., 2013), which highlights the importance of rumination in AN. While the relevance of rumination in the context of AN is well established, its role within the framework of the disorder remains to be determined.

1.2.1 Goal Progress Theory of Rumination: Relevance in the Context of Anorexia Nervosa

A general model of rumination (not specific to AN) is the Goal Progress Theory (GTP) (Carver & Scheier, 1990; Martin & Tesser, 1996). This theory proposes that rumination arises whenever an individual experiences a discrepancy between a current state and a desired goal, and progress towards this goal is perceived as insufficient. Rumination then continues until the goal is either reached or abandoned. This theory is supported by findings of associations between heightened rumination and unresolved goals, low goal success, or goal frustration (Koole, Smeets, Van Knippenberg, & Dijksterhuis, 1999; Moberly & Watkins, 2010; Roberts, Watkins, & Wills, 2013). In fact, it has been suggested that the GPT presents the most fitting theoretical framework for explaining why rumination occurs in the general population as well as in individuals with psychiatric disorders (Watkins, 2008). Regarding the well-established association of rumination with negative affective states and depression (Naumann, Tuschen-Caffier, Voderholzer, Caffier, & Svaldi, 2015), the GPT proposes that negative affect occurs as a consequence of rumination. Findings of negative affect following rumination in everyday life support this proposal (Moberly & Watkins, 2010), as do findings of associations between rumination and depression specifically

in individuals who ruminate (Jones, Papadakis, Hogan, & Strauman, 2009). These general considerations regarding rumination are relevant in the context of AN. Patients with AN typically set extremely low weight-goals for themselves, which (according to the GPT) could explain the heightened rumination about bodyweight and figure in AN. Feelings of inefficiency and perceived lack of control while striving towards these goals have also been discussed above as a core aspect of the disorder. It could therefore be argued that unreachable weight-goals and striving for an unachievable level of control could be the underlying trigger of constant rumination about food, bodyweight, and figure in AN – which leads to negative mood and comorbid depressive symptoms. The empirical findings regarding inefficiency, need for control, and rumination in AN as discussed above underline the relevance of this perspective bringing the GPT into context with AN – however, research specifically addressing the integration of this theory into a framework of the disorder is lacking thus far. Study 1 (Fürtjes, Seidel, et al., 2020) aims to fill this gap.

1.2.2 Further Theoretical Approaches to Rumination in Anorexia Nervosa

1.2.2.1 Affective Dysregulation

Although the GPT presents a compelling framework for rumination in AN (especially against the backdrop of aspects of the disorder related to control and inefficiency), there are further theoretical approaches that ought not be neglected. The Response-Styles-Theory (RST) (Nolen-Hoeksema, 2004) has long been considered an important framework of rumination. The RST proposes that rumination and negative affect are associated with each other in a reciprocal manner: rumination increases negative affect, and negative affect leads to heightened rumination. This theory has been supported by studies of ruminative thoughts and affect in everyday life which report such reciprocal relations (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Moberly & Watkins, 2008). While originally placed in the context of depression (Nolen-Hoeksema, 1991), the RST has since been brought into a broader frame, proposing that rumination is linked with dysfunctional emotion regulation in general and might play an important role as a transdiagnostic factor of different psychiatric disorders (McEvoy, Watson, Watkins, & Nathan, 2013; McLaughlin & Nolen-Hoeksema, 2011). This could apply to AN, considering that affective dysregulation is an important aspect of AN (Cooper, 2005; Oldershaw, Lavender, Sallis, Stahl, & Schmidt, 2015). It has been suggested that rumination in AN might present a dysfunctional strategy to regulate affect (Oldershaw et al., 2015). This is supported by empirical findings of associations between rumination and negative affect as well as symptoms such as desire to engage in restrictive behaviour in AN (Naumann et al., 2015; Naumann, Tuschen-Caffier, Voderholzer,

& Svaldi, 2014; Seidel et al., 2016). Considering the high prevalence of comorbid depressive symptoms in AN (Hudson, Hiripi, Pope Jr., & Kessler, 2007) and the empirical evidence of associations between rumination, negative affect, and AN symptoms, it follows that the RST presents an alternative theoretical approach to rumination in AN which should also be included in an investigation of the topic. Studies 1 and 2 (Fürtjes et al., 2018; Fürtjes, Seidel, et al., 2020) take this into consideration.

1.2.2.2 Physiological Context

Both the GPT and the RST are theories of rumination that focus on cognitive-affective processes. While this is certainly immanent to the subject, a further theoretical approach which diverges from this perspective also needs to be taken into account. Studies have shown that starvation or severe undernourishment lead to constant thoughts about food and preoccupation with the topic (Keys, Brozek, Henschel, Mickelsen, & Taylor, 1950; Polivy, 1996). Even in individuals in a healthy, nourished physiological state dieting has been found to be associated with elevated levels of ruminative thoughts (Kemps & Tiggemann, 2005). The case could be made that the repetitive thoughts (especially about food) in AN are not solely a cognitive-affective phenomenon but can be brought into context with the physiological aspects of the disorder. Theoretical models of AN have suggested that the severely undernourished state of acute AN leads to a narrowing of interests and thoughts centred around content related to the disorder (such as food and bodyweight or figure) – a proposal that is supported by findings of bias towards information related to food during cognitive processing in both AN as well as healthy individuals who report restrictive eating behaviour (King, Polivy, & Herman, 1991). This perspective on rumination in AN has not been studied to the same extent as the cognitive-affective theories but nevertheless should be considered as a possible explanation for elevated rumination in AN – especially in the acute state, when undernourishment is severe. This perspective is addressed in Study 2 (Fürtjes et al., 2018).

1.2.3 Integrative Perspective

Three different perspectives on rumination in AN have been discussed: rumination as the result of feelings of discrepancy between actual and desired states which leads to negative affect (GPT), rumination as an aspect of emotion-dysregulation (RST), and rumination as the result of undernourishment (physiological context). These perspectives need not stand in contrast with each other but might complement each other by highlighting different aspects of the topic. One objective of this work is to provide an integrative approach which enables a broader understanding

of rumination in AN. While the repetitive thoughts about food could be understood as a consequence of undernourishment (physiological context), the rumination about bodyweight, figure, and further topics related to the disorder could be the consequence of perceived goal discrepancies and lack of control (GPT). Ruminative thoughts could lead to negative affect (GPT and RST), resulting in a reciprocal process of affective dysregulation (RST). This theoretical framework is based on the considerations and empirical findings discussed up until this point and offers the possibility of a broader understanding of the role of rumination within AN by including associations with further cognitive aspects of the disorder (heightened need for control), affective aspects (comorbid depressive symptoms and affective dysregulation), and physiological aspects (undernourishment).

1.3 Eating Behaviour: Theoretical Approaches

Limiting food intake and following strict rules regarding eating behaviour is not only the core symptom of AN, it might also play a functional role in the development and maintenance of the disorder. As mentioned at the beginning of this work, excessive dieting and food restriction is thought to present the means by which patients with AN achieve a feeling of control (Fairburn et al., 1999; Serpell et al., 1999). Food restriction as a behavioural aspect of AN is therefore most likely also closely linked to the cognitive-affective processes discussed above. It could be argued that food restriction provides a feeling of control which lessens distressing symptoms of the disorder such as ruminative thoughts and negative affect. Considering that restriction of food intake is likely of a high relevance for patients with AN to feel efficient and in control, a closer look should be taken at the question how they succeed in employing the heightened self-control that is needed to continue extreme dieting despite severe physiological consequences.

1.3.1 Self-Control and Eating Behaviour

Based on the introductory considerations, it would appear plausible to assume that self-control as a core aspect of the disorder also represents the main instrument through which patients with AN succeed in reaching and maintaining extremely low bodyweight. In the general population higher values in different measures of self-control and cognitive control (a related construct referring to cognitive processes that organize behaviour in a goal-directed manner (Cohen, 2017)) have been associated with successful weight-loss, constrained eating behaviour

(e.g. less consumption of foods rich in fat), and lower BMI (Allom & Mullan, 2014; Bickel, Moody, Koffarnus, Thomas, & Wing, 2018; Hall, 2012; Jasinska et al., 2012). Such findings suggest that self-control and cognitive control indeed influence eating behaviour and contribute to attaining and maintaining low bodyweight. The research addressing this topic stretches over a wide variety of methodical approaches. Self-reported trait self-control was found to predict self-reported eating behaviour (Forestier et al., 2018) as well as faster resolution of conflict during food choices (Gillebaart, Schneider, & de Ridder, 2016). Task-based measures of different aspects of heightened cognitive control (parameters of classic tasks such as e.g. Stroop) have been associated with less snack consumption in laboratory settings (Houben, 2011), resistance to food desires in everyday life, and successful weight-loss (Hofmann, Adriaanse, Vohs, & Baumeister, 2014). Even intra-individual fluctuations in task-based measures of cognitive control during the day were found to predict snacking behaviour (Powell, McMinn, & Allan, 2017). It has also been suggested that training of control can influence eating behaviour in lab-based studies (Houben & Jansen, 2011). Taken together, there exists considerable evidence that a) control represents a core aspect of AN and b) eating behaviour is associated with self- and cognitive control. It could therefore be assumed that the rigorous food restriction in AN is achieved via mechanisms of control.

1.3.2 Habits and Eating Behaviour

While the considerations discussed in the previous paragraph are certainly valid, a different perspective has also received considerable attention in recent research. It has been suggested that not only self-control is an immanent aspect of AN, but that rigid behavioural patterns and habits (which can be defined as learned responses to contextual cues, activated independently from short-term goals (Wood & Rünger, 2016)) also play an important role (Schmidt & Treasure, 2006; Treasure & Schmidt, 2013). Patients with AN typically display high levels of rigidity and habitual behaviour, many also show comorbid symptoms of obsessive-compulsive disorder and struggle with set-shifting (i.e. the ability to flexibly switch between tasks and mindsets) (Halmi et al., 2003; Treasure & Schmidt, 2013). It has therefore been proposed that food restriction in AN might not be merely related to self-control, but could also be understood as a habit which – once it has been established – occurs relatively independent of self-control (Coniglio et al., 2017). This theoretical framework of food restriction via habitual behaviour instead of self-control is in line with the results of studies of eating behaviour in the general population, where habit-based approaches to weight-loss diets are considered among the most successful interventions, with promising long-term results of weight-loss and maintenance (Beeken et al., 2016; Cleo, Isenring,

Thomas, & Glasziou, 2017). Independently from weight-loss diets, eating behaviour in general has been found to be largely guided by habits, automaticity (an aspect of habit regarding effortless, fast, and inflexible processing (Wood & Rünger, 2016)), and reactions to contextual cues – whereas self-control appears to play a subordinate role (Cohen & Farley, 2008; van't Riet, Sijtsema, Dagevos, & de Bruijn, 2011; Wansink, 2004). Just like the research regarding self-control, this different line of investigations of eating behaviour focusing on habits and automaticities is also based on varying methodological approaches. For example, parameters of automatic (not controlled) processing during reaction-time tasks were found to predict chocolate consumption in laboratory settings (Allan, Johnston, & Campbell, 2010). In real-life assessments, eating behaviour was found to be guided by momentary contextual cues – but not by intentions or self-control (Elliston, Ferguson, & Schüz, 2017). It can therefore be assumed that habits and automaticity play an important role in food choices and consumption. Taken together, the characteristic rigid and habitual behaviour in AN and the general strong association between automatic processing and habits with food consumption and success of weight-loss diets indicate that patients with AN might be able to keep up their extreme food restriction not solely by engaging in self-control, but rather by developing restrictive eating habits.

1.3.3 Integrative Perspective

As discussed above, there is substantial evidence for both perspectives on the mechanisms behind restrictive eating behaviour in AN: cognitive control and self-control as well as automaticity and habits. This suggests that both aspects might be involved but differ in the nature of their role in restriction of food intake. When trying to integrate the different theoretical accounts into a broader perspective, it should be noted that the traditional dichotomy between self-control and habits, between cognitive control and automaticity (Shiffrin & Schneider, 1977) has been challenged in recent scientific debate (Awh, Belopolsky, & Theeuwes, 2012). An integrative perspective has emerged which suggests that controlled and automatic processes which guide human behaviour are not separate, but in fact intertwined. On the level of cognitive processing, it has been found that controlled and automatic processes interact with each other in directing responses in classic reaction-time tasks (Crump, Gong, & Milliken, 2006). For example, controlled processing can be adjusted through automatic reactions to contextual cues, leading to an efficient processing style that engages in (effortful) control when it is needed to resolve conflict and otherwise relies on (effortless) automatic processing (Bugg & Crump, 2012; Egner, 2014). Similarly, it has been proposed that self-control and habits interact in their influence on behaviour in everyday life (Bargh & Chartrand, 1999; Gillebaart & de Ridder, 2015). The impact of self-

control on behaviour (and consequently on real-life outcomes such as e.g. BMI, health, professional success, etc.) is likely mediated via habits in such a way that establishing habits and adaptive routines that serve long-term goals might be the most efficient mechanism by which self-control can operate (de Ridder & Gillebaart, 2017; Galla & Duckworth, 2015). This integration of controlled and automatic aspects of cognitive processing and behaviour is supported by findings in the context of eating behaviour. Cognitive control was shown to be associated with eating behaviour via automatic responses to situational cues (Jasinska et al., 2012), and the association between self-control and consumption of snack foods was found to be mediated via snacking habits (Adriaanse, Kroese, Gillebaart, & de Ridder, 2014). The effect of self-control on eating behaviour in general has also been suggested to be mediated via habits which guide food consumption (de Bruijn et al., 2007; Lin, Wood, & Monterosso, 2015), and self-control during food choice was found to work via automatic processing that is in line with self-controlled choices (Georgii, Schulte-Mecklenbeck, Richard, van Dyck, & Blechert, 2019). Self-controlled behaviour in the context of eating was also found to be improved by establishing rituals which alter automatic responses in conflicting situations during food choice (Tian et al., 2018) – an interesting finding supporting the notion that an efficient way of exercising self-control could be to establish habits that are in line with long-term goals. Based on the research discussed here it can be proposed that restrictive eating in AN might not be either a result of self-control or of habit, but that instead both aspects work together in establishing and maintaining excessive dieting. Extreme food restriction in AN could be achieved via high self-control operating via the establishment of eating habits which enable patients to continue with strict dieting despite physical harm and further negative consequences (Marsh, Steinglass, Graziano, Peterson, & Walsh, 2007). While broad empirical evidence for different single aspects of this perspective has been discussed, research explicitly investigating this integrative framework of the mechanisms behind restrictive eating in AN is lacking to date. Study 3 aims to provide general empirical evidence for the proposed associations between self-control, habitual behaviour, and eating behaviour.

1.4 Research Objectives and Study Hypotheses

The theoretical considerations regarding elevated control and need for control, high habitual behaviour, rumination, and negative affect in AN presented above lead to several open questions.

As illustrated above, it remains unclear whether the extreme food restriction in AN presents a result of elevated cognitive and self-control or rather a habit. Both perspectives are theoretically founded and can draw support from empirical findings. Instead of addressing this question as a

dichotomy, it can be proposed that self-control and habitual behaviour in AN are connected to each other and both contribute to the excessive dieting: high self-control might initially enable patients with AN to establish the restrictive eating behaviour, a proneness to routine and habitual behaviour accompanied by cognitive rigidity and impaired set-shifting could maintain it. While previous findings lend some support to this proposal, research is needed to investigate whether such associations between self-control, habitual behaviour, and restrictive eating can indeed be observed.

A further open question regards the role of heightened rumination in AN. While empirical findings have supported associations with negative affect, a possible connection to need for control and feelings of inefficient goal-progress has so far been mostly neglected in research, even though the theoretical background is well established. The same can be said for possible associations with physiological aspects of the disorder such as undernourishment. Just like restrictive eating, the topic of rumination in AN could also be viewed from an integrative perspective. A differentiation between rumination about food vs. rumination about bodyweight and figure would allow for the connection of the different theoretical approaches: rumination about food could be explained by undernourishment, whereas rumination about bodyweight and figure might result from feelings of inefficiency and lack of control. Rumination about bodyweight and figure could consequently lead to negative affect and play a role in affective dysregulation. Research addressing this broader framework of the role of rumination in AN is warranted to establish an empirical basis for the theoretical considerations.

Taken together, an investigation of these open questions would allow for a better understanding of the associations between a) need for control and inefficiency, rumination, and negative affect in AN as well as b) self-control, habitual behaviour, and eating behaviour. A visual representation of the proposed framework of these associations can be found below in *Figure 1.1*. The placement of the individual studies presented in the second part of this thesis within the framework is depicted subsequent to the description of the objectives and hypotheses in *Figure 1.2*.

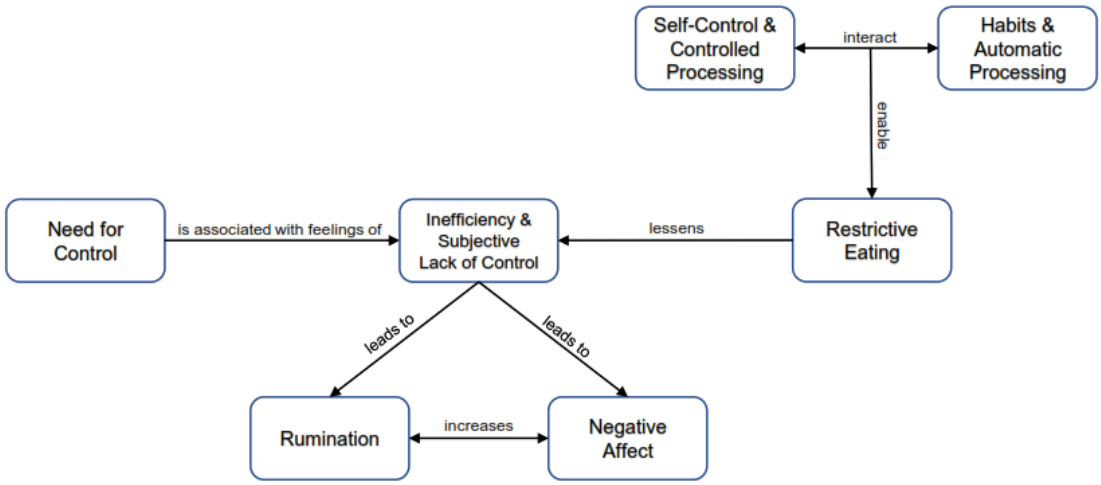


Figure 1.1. Visual representation of the proposed associations between need for control, rumination, negative affect, self-control, and habitual behaviour in AN.

1.4.1 Objectives and Hypotheses: Study 1

Study 1 (Fürtjes, Seidel, et al., 2020) investigated associations between inefficiency, rumination, and affect. The hypotheses were proposed that a) AN experience heightened feelings of inefficiency and lack of control compared with HC, b) inefficiency is generally linked to heightened rumination and (via this association) negative affect, and c) that these associations are more pronounced in individuals with AN compared to HC. Associations between rumination and affect were assessed in everyday life of individuals with a history of AN via smartphone-based ecological momentary assessment (EMA). EMA consists of multiple assessments via short questionnaires per day over a period of several days and is therefore able to capture not only inter- but also intraindividual differences and fluctuations (Ebner-Priemer & Trull, 2009; Lavender et al., 2013; Shiffman, Stone, & Hufford, 2008). This method enabled the investigation of associations between rumination and affect in real-time during everyday life of the participants. Comparing individuals with AN to HC, these associations were analysed in their relation to inefficiency. Addressing these research questions allowed for a deeper understanding of the role of rumination in AN in the context of feelings of inefficiency and lack of control, thereby collecting empirical support for the relevance of the GPT in the context of the disorder.

1.4.2 Objectives and Hypotheses: Study 2

Study 2 (Fürtjes et al., 2018) investigated whether a distinction between rumination about food vs. bodyweight and figure is needed to enable a better understanding of the role of rumination in AN. The central research hypothesis was that food-related rumination in AN would be linked to undernourishment and physiological aspects of AN, whereas rumination about bodyweight and figure would be relevant in the cognitive-affective context of the disorder. As in Study 1, the assessment of rumination and affect was conducted via EMA in the everyday life of the participants, the sample consisted of participants with acute AN. The EMA data on rumination and affect was analysed in the context of the physiological parameters BMI and leptin – a hormone secreted by adipocytes which indicates nutritional status. Assessments were conducted once at the very acute state of the disorder with severely low bodyweight and were repeated after weight-restoration when bodyweight had largely normalized. The combination of EMA and neuroendocrinological parameters in a longitudinal study design facilitated a thorough and highly informative investigation of associations between rumination, affect, and undernourishment in AN.

1.4.3 Objectives and Hypotheses: Study 3

In Study 3 (Fürtjes, King, et al., 2020), associations between cognitive control and self-control, automaticity and habitual behaviour, and eating behaviour were investigated in a large female sample of the general population to collect preliminary evidence for the integrative perspective on the mechanisms behind restrictive eating in AN as discussed at the beginning of this work. This study aimed to explore the hypothesis that controlled and automatic aspects of behaviour interact in guiding eating behaviour. It was proposed that a) eating behaviour is largely guided by automaticity and habits, and b) that the impact of self-control on eating behaviour is mediated via habits and automatic behaviour. By integrating task-based measures of cognitive control and automaticity with self-report measures of self-control and habitual behaviour in an online study-design, associations between these variables and self-reported eating behaviour were analysed in a large female sample via crowdsourcing. The implications for real-life outcomes were addressed by including BMI and success of weight-loss diets. Confirming the proposed mechanisms guiding eating behaviour in the general population would present an empirical basis for further research of this topic in AN. It was the objective of Study 3 to collect such empirical evidence as a starting point for further investigations of the associations between control, automaticity, and restrictive eating in AN.

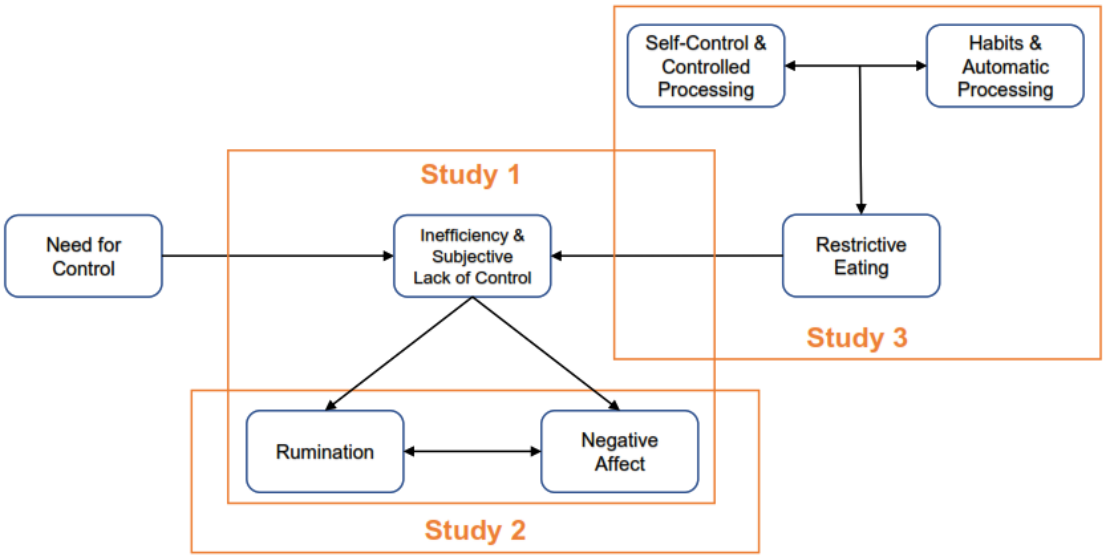


Figure 1.2. Visual representation of the three studies showing which aspect of the proposed framework of need for control, rumination, negative affect, self-control, and habitual behaviour in AN they address.

2 A Naturalistic Investigation of Cognitive-Affective Dysfunction in Anorexia Nervosa: The Role of Inefficiency

2.1 Abstract

Research has shown that rumination and negative affect are elevated in patients with Anorexia nervosa (AN), but the underlying origins remain unclear. Drawing from the theoretical framework of the Goal Progress Theory of rumination, we propose that heightened feelings of "inefficiency" (i.e. low self-efficacy) in AN might play an important role in these dysfunctional cognitive-affective processes. 32 weight-recovered participants with a history of AN and 32 healthy control participants filled out questionnaires regarding rumination and affect six times a day over a period of two weeks via ecological momentary assessment in real-life. Analyses via hierarchical as well as conceptual process modelling suggest that while inefficiency is generally associated with more rumination and negative affect, additional amplifying mechanisms between these variables exist specifically in recovered participants with a history of AN. Inefficiency as a core aspect of AN appears to trigger dysfunctional cognitive-affective processes which may contribute to vulnerability for AN.

2.2 Introduction

Rumination, which can be described as repetitive thoughts about distressing topics, is an important aspect of anorexia nervosa (AN) and has received growing attention in recent research (e.g., Smith, Mason, & Lavender, 2018). Although the exact definition of rumination and its relation to other constructs of repetitive thinking is a subject of debate, it is commonly assumed that ruminative thoughts repeatedly circle around the self and personal concerns (and therefore differ from related constructs such as "worry", which tends to be more future-focused, or "preoccupation", which may include behavioural aspects; Smith & Alloy, 2009; Smith et al., 2018; Startup et al., 2013). The frequency of ruminative thoughts (especially about topics such as weight and figure) has been found to be elevated in patients with AN (e.g., Seidel et al., 2016; Startup et al., 2013) and predictive of eating disorder symptoms even after accounting for depression or anxiety (Cowdrey & Park, 2012; Startup et al., 2013). Nevertheless, the role of rumination in AN remains unclear. Research to date has primarily focused on its association with emotion-regulation and affect (e.g., Fürtjes et al., 2018; Oldershaw, Lavender, Sallis, Stahl, &

Schmidt, 2015; Seidel et al., 2018). Associations between both rumination and negative affect as well as negative affect and eating disorder behaviour have previously been reported (Engel et al., 2013; Goldschmidt et al., 2014; Seidel et al., 2016) and ruminative thoughts have been suggested to contribute to maintenance of eating disorders (Treasure & Schmidt, 2013). However, to our knowledge, no studies have sought to identify the underpinnings of elevated rumination in AN.

Regarding the general underlying mechanisms of ruminative thoughts, Carver and Scheier (1990) proposed the Goal Progress Theory (GPT) which suggests that rumination is the result of goal discrepancies that arise when a person strives towards a goal without reaching it. If progress towards this goal is insufficient, the resulting rumination is accompanied by negative affect. This proposed connection of rumination and affect with (perceived) lack of goal-progress is supported by empirical findings. For example, cueing unreached goals has been shown to lead to an increase in ruminative self-focus (Roberts et al., 2013). In a study collecting situational data on rumination, affect, and goal attainment in everyday life of healthy participants, low goal attainment was also associated with more ruminative self-focus and more negative affect, especially when subjective goal-importance was high (Moberly & Watkins, 2008, 2010). The impact on affect included aspects such as valence (i.e. positive or negative), but also aspects related to arousal or tension. This is in line with a general theory of affective states proposing the three dimensions valence, arousal, and tension, which was first introduced by Wundt (1896) and has been well-recognized in the field (e.g., Russell, 2003). Patients with AN typically set themselves extremely low weight-goals and once these are reached still feel fat and set themselves even lower weight-goals (Fairburn & Harrison, 2003). Thus, they are never attaining an overall goal of feeling satisfied with their weight. Surprisingly, despite this common pattern, the GPT has been neglected in research on rumination as a symptom in AN.

Another related aspect discussed in the AN literature is “inefficiency”, or “ineffectiveness”, i.e. feelings of inadequacy and lack of control concerning personal goals or competence (Bruch, 1978; Froreich et al., 2016; Jacobi, Paul, de Zwaan, Nutzinger, & Dahme, 2004; Surgenor et al., 2007). Inefficiency is related to constructs in general and personality psychology regarding perceived control (e.g., low self-efficacy, low sense of control) as well as self-esteem (Froreich et al., 2016; Karpowicz, Skärsäter, & Nevonen, 2009) and includes feelings of deficient subjective control and worthlessness. Inefficiency as a core aspect of AN was first introduced by Bruch (Bruch, 1978). It is typically gauged via self-report and has been shown to influence risk of development of an eating disorder, duration of treatment, and treatment outcome (Olatunji et al., 2018; Pinto et al., 2008; Surgenor et al., 2007; Wade, Wilksch, Paxton, Byrne, & Austin, 2015). Within the framework of the GPT, one could hypothesize that a heightened feeling of inefficiency may lead to elevated rumination (e.g., about unreached goals regarding bodyweight or figure) in

AN and, consequently, negative affect. Thus, while rumination may be a key mediating variable of affect in AN, inefficiency might be the underlying trigger of dysfunctional cognitive-affective processes which could play a role in maintaining aspects of the disorder. As emotion regulation models of eating disorders suggest, patients try to escape the resulting negative affect using typical illness-related behaviours such as exercising, body-checking, or purging (Engel et al., 2013; Goldschmidt et al., 2014; Lavender et al., 2015).

In the present work we investigate how inefficiency relates to rumination and affect in a sample of individuals with a history of AN and age-matched healthy control participants (HC). Since previous research has shown that such cognitive and affective interplay might be overshadowed by physiological variables during the very acute state of undernutrition (Fürtjes et al., 2018; Treasure et al., 2015), we chose a sample of participants who have recovered from the disorder in terms of weight and eating behaviour, but still tend to show residual cognitive and affective symptoms. In addition, a sample of weight-recovered individuals could provide insight regarding possible vulnerability markers for risk of AN or even risk of relapse as well as possible factors for maintenance of residual symptoms. Rumination is difficult to assess in a laboratory setting, because retrospective measures of automatic and not always entirely conscious cognitive processes are influenced by memory bias. To avoid this problem, ecological momentary assessment (EMA), as used in the current study, has proven to be a useful tool for assessment of rumination as well as affect in real-life (e.g., Moberly & Watkins, 2010). Situational information can be gathered via smartphone in real-time and in the everyday environment of the participants. Variance can be assessed not only between, but also within participants through data collection over a period of several days.

To help elucidate the origins and functional role of rumination in AN and thereby foster a more comprehensive understanding of the disorder, we generated the following hypotheses based on the theoretical accounts discussed above. First, we expected that heightened self-reported inefficiency is generally associated with more ruminative thoughts and more negative affect (Hypothesis I). Second, we expected that AN would report more inefficiency (and therefore also more rumination and negative affect) than HC and possibly also show stronger associations between rumination and affect (Hypothesis II). Additionally, we expected that the association between inefficiency and negative affect would be partially mediated through rumination (Hypothesis III).

2.3 Methods

2.3.1 Participants

64 female volunteers between the ages of 15.4 and 29.7 participated in the study. Half of the participants were individuals who had recovered from AN in terms of weight and eating behaviour (AN), but still showed some residual symptoms of the disorder. Criteria for this status were: maintenance of a BMI higher than 18.5 for at least six months for participants who were 18 years old or older or of a BMI higher than the tenth age percentile for participants younger than 18 years, menses, absence of binging, purging, or restrictive eating patterns. These criteria as well as the previous diagnosis of AN were assessed with the structured interview for anorexic and bulimic disorders (SIAB-EX; Fichter & Quadflieg, 2001), supplemented by our own semi-structured interview. The other half of the sample consisted of age-matched HC participants, who met the criteria of a healthy bodyweight, menses, and no history of psychiatric illness. Exclusion criteria for both groups included among other aspects substance abuse and neurological conditions (see Appendix A 7.1.1.1 for more details).

2.3.2 Materials and Procedure

2.3.2.1 EMA Assessment

For the EMA data collection, rumination about weight/figure and food was assessed via modified items of the SIAB-EX interview (Q60, *"Since the last alarm, did you think about things related to food, nourishment, cooking, or calories?"*; Q61, *"Since the last alarm, did you think about your shape/figure or your bodyweight?"*). Answers were logged on a scale from 0 (*"not at all"*) to 100 (*"constantly"*). These two topics were considered most applicable to the research question, because they provide a focus on AN without lacking relevance in daily life of the sample of female HC and weight-recovered AN. Affect was assessed via a modified version of the multidimensional mood questionnaire (MDMQ; Steyer, Schwenkmezger, Notz, & Eid, 1997). The MDMQ measures current valence of affect, calmness, and energetic arousal via six items, also with visual analogue scales. These scales have two opposites as anchors (valence of affect: *content-discontent, well-unwell*; calmness: *agitated-calm, relaxed-tense*; energetic arousal: *tired-awake, high energy-low energy*) and answers were logged on a range from 0 (far left pole) to 100 (far right pole). Higher values indicate more positive valence, more calmness, and more energetic arousal. In addition to the assessment of rumination and affect, participants gave information about several contextual control variables (primary activity, company of others, etc.; see

Appendix A 7.1.1.2 for specific details).

2.3.2.2 Baseline Assessment

To operationalize inefficiency, we utilized the corresponding sub-scale of the Eating Disorder Inventory 2 (EDI-2; Thiel et al., 1997; including questions such as: *"I feel that I can achieve my standards."*), which has previously been established as a measure for feelings of ineffectiveness (Froreich et al., 2016; Jacobi et al., 2004; Tiggemann & Raven, 1998).

To account for possible differences in bodyweight, we assessed age-corrected body mass index standard deviation scores (BMI-SDS; Hemmelmann, Brose, Vens, Hebebrand, & Ziegler, 2010; Kromeyer-Hauschild et al., 2001).

2.3.2.3 Procedure

The study procedure was approved by the local ethics committee. Before participating in the study, participants (and if underage their legal guardians) gave informed consent. Participants were first interviewed, weighed, and measured prior to being instructed in a detailed tutorial on how to handle the smartphone for EMA assessment and fill out questionnaires. The signal-contingent assessment started on the following day and lasted for 14 days. Participants received a prompt to fill out the EMA questionnaire every day at six semi-random times during a 14-hour period (individually adapted to suit different daily routines). Prompts were anchored within six smaller intervals of two 2 ½ hour intervals (before midday) and four 1 ½ hour intervals (after midday). Between the intervals were 30-minutes breaks. Participants were instructed to fill out the questionnaire as soon as the prompt appeared, but a delay of a maximum of 30 minutes was possible when unable to reply (e.g., during class or work) or safety was a concern (e.g., while driving). After the 14 days of the study, participants returned the smartphone and received compensation for their participation.

2.3.3 Data Analyses

The nested data collected via EMA assessment requires consideration of the hierarchical structure nesting situations (level 1) into days (level 2) into participants (level 3). Our goal was to estimate direct effects of inefficiency (as a person-level variable) on rumination and affect (on the situational level). We therefore chose hierarchical linear modelling (HLM) for our main analyses, which can reliably produce estimates for the effects of interest (Raudenbush & Bryk, 2002). To investigate Hypothesis I regarding associations of inefficiency with rumination and

affect, we calculated two models predicting rumination (level 1) through inefficiency (level 3) and affect (level 1) (HLM models 1a+b; rumination about food and rumination about weight as outcome), and three models predicting affect (level 1) through inefficiency (level 3) and rumination (level 1) (HLM models 2a-c; valence, energetic arousal, and calmness as outcome). To address Hypothesis II regarding differences between AN and HC, all HLM analyses included group (level 3) as a predictor of rumination and affect (level 1) as well as a cross-level interaction of group (level 3) as a moderator variable for the association between rumination and affect (level 1). To investigate Hypothesis III, we conducted conditional process modelling (CPM), which is an integration of mediation and moderation analyses, for the person-level data. This allowed for estimation of mediation effects, which cannot be estimated via HLM. To facilitate these analyses, the situational data collected on rumination and affect was aggregated on the person level by calculating each participant's mean of the five variables (rumination about food, rumination about bodyweight/figure, valence of affect, energetic arousal, calmness) based on the individual values collected on the situational level. Three CPM models were calculated to analyse both direct and indirect effects of inefficiency on affect including rumination about weight as a mediator (CPM models a-c; valence, energetic arousal, and calmness as outcome). The CPM models also included group as a moderator of the effect of rumination about weight on affect, so that Hypotheses II was also addressed. An overview of all statistical models and matching hypotheses can be found in the Supplementary Material (see Appendix A 7.1.1.3).

In the HLM models, predictors were always included simultaneously to control for shared variance. All analyses included the variable day of study on level 2 and the variable time of day on level 1 to control for possible confounding effects that might arise due to the longitudinal design (e.g., effects of daily rhythms and patterns, or effects of increased sensitivity due to repeated questions about the same topic). For the same reason, dummy-coded variables representing the company of others and primary activity were included on level 1 to control for possible influence of contextual aspects that were present at the time of the assessments. Missing values on level 1 were excluded from analyses via pairwise deletion. As can be derived from *Table* 1, the mean rate of missings on level 1 was 20% in the AN group and 21% in the HC group. Because of the large amount of data collected (over 4.000 datapoints were included in the analyses), HLM can accommodate missing data without significant distortion of the estimated parameters (Hox, 2010; Raudenbush, Bryk, & Congdon, 2017). The variables for rumination and affect on level 1 were centred around the participant's mean, the variable for inefficiency on level 3 was centred around the grand mean (Hox, 2010). Additional models excluding inefficiency, predicting rumination and affect only through group on the person-level, were calculated to ensure that effects were not better explained by group differences than by inefficiency. Further models

covarying for age, BMI-SDS, and duration of recovery regarding weight and eating behaviour were calculated to rule out possible confounding influences. Details and results can be found in the Supplementary Material (Appendix A 7.1.2).

In the CPM models all variables were also entered simultaneously and were not centred (Hayes, 2013).

2.4 Results

2.4.1 Sample and Descriptive Statistics

Descriptive statistics of the sample characteristics and the applied measures can be found in *Table 2.1.* HC and AN differed significantly in BMI-SDS, rumination about weight/figure, and valence of affect as assessed by the EMA questionnaire. The groups did not differ in rumination about food or in energy and calmness. The participants with a history of AN showed more general eating disorder symptoms and higher perceived inefficiency as assessed by the EDI-2.

Table 2.1. Descriptive statistics and group differences between AN and HC

	AN (*M* ± *SD*)	**HC (*M* ± *SD*)**	***t***
Age	22.47 ± 3.50	22.19 ± 3.51	-.32
recovered since (months)	51.44 ± 37.03		
BMI-SDS	-.59 ± .57	-.09 ± .55	-3.61**
EMA compliance	79.97 ± 15.72	79.11 ± 12.74	.24
EMA:			
Rumination about Weight	32.88 ± 19.07	19.78 ± 12.67	3.24**
Rumination about Food	33.22 ± 16.90	36.26 ± 12.21	.82
Valence of Affect	131.11 ± 30.18	147.58 ± 20.24	-2.53**
Energetic Arousal	114.39 ± 27.35	119.79 ± 22.69	-.86
Calmness	132.96 ± 30.40	139.33 ± 22.33	-.96
EDI-2:			
total score	183.83 ± 54.30	126.44 ± 24.62	5.44**
Inefficiency	27.84 ± 11.43	19.53 ± 5.46	3.71**

Notes. * = significant at $\alpha \leq .05$, ** = significant at $\alpha \leq .01$, $df = 62$ for all *t*-tests. $N = 64$ ($n = 32$ per group). AN = weight-restored individuals with a history of Anorexia nervosa. HC = healthy control participants. Age is given in years. BMI-SDS = body mass index standard deviation score. EMA = ecological momentary assessment. Compliance is given as the percentage of filled-out questionnaires. Rumination and affect are given as measured by the EMA questionnaire and aggregated on the person-level. EDI-2 = Eating Disorder Inventory 2.

2.4.2 Results Regarding Hypothesis I

The HLM models confirmed significant effects of inefficiency on both rumination about food and weight as well as on valence of affect, energetic arousal, and calmness (see *Table 2.2a*

and *Table 2.2b*). More inefficiency was associated with more ruminative thoughts (HLM models 1a+b), more negative affect (HLM model 2a), more energetic arousal (HLM model 2b), and less calmness (HLM model 2c).

Table 2.2a. Results of the HLM models 1a+b: associations between rumination, affect, and inefficiency

	Models 1a+b: Rumination	
Predictor	**Food**	**Weight**
Level 1:		
Valence of Affect	.01	-.03
Energy	.03	.04*
Calmness	-.05*	-.01
Level 3:		
Group	-6.31	7.26
Inefficiency	.56*	.83**
Cross-Level Interaction:		
Group x Valence of Affect	-.13**	-.10**
Group x Energetic Arousal	.01	.01
Group x Calmness	.03	-.01
Inefficiency x Valence of Affect	.00	.00
Inefficiency x Energetic Arousal	.00	-.01
Inefficiency x Calmness	.00	.00

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$; ** = significant at $\alpha \leq .01$. $N = 64$. Rumination and affect are given as measured by the EMA questionnaire. Inefficiency is given as measured by the EDI-2. Predictors were always entered simultaneously. Group was coded 0 = healthy control participant; 1 = weight-restored individual with a history of Anorexia nervosa. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for primary activity and the company of others.

Table 2.2b. Results of the HLM models 2a-c: associations between rumination, affect, and inefficiency

	Models 2a-c: Affect		
Predictor	**Valence**	**Energetic Arousal**	**Calmness**
Level 1:			
Rumination about Food	-.03	-.05	-.11**
Rumination about Weight	-.03	.17**	-.02
Level 3:			
Group	-.65	3.54	8.54
Inefficiency	-1.80**	-1.04**	-1.66**
Cross-Level Interaction:			
Group x Rumination about Food	-.06	.03	.05
Group x Rumination about Weight	-.22*	-.17*	-.12
Inefficiency x Rumination about Food	.00	-.01**	-.01*
Inefficiency x Rumination about Weight	.00	.01	.00

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$; ** = significant at $\alpha \leq .01$. $N = 64$. Rumination and affect are given as measured by the EMA questionnaire. Inefficiency is given as measured by the EDI-2. Predictors were always entered simultaneously. Group was coded 0 = healthy control participant; 1 = weight-restored individual with a history of Anorexia nervosa. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for primary activity and the company of others.

2.4.3 Results Regarding Hypothesis II

Group had no direct effect on rumination or affect after inefficiency was included in the HLM analyses (see Appendix A 7.1.3.1 for models without inefficiency as a predictor), instead the analyses revealed a significant cross-level interaction, indicating that the association between rumination and valence of affect as well as the association between rumination about weight and energetic arousal was moderated by group (see *Table 2.2* and *Figure 2.1*). The association between rumination about weight and valence of affect/energetic arousal was significantly stronger in the AN group. These findings were partially supported by the CPM analyses, which also showed that the association between rumination about weight and valence of affect as well as energetic arousal was significant only for AN and not for HC (see *Table 2.3* and *Figure 2.2*). In these analyses, the moderation itself showed trend-level support (the interaction term was significant only at $\alpha = .10$).

Table 2.3. Results of the CPM models: direct and indirect associations between inefficiency and affect

Predictors	Model a: Valence of Affect	Model b: Energetic Arousal	Model c: Calmness
direct effects:			
Inefficiency	-.81**	-.52	-.93**
Rumination about Weight	-.35	-.03	-.64*
moderated direct effects:			
Group x Rumination about Weight	-.57^{+}	-.64^{+}	-.26
direct effect for HC	-.35	-.03	-.64*
direct effect for AN	-.92*	-.67*	-.91*
moderated indirect effects of inefficiency via rumination about weight:			
indirect effect for HC	-.28	-.02	-.52*
indirect effect for AN	-.74*	-.55*	-.74*
total effect of inefficiency:			
total effect for HC	-.81**	/	-1.45*
total effect for AN	-.1.55*	-.55*	-1.67*

Notes: Standardized β-values of the conditional process models. HC = healthy control participants; AN = weight-restored individuals with a history of Anorexia nerovsa. $N = 64$. ** = significant at $\alpha \leq .01$; * = significant at $\alpha \leq .05$ * = significant at $\alpha \leq .05$ resp. significant according to boot-strapped confidence intervals; $^{+}$ = significant at $\alpha \leq .10$. Total effects are estimated as the sum of significant direct and indirect effects. Rumination and affect are given as measured by the EMA questionnaire and aggregated on the person level. Inefficiency is given as measured by the EDI-2. Predictors were always entered simultaneously.

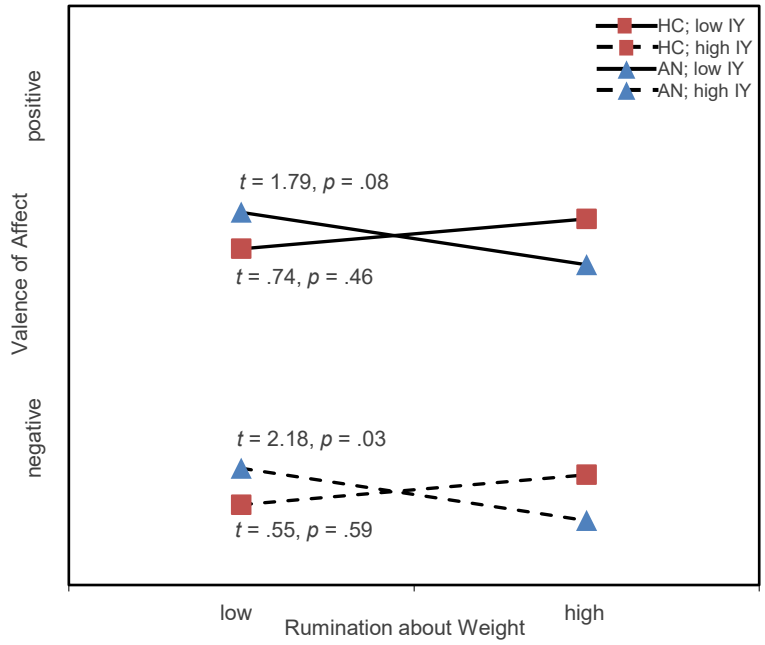
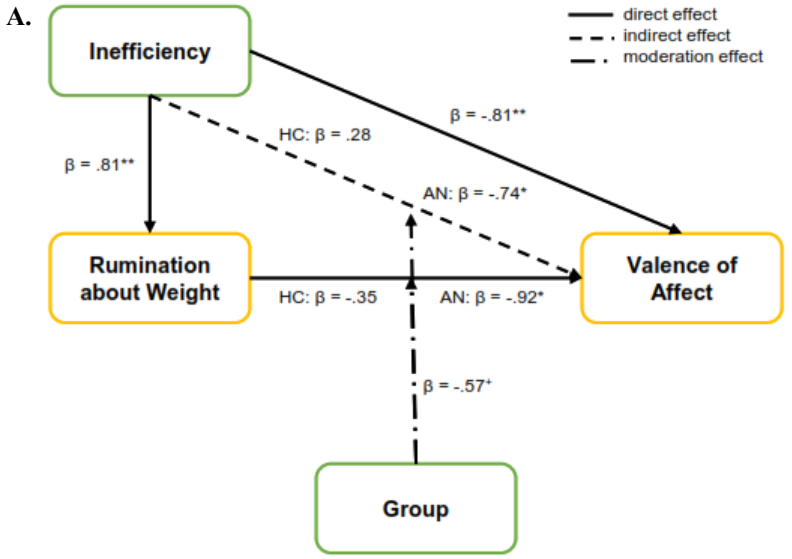
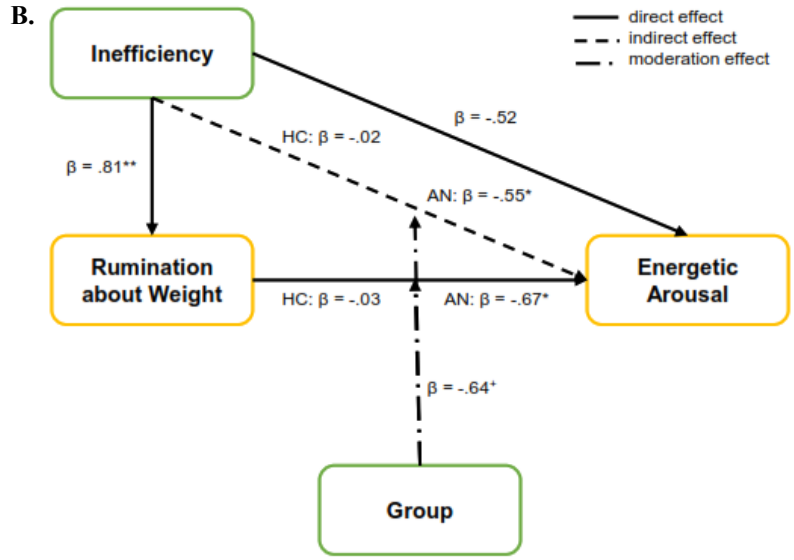


Figure 2.1 Associations between rumination about weight and valence of affect in dependence of group and inefficiency. Graphic representation of the HLM model 2a. *N* = 64. HC = healthy control participants; AN = weight-restored individuals with a history of Anorexia nervosa; IY = inefficiency. Depicted t-values refer to t-tests for significance of the slopes. Rumination and affect are given as measured by the EMA questionnaire. Inefficiency is given as measured by the EDI-2. A main effect for inefficiency on valence of affect as well as an interaction effect for group on the association between rumination about weight and valence of affect are visible.

2.4.4 Results Regarding Hypothesis III

The CPM models showed an indirect effect of inefficiency on calmness mediated via rumination about weight in addition to the direct effect (see *Table 2.3* and *Figure 2.2*), indicating that the influence of inefficiency on this variable was partially mediated by rumination. An indirect effect of inefficiency on valence of affect and energetic arousal (mediated via rumination about weight) was found only in AN. Therefore, the total effect of inefficiency on valence of affect and energetic arousal was higher in the AN group. This is in line with the group differences regarding the association between rumination about weight and valence of affect as well as energetic arousal discussed above.


A.
Inefficiency
direct effect
indirect effect
moderation effect
β = -.81**
HC: β = .28
β = .81**
AN: β = -.74*
Rumination about Weight
Valence of Affect
HC: β = -.35
AN: β = -.92*
β = -.57+
Group


B.
Inefficiency
direct effect
indirect effect
moderation effect
β = -.52
HC: β = -.02
β = .81**
AN: β = -.55*
Rumination about Weight
Energetic Arousal
HC: β = -.03
AN: β = -.67*
β = -.64+
Group

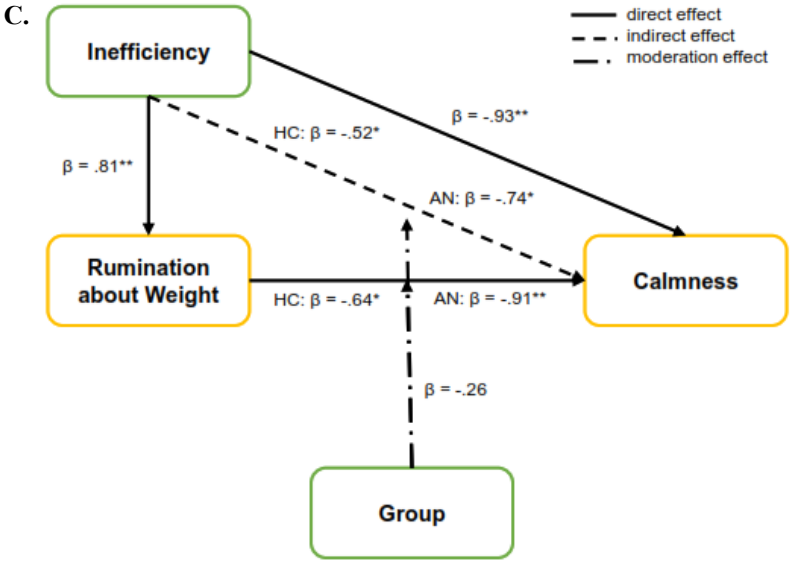

C.
Inefficiency
direct effect
indirect effect
moderation effect
β = -.93**
HC: β = -.52*
β = .81**
AN: β = -.74*
Rumination about Weight
Calmness
HC: β = -.64*
AN: β = -.91**
β = -.26
Group

Figure 2.2. Associations between inefficiency and affect mediated via rumination about weight. Visual representation of the CPM analyses (standardized β-values), including moderating effect of group on the association between rumination about weight and affect. ** = significant at $\alpha \leq .01$; * = significant at $\alpha \leq .05$; $^{+}$ = significant at $\alpha \leq .10$. $N = 64$. HC = healthy control participants; AN = weight-restored individuals with a history of Anorexia nervosa. Rumination and affect are given as the participant's mean of the variables measured by the EMA questionnaire. Inefficiency is given as measured by the EDI-2. A. Analysis with valence of affect as outcome. Inefficiency has a direct effect on valence of affect. It also has an indirect effect via rumination about weight only in AN, not in HC. B. Analysis with energetic arousal as outcome. Inefficiency has no direct effect on energetic arousal, but an indirect effect via rumination about weight in AN, but not in HC. C. Analysis with calmness as outcome. Inefficiency has a direct effect on calmness as well as an indirect effect via rumination about weight for both groups.

2.5 Discussion

By analysing real-life data related to ruminative thinking and affect collected over a period of two weeks in real-life situations using a smart-phone app, we unravelled complex associations with an important person-level variable in AN – inefficiency – which provide a new perspective on cognitive-affective dysfunction in the disorder. As expected, inefficiency significantly influenced rumination and affect in everyday life. In line with the postulations of the GPT (Carver & Scheier, 1990; Moberly & Watkins, 2010) and Hypothesis I, higher feelings of inefficiency were generally associated with more ruminative thoughts, more negative valence of affect and energetic arousal, and less calmness. Importantly, however, weight-recovered individuals with a history of AN showed higher levels of inefficiency, rumination, and negative affect. In addition to the direct effects on rumination and affect, inefficiency also indirectly influenced valence of affect and energetic arousal in the AN sample. An indirect effect of inefficiency on these variables was mediated by rumination about weight, which was associated with more negative affect and more energetic arousal specifically in AN. These findings from the CPM models are in line with the moderating effects of group found in the HLM analyses and lend support to our main Hypothesis III indicating that while inefficiency generally predicts more rumination and negative affect, individuals with a history of AN additionally show an amplifying association between these variables. This is a particularly interesting finding with respect to cognitive-affective dysfunction in AN which illustrates that AN may differ from HC in such processes. Similar associations were found for calmness in both groups, supporting Hypothesis II and indicating an

inverse association between rumination and calmness with more rumination leading to a decrease in calmness in both groups.

One possible interpretation of these findings is that individuals with or at risk of AN not only experience more inefficiency than HC, but inefficiency also impacts their affect in everyday life via heightened rumination, as indicated by the significant cross-level interaction in the HLM models. It is therefore likely that while the GPT has some general relevance for associations between inefficiency, rumination, and affect (especially calmness), it is even more important in AN. Research has shown that feelings of inefficiency are not only a core feature of AN, but also predict the duration of treatment and treatment outcome – including depressive symptoms after treatment (Olatunji et al., 2018; Pinto et al., 2008). The present study sheds some initial light on the underlying psychological mechanisms why inefficiency may contribute to vulnerability for AN or even the risk of relapse by maintaining dysfunctional cognitive processes and impacting affect in daily life. Such an interpretation is based on our findings which show that inefficiency triggers cognitive-affective processes that negatively impact thoughts and affect in everyday life even after weight, menstrual functioning and eating behaviour have largely normalized. This might make it difficult for individuals with or at risk of AN to disengage from their weight-goals, because feelings of inefficiency prime precisely these concerns. This focus on goals and subsequent ruminative thoughts possibly also interferes with interoceptive function (Duffy et al., 2019) and, furthermore, the constant repetitive thoughts might hinder therapeutic progress by impeding corrective learning processes (Reilly et al., 2019).

While confirming previous evidence that inefficiency, rumination, and negative affect are elevated in AN (e.g., Froreich et al., 2016; Fürtjes et al., 2018; Jacobi et al., 2004; Startup et al., 2013), the current study also demonstrates that this is the case even after weight and eating behaviour have largely normalized. This indicates that inefficiency presents a particularly important aspect of the disorder, possibly contributing to maintenance of distressing symptoms even after weight-recovery and therefore maybe also to vulnerability for relapse. However, since the present research is based on data from individuals with a history of AN, it cannot answer the question whether inefficiency as a trait presents a vulnerability factor for the development of AN, or whether it is a scar of the disorder – a topic that should be addressed by future research. By combining a measure of inefficiency with EMA assessment of rumination and affect in everyday life, we were able to show that a likely underlying process lies in the influence of inefficiency on associations between ruminative thoughts and affect in AN. This confirms similar findings regarding the GPT (Moberly & Watkins, 2008, 2010) and integrates this theory into AN research.

While these findings lend support to our hypotheses regarding associations between

inefficiency, rumination, and affect as aspects of AN, some limitations should be noted. First, a problem inherent to the EMA method is that repeatedly asking for information about a certain topic could lead to an increase in sensitivity for this topic, which might influence the data. We addressed this possibility by controlling for day of study as well as time of day in all HLM analyses but cannot rule out undue influence of such priming effects. Second, data on inefficiency was collected only once, not consistently over the period of the study. Inefficiency was therefore treated as a trait-variable, not as a dynamic variable of daily life. Future research should consider including inefficiency into EMA assessment to provide further insight on the associations between feelings of inefficiency and rumination as well as affect also on a situational level in everyday life (Moberly & Watkins, 2010). Third, it should be kept in mind that for reasons of feasibility our study focused on rumination about topics specifically relevant for AN, bodyweight/figure and food. Future research might consider assessing rumination about disorder-unspecific topics. The conceptualization of rumination based on the GPT employed in this research also differs from other theoretical approaches such as the Response Style Theory (RST), which suggests that rumination revolves around more abstract concepts of the causes for distress. To date, the RST has been more frequently applied in eating disorder research (e.g., Nolen-Hoeksema, Stice, Wade, & Bohon, 2007; Rivière & Douilliez, 2017). This should be kept in mind when integrating our findings into the body of literature on eating disorders and rumination. Fourth, it should be noted that while the moderating effect of group on the associations between rumination and valence of affect as well as energetic arousal was significant in the HLM models, the interaction term reached only trend-level significance in the CPM analyses, where a difference between the groups could only be demonstrated by showing that the direct and indirect effects between rumination and affect were present in one group, but absent in the other. The fact that the interaction term reached significance in the HLM, but not the CPM analyses, is likely due to the relatively small sample-size and limited power when data are aggregated. Fifth, while the HLM approach employed here has several advantages, other statistical approaches such as e.g. multilevel structural equation modelling (MSEM) might be equally valid and have their own merits (e.g., the estimation of multilevel mediation, which is not facilitated by HLM). Future research might also aim at comparing different models via MSEM. Last, based on our sample of weight-recovered individuals with a history of AN, the interpretation of inefficiency as a factor of vulnerability or risk of relapse is likely, but alternate interpretations are also possible. As already mentioned above, we cannot rule out that inefficiency is a scar of the disorder rather than a marker for vulnerability towards AN.

The present work offers a new perspective within the framework of the GPT highlighting the relevance of inefficiency as an important aspect of AN. Inefficiency generally appears to

trigger rumination and negative affect, both directly and indirectly. These associations predicted by the GPT were found to be especially relevant in participants with a history of AN. Specifically, former patients reported more feelings of inefficiency, more rumination, and more negative affect in everyday life compared with HC, and the mechanisms connecting these variables were more pronounced in these participants. Thus, inefficiency may represent a vulnerability marker of AN which amplifies dysfunctional cognitive-affective processes that impact the everyday life of individuals with an increased risk for AN. However, further research is needed to continue the investigation of the role of inefficiency in the aetiology and maintenance of AN and to clarify whether it functions as a vulnerability factor, a maintenance factor, a scar, or a combination of these aspects. These findings are therefore particularly relevant in a clinical context. Specifically, targeting feelings of inefficiency in therapy might potentially lead to a decrease of these dysfunctional processes and therefore support long-term treatment success of AN.

3 Rumination in Anorexia Nervosa: Cognitive-Affective and Neuroendocrinological Aspects

3.1 Abstract

Rumination about body weight/figure as well as food is common in patients with Anorexia nervosa (AN) and may be a maintenance factor of the disorder. While rumination can generally be considered as a cognitive-affective process, food-related rumination may be driven primarily by a physiological response to undernutrition. In the current longitudinal study, we integrate ecological momentary assessment of rumination and affect and, as a biological marker of undernutrition, plasma leptin levels collected from 33 AN patients. At the very acute stage and again after short-term weight-restoration patients answered short questionnaires six times per day over two weeks. Analyses via hierarchical linear modelling confirmed that rumination is closely linked to affect in AN before and after weight-restoration. Rumination about food decreased during weight-restoration and was correlated with leptin levels. In contrast, rumination about body weight/figure was not linked to leptin, persisted after weight gain, and showed stronger connections with affect. This suggests that rumination about body weight/figure seems to be a cognitive-affective aspect of the disorder, but food-related rumination may need to be considered from a physiological perspective. It is possible that food-related ruminative thoughts reflect a physiological symptom induced by undernutrition, similar to well-described leptin-associated changes in physical activity.

3.2 Introduction

Rumination, which can be conceptualized as repetitive thought fixating on topics that are associated with distress or general discomfort without active search for a solution (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; for a review see Watkins, 2008), has long been subject of psychological research. It has repeatedly been brought into context with different psychological disorders, including eating disorders (ED). In fact, cognitive theories of ED postulate rumination as a core aspect of this group of disorders (Fairburn, Cooper, & Shafran, 2003; Fairburn et al., 1999; Fairburn & Harrison, 2003; Naumann et al., 2015). This is supported by several studies reporting that rumination is increased in anorexia nervosa (AN) (e.g. Rawal et al., 2010; Seidel et al., 2016; Startup et al., 2013; Troop, Holbrey, & Treasure, 1998). Regarding the content of rumination in ED, bodyweight/figure and food are generally considered the main aspects. ED-

typical behaviours such as body-checking can also be considered a sign of constant concern with bodyweight and figure (Shafran, Fairburn, Robinson, & Lask, 2004). Even in healthy individuals increased rumination is not only associated with subthreshold depressive symptoms but also ED symptoms (Cowdrey & Park, 2012). While these findings all indicate a close association between rumination and ED pathology, the nature of this connection remains unclear.

Theoretical models suggest that rumination about bodyweight/figure and food functions as a key maintenance factor (Cooper, Wells, & Todd, 2004; Cowdrey & Park, 2012; Fairburn & Harrison, 2003; Naumann, Tuschen-Caffier, Voderholzer, Schäfer, & Svaldi, 2016). Research showing that change in ED symptoms correlates with change in rumination supports this theory (Rawal et al., 2010) and findings suggesting that rumination can predict ED behaviour and vice versa lend even further support (Nolen-Hoeksema et al., 2007). A different theoretical approach to the subject of rumination in AN (Park et al., 2011) proposes that it functions as a means to avoid emotions; a point of view in line with a general theory of rumination as a cognitive regulation strategy for (negative) affect (Aldao & Nolen-Hoeksema, 2010; Aldao, Nolen-Hoeksema, & Schweizer, 2010; Cowdrey & Park, 2012). This has been underlined by findings concerning emotion-dysregulation in ED. For example, it has been shown that patients with ED tend to use dysfunctional strategies to regulate affect (e.g. Brockmeyer et al., 2012; Harrison et al., 2010; for an extensive review see Oldershaw et al., 2015). Such maladaptive strategies include ED-specific behaviour (Engel et al., 2013; Haedt-Matt & Keel, 2011; Naumann et al., 2014) and rumination (Aldao & Nolen-Hoeksema, 2010; Aldao et al., 2010; Cowdrey & Park, 2012; Gilboa-Schechtman et al., 2006). ED patients themselves also report using rumination as an emotion-regulation strategy (Serpell et al., 1999).

A newer approach to the subject of rumination in ED diverges from the cognitive-affective theories introduced above. Instead, this view places repetitive thinking about food into the context of undernutrition, claiming that constant thoughts about food are the result of semi-starvation (Schmidt & Treasure, 2006). This is supported by studies showing that undernutrition leads to constant preoccupation with food even in healthy individuals (Polivy, 1996). A qualitative study has also shown that AN patients experience constant thoughts about food as an especially upsetting part of their illness, suggesting that the thoughts about food are involuntary and uncomfortable (Serpell et al., 1999).

The current longitudinal study aims to take a closer look on the role of rumination in AN. Since rumination often occurs automatically, it is difficult to assess in a laboratory setting where retrospective measurement is influenced by memory bias. Therefore, a methodical approach via ecological momentary assessment (EMA) is indicated. EMA gathers situational information via

smartphone in real time and in the everyday environment of the participants, which allows assessment in real-life and minimizes memory bias. A further advantage is the possibility to assess variance between and within subjects. EMA has been established as a method suitable for ED research and has previously been used to study associations between variables such as affect and behaviour in ED (Engel et al., 2013; Haedt-Matt & Keel, 2011; Lavender et al., 2013; Seidel et al., 2016; Stein & Corte, 2003).

The aim of the current study is to disambiguate between the two different theoretical approaches to rumination in AN discussed above (cognitive-affective factor or result of undernutrition). We propose for this purpose that a distinction between rumination about bodyweight/figure and food-related rumination should be made. We suggest that rumination about bodyweight/figure in AN is linked to emotion, as proposed in the cognitive theories discussed above (Cooper et al., 2004; Cowdrey & Park, 2012; Fairburn & Harrison, 2003). In contrast, we hypothesize food-related rumination to be linked to the severe undernutrition in acute AN, as suggested by Schmidt and Treasure (2006). Therefore, we expect that rumination about bodyweight/figure as a cognitive aspect of the disorder should have a strong link with affect and should persist even after initial weight rehabilitation. On the other hand, the association between food-related rumination and affect should be weaker and decrease during weight-rehabilitation, mainly because food-related rumination itself should decrease once the nutritional status has reached a healthy level.

3.3 Methods

3.3.1 Participants

The study sample consisted of 33 female volunteers between the ages of 12.1 and 18.8 who gave informed consent to participate in the study. All subjects were patients with acute AN according to DSM-5 and took part in ED treatment at a university child and adolescent psychiatric department. To assess exclusion criteria and possible confounding variables all participants were interviewed with the semi-structured SIAB-EX interview (Fichter & Quadflieg, 2001), complimented by our own semi-structured interview, the German version of the Eating Disorders Inventory (EDI-2; Thiel et al., 1997), and the German version of the Beck Depression Inventory (BDI-II; Hautzinger et al., 2009) (see Appendix B 7.2.1.1). During inpatient treatment, patients were enrolled in a comprehensive multimodal psychiatric and psychotherapeutic treatment program that consisted of individual, group, as well as family therapy. Central elements of the

treatment program were an operant behavioural program to achieve weight gain (> 700g per week) including a meal-plan and supervised meals at the beginning of the treatment and cognitive-behavioural treatment in individual, family, and group therapy sessions. This was supplemented by individual as well as group-based body-focused psychotherapy including exposure therapy, as well as a relapse prevention module and reintegration into community activities in the last third of the treatment program.

There was an overlap between the current sample and that of (Seidel et al., 2018, 2016); data from 26 patients has previously been published there. This regards only EMA data collected at the acute stage of the disorder. The longitudinal data as well as the analyses regarding endocrinological data have not been published before. There is also a sample overlap with other publications (Bernardoni et al., 2016; King et al., 2015), which focused on neuroimaging data.

3.3.2 Materials and Procedure

3.3.2.1 Measures and Materials

For the EMA assessment we designed a self-report questionnaire assessing affect and rumination about bodyweight/figure and food. Affect was assessed via a modified version of the multidimensional mood questionnaire (MDMQ; Steyer, Schwenkmezger, Notz, & Eid, 1997) consisting of six items measuring current valence of affect, calmness, and energetic arousal on visual analogue scales. These scales had two opposites as anchors (e.g. *content* and *discontent*), answers were logged on a range from 0 (far left pole) to 100 (far right pole). Higher values indicate more positive valence, more calmness, and more energetic arousal. Rumination was assessed via two modified items of the SIAB-EX interview *(*Q60, *"Since the last alarm, did you think about things related to food, nourishment, cooking, or calories?";* Q61, *"Since the last alarm, did you think about your shape/figure or your bodyweight?"*), answers were also logged on a scale from 0 (no rumination at all) to 100 (constant rumination). Additionally, participants gave information about several contextual control variables, e.g. primary activity, company of others etc. (see Appendix B 7.2.1.3 for specific details).

To operationalize the nutritional status of the participants we used the body mass index standard deviation score (BMI-SDS), which is an age-adapted BMI score indicating how much the BMI differs from the mean BMI of individuals with the same gender and age (Kromeyer-Hauschild et al., 2001). Because BMI-SDS alone is not a sufficient measure of undernutrition, we also used blood samples to measure leptin concentrations. Leptin is a hormone secreted by

adipocytes and involved in signalling and regulating energy balance. Previous research has proven leptin to be a sensitive indicator for nutritional status, especially in AN (e.g. Ehrlich et al., 2009; Hebebrand, Muller, Holtkamp, & Herpetz-Dahlmann, 2007). We collected venous blood into vacutainer tubes in the morning on an empty stomach after an overnight fast. The samples were centrifuged (800 x *g* for 15min), aliquoted, and stored at -80°C until analysis. Plasma leptin concentration was analysed in one session at the same lab via the commercially available software Enzyme Linked-Immunosorbent Assay (ELISA; AdipoGen; see Appendix A 7.2.1.4).

3.3.2.2 Procedure

Within the first 96 hours after being admitted to treatment, patients were interviewed and gave informed consent. They then had blood samples taken, were weighed, and received detailed instruction on how to handle the smartphone and fill out the questionnaires. The signal-contingent assessment started on the following day and lasted for 14 days. Every day at semi-random times (allowing for undisturbed participation in the treatment program) participants received six prompts to fill out the EMA questionnaire. This exact procedure of weighing, taking blood samples, and EMA assessment was repeated after patients reached a minimum of 10% increase in BMI. We therefore collected data over a period of 14 days at the acute stadium of the disorder (TP1) and again over a period of 14 days after short-term weight-restoration (TP2).

3.3.3 Statistics

Because EMA assessment results in nested data, hierarchical analyses were required. We conducted hierarchical linear modelling to analyse the momentary relationship between rumination and affect and the relationship between rumination and nutritional status (i.e. BMI-SDS and leptin). To test our hypothesis regarding the associations between rumination and affect, we calculated two hierarchical models predicting affect through rumination. One class of models represents the momentary association (model 1a), the other models also take time-lagged associations i.e. possible carry-over effects into account (model 2a; valence of affect at *t* is predicted by rumination at *t-1*). Corresponding models representing the associations between rumination and calmness as well as energetic arousal were also calculated (models 1b and 1c and models 2b and 2c). For reasons of brevity and clarity, details and results concerning these additional models predicting mood will be displayed only in the Supplementary Material (see Appendix B 7.2.2). To test our hypothesis regarding the link between rumination and physiological variables, we conducted further hierarchical linear modelling to analyse the

relationship between rumination and nutritional status (i.e. BMI-SDS and leptin). Two models predicting rumination on level 1 with BMI-SDS and leptin on level 3 were evaluated (models 3a and 3b; rumination about bodyweight/figure and food as outcome).

All models included three levels, nesting situations (level 1) into days (level 2) into participants (level 3). All analyses were conducted once for TP1 and repeated for TP2. Analyses for TP2 data were supplemented with two additional models predicting rumination by the individual change in BMI-SDS and leptin (i.e. the individual difference calculated by subtracting values at TP1 from values at TP2; model 3c and 3d; rumination about bodyweight/figure and food as outcome).

Predictors were always included simultaneously to control for shared variance. All analyses included the variable day of study on level 2 and the variable time of day on level 1 to control for confounding effects. For the same reason, dummy-coded variables representing the contextual factors of company and activity were included on level.1 To control for possible reciprocal effects caused by associations between the two kinds of rumination, all models predicting rumination about food also included rumination about bodyweight/figure, and vice versa, on level 1. Variables on level 1 were centred around the subject's mean, variables on level 3 were centred around the grand mean.

To analyse the difference between the association of affect with rumination about bodyweight/figure vs. food even further, we extracted individual slope-values for these effects from the hierarchical models (model 1a) and entered these values into dependent t-tests. This allows for a more specific statement regarding the question whether there is a difference between the association between affect and rumination about bodyweight/figure vs. food.

3.4 Results

3.4.1 Sample and Descriptive Statistics

The mean values for rumination, affect, EDI-2, BMI-SDS and leptin are displayed in *Table 3.1*. As expected, the longitudinal comparison revealed that patients had higher BMI-SDS and leptin values and reported less rumination at TP2 compared to TP1. Interestingly, the decline in mean rumination between TP1 and TP2 was greater for thoughts about food than for thoughts about bodyweight/figure ($t = -2.27$, $p = .03$). Accordingly, timepoint-specific analyses showed that while no difference was found for TP1, at TP2 patients reported significantly less rumination about food than about bodyweight/figure ($t = -3.26$, $p = .003$). Furthermore, patients also reported

significantly more positive valence of affect and more calmness at TP2 in comparison with TP1.

Table 3.1. Demographics and descriptive statistics

	TP1 (*M* ± *SD*)	**TP2 (*M* ± *SD*)**	**t**	**change (TP2 - TP1)**
Age	15.4 ± 1.8			
EDI-2	213.06 ± 43.32	190.39 ± 41.23	3.30**	-22.67 ± 39.44
BDI-II	23.73 ± 10.17	12.33 ± 8.61	6.34**	-11.39 ± 10.33
Nutritional Status:				
BMI-SDS	-2.90 ± .88	-.61 ± .50	-	2.34 ± .71
Leptin	1.85 ± 2.55	13.17 ± 8.91	18.55**	11.33 ± 7.52
			-7.07**	
Rumination:				
Rumination about Weight	59.10 ± 23.59	49.35 ± 24.81	2.30*	-9.75 ± 24.34
Rumination about Food	57.30 ± 21.55	41.28 ± 21.84	3.90**	-16.02 ± 23.59
Affect:				
Valence	86.00 ± 35.89	116.14 ± 41.34	-4.49**	30.14 ± 38.57
Calmness	105.55 ± 42.32	122.32 ± 38.47	-2.73**	16.77 ± 35.35
Energetic Arousal	121.80 ± 38.00	128.56 ± 31.26	-1.18	6.76 ± 32.88
EMA compliance	85.28 ± 11.66	79.41 ± 16.52	2.89**	-5.87 ± 11.69
Number of days since TP1		94.67 ± 32.83		

Notes: Descriptive statistics and dependent t-tests. * = significant at $\alpha \leq .05$, ** = significant at $\alpha \leq .01$. $N = 33$ for all variables except leptin ($n = 22$). One of the included patients was on an antidepressant medication (Sertralin) during the EMA data collection at both timepoints. Age is given in years. EDI-2 = Eating Disorder Inventory 2. BDI-II = Beck Depression Inventory II. BMI-SDS = body mass index standard deviation score. Leptin is given in ng/ml. Rumination and Affect are given as measured by the ecological momentary assessment (EMA) questionnaire. EMA compliance is given as percentage of filled out questionnaires.

3.4.2 Hierarchical Linear Modelling

3.4.2.1 Rumination and Affect

The hierarchical analyses revealed that at TP1 rumination significantly predicted valence of affect on a momentary level, with more rumination being associated with less positive affect. Dependent t-tests of the slopes extracted from these models showed that the effect of rumination about weight/figure on valence of affect was stronger than the effect of rumination about food ($t = 6.38$, $p < .001$; see *Figure 3.1A* and *Table 3.2*). The same associations were found at TP2; analyses again displayed a momentary influence of rumination on valence of affect with rumination about weight/figure having a stronger impact than rumination about food ($t = 5.05$, $p < .001$; see *Figure 3.1* and *Table 3.2)*. The longitudinal approach contrasting the change in the slopes for the effect of rumination about food vs. bodyweight/figure on valence of affect revealed a trend, indicating that the effect of food-related rumination decreased more steeply than that about weight/figure ($t = -1.89$, $p = .07$; see also Appendix B 7.2.2). The time-lagged analyses

revealed that only at TP1 rumination about food at *t-1* had an effect on valence of affect at *t*, indicating that in addition to the momentary association rumination about food had a longer-lasting impact on valence of affect at the very acute state of the disorder (see *Table 3.2*). For TP2 and for rumination about weight/figure no longer-lasting effects were found.

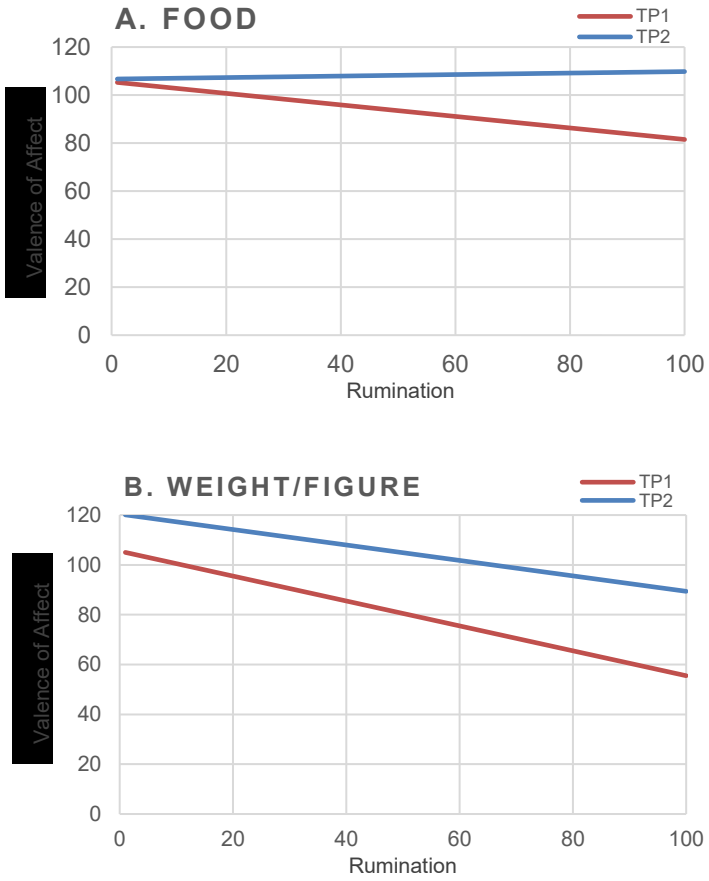


Figure 3.1. A: Relationship between rumination about food and valence of affect. B: Relationship between rumination about weight/figure and valence of affect. $N = 33$. Variables are given as measured by the EMA questionnaire. Higher numbers on the y-axis represent more positive affect.

Table 3.2. Momentary and time-lagged relationship between rumination and affect

Outcome	Predictor	TP1: β	TP2: β
Model 1a - momentary association:			
Valence of Affect (t*)*	Rumination about Food (*t*)	-.24**	-.13*
	Rumination about Weight (*t*)	-.50**	-.31**
Model 2a - time-lagged association:			
Valence of Affect (*t*)	Rumination about Food (*t*)	-.28**	-.17*
	Rumination about Weight (*t*)	-.46**	-.36**
	Rumination about Food (*t-1*)	-.10*	-.05
	Rumination about Weight (*t-1*)	.05	.02

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at α ≤ .05, ** = significant at α ≤ .01. *N* = 33. Rumination and Affect are given as measured by the EMA questionnaire. Predictors were always entered simultaneously. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for activity and company; for the time-lagged model also Valence of Affect at *t-1*. For the results of the additional models with Calmness and Energy as outcome (models 1b+c and models 2b+c) see the Supplementary Material.

3.4.2.2 Rumination and Nutritional Status

At TP1 the two models predicting rumination through BMI-SDS and leptin revealed no significant effects. In contrast, the analyses regarding nutritional status showed significant associations at TP2. Leptin (but not BMI-SDS) as a person-level variable had a negative effect on food-related rumination (β = -.91, *p* = .03; see *Figure 3.2* and *Table 3.3*), indicating that higher leptin was associated with less rumination about food during the day. This indicates that leptin accounted for variance in food-related rumination independently from BMI-SDS. For rumination about bodyweight/figure no significant effects were found. A similar effect was found in the longitudinal approach; the individual change in leptin between TP1 and TP2 predicted rumination about food at TP2 (β = -1.31, *p* = .03; see *Table 3.3*); a greater increase in leptin was associated with less rumination. The change in BMI-SDS on the other hand had no significant influence on rumination, again suggesting that leptin was associated with food-related rumination independently from BMI-SDS. Again, no effects were found for rumination about bodyweight/figure.

Table 3.3. Relationship between rumination on Level 1 (situation) and undernutrition on Level 3 (person)

Outcome	**Predictor**	**TP1: β**	**TP2: β**
Models 3a+b - cross-sectional:			
Rumination about Food (*t*)	BMI-SDS	-3.44	-7.91
	Leptin	-2.02	-.91*
Rumination about Weight (*t*)	BMI-SDS	-7.79	-5.81
	Leptin	-2.48	-.08
Models 3c+d - longitudinally:			
Rumination about Food (*t*)	change in BMI-SDS		8.98
	change in Leptin		-1.31*
Rumination about Weight (*t*)	change in BMI-SDS		10.33
	change in Leptin		- .39

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$. $n = 22$. Age is given in years. Rumination is given as measured by the EMA questionnaire. BMI-SDS = body mass index standard deviation score. Leptin is given in ng/ml. Predictors were always entered simultaneously. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for activity and company; for models predicting Rumination about Food also Rumination about Weight and vice versa.

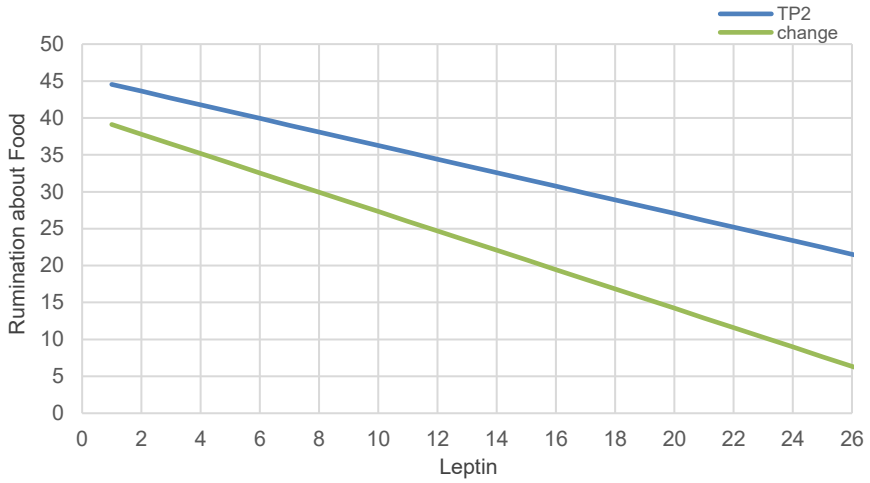


Figure 3.2. Relationship between rumination about food and leptin at TP2 resp. between rumination about food and change in leptin between TP1 and TP2 according to the hierarchical model. Data are controlled for BMI-SDS. $n = 22$. Rumination about food is given as measured by the EMA questionnaire. Leptin is given in ng/ml.

3.5 Discussion

Analysing EMA data collected six times a day over two weeks at the beginning of inpatient treatment and again after partial weight recovery we found a strong momentary link between rumination and valence of affect in patients with acute AN. This momentary association between rumination and affect was stronger for rumination about bodyweight/figure than for food. At T1 rumination about food additionally had a time-lagged effect on affect, suggesting a weaker, but more persistent influence. The longitudinal approach also revealed that food-related rumination not only showed the stronger decrease between TP1 and TP2, but at TP2 the association with affect was also weaker than the one between affect and rumination about bodyweight/figure. While no association with nutritional status was found for rumination about bodyweight/figure, food-related rumination was linked to individual plasma leptin levels (but not BMI-SDS) at TP2. Lower leptin levels were predictive of increased rumination. Additionally, the change in leptin from TP1 to TP2 also had a significant effect on food-related rumination at TP2; the greater the increase in leptin, the less rumination about food was reported.

These findings support our motivating hypothesis that a distinction between rumination about bodyweight/figure vs. food is necessary, as they seem to differ in their role in AN and could have different biological underpinnings. Our results concerning rumination about bweight/figure imply a connection between rumination and affect in ED which has been postulated previously (e.g. Aldao & Nolen-Hoeksema, 2010; Cowdrey & Park, 2012; Seidel et al., 2016). It can be assumed that in acute AN rumination and negative affect represent a part of the pathology which ameliorates as the disorder regresses, as suggested in several cognitive models of AN (e.g. Cooper et al., 2004; Fairburn & Harrison, 2003; Park et al., 2011). While our findings concerning rumination about bodyweight/figure are fully in line with this cognitive-affective perspective, this perspective does not explain the results concerning food-related rumination. Rumination about food seems to be more loosely linked to affect on a momentary level and it appears to be more prevalent at the very acute state of AN.

An even greater discrepancy between rumination about weight/figure and food was found in their relationship to nutritional status, suggesting that while leptin levels are linked to food-related rumination, no such association exists with rumination about bodyweight/figure. While these associations do not allow for direct inference regarding causal mechanisms, they could be interpreted as support for the hypothesis that rumination about food is driven by undernutrition (Schmidt and Treasure, 2006). They are also in line with research reporting increased sensitivity for food-related stimuli and more general preoccupation with food in semi-starved healthy individuals (Keys et al., 1950; Polivy, 1996) or restrained eaters (D'Anci, Watts, Kanarek, &

Taylor, 2009; King et al., 1991), although this preoccupation with food in starving healthy individuals might have different characteristics than the rumination about food in AN. A speculative interpretation could be that, unlike rumination about bodyweight/figure, the repetitive thoughts about food are not part of the core cognitive-affective symptom complex of AN. Instead, it might be advisable to also consider them within the physiological and neuroendocrinological context of the disorder. Prior research has shown that leptin is not merely a "satiety-hormone" regulating energy-homoeostasis, but also has an impact on cognitive-behavioural variables such as e.g. physical hyperactivity or sexual interest (e.g. Ehrlich et al., 2009; Holtkamp et al., 2003). It is therefore not unlikely that food-related rumination might present a further AN symptom connected to the neuroendocrinological aspects of the disorder. The association between leptin and food-related rumination might be similar to the association between leptin and excessive physical activity, which is not only a common symptom in AN patients (Casper, 1998), but can also be induced in rats through semi-starvation (so called Activity-based Anorexia Model (ABA); see Hebebrand et al., 2007 for a review). A common interpretation of the latter studies is the suggestion that undernutrition triggers restlessness as an expression of foraging. In a similar vein, it could be argued that hypoleptinaemia might also trigger constant thoughts about food which then trigger foraging. As already pointed out, given our purely correlational analytic approach this interpretation is speculative and different interpretations are equally likely. For example, leptin might function merely as a marker for undernutrition/hunger, which triggers increased rumination about food via some other mechanisms (e.g. ghrelin; Higgins, Gueorguiev, & Korbonits, 2007). Interventional studies, e.g. including a leptin treatment arm (similar to interventional ABA studies) are needed to establish causality.

Together, the current findings illustrate that differentiating the precise content of ruminative thinking (e.g. weight/figure vs. food) may allow for a more precise understanding of its role within AN pathology. To our knowledge, no previous study has addressed rumination in AN from such a content-specific angle. However, content of repetitive thought has been subject of research in the context of the general association between rumination an (negative) affect. Several studies have shown that the content of ruminative thoughts can moderate their effect on affect, with e.g. self-critical or evaluative content leading to more negative affect (Treynor, Gonzalez, & Nolen-Hoeksema, 2003; Watkins, 2008). These findings are compatible with our results. Thoughts about body weight/figure in AN are typically both self-critical and self-evaluative, therefore triggering negative affect. Thoughts about food on the other hand may be less intertwined with personal goals and values, which could explain the weaker influence on affect, especially after weight gain. It could therefore be hypothesized that two different kinds of ruminative processes exist within AN: a cognitive-affective aspect concerning rumination about

bodyweight/figure which is closely associated with the self-image and represents an immanent factor of the disorder, maintaining it; and a cognitive-physiological aspect concerning rumination about food, which is mainly a symptom of undernutrition. In this context one should also consider the Goal Progress Theory of repetitive thought (Carver & Scheier, 1990), which postulates goal-discrepancies as the source of rumination. It can be assumed that thoughts regarding weight/figure are linked to higher-level, abstract goals (i.e. unreachable bodyweight) and are therefore both more persistent during recovery (even while other symptoms decline) and stronger in their affective consequences. AN patients typically also have goals concerning daily e.g. food/calorie intake, but these goals might exists on a lower, more concrete level and therefore produce less rumination with weaker affective consequences. This would be in line with a cognitive-physiological aspect of rumination in AN mainly associated with undernutrition and more loosely linked to personal goals.

Our findings extend previous research in several important aspects. The EMA method allowed for real-time data collected in the daily life of the patients and the longitudinal approach enabled us to observe trajectories of rumination, comparing data from the very acute state with data from a state of short-term weight rehabilitation. We are also not aware of any previous research that has studied rumination in the context of biological variables in AN. However, our results should also be considered in the light of several limitations. First, an inherent limitation of the EMA method is the possibility that the repeated cognitive activation of a certain topic through the multiple questionnaires could lead to an increase in sensitivity regarding this topic, which might influence the data. We addressed this question by modelling “day of study” as a control variable on the second level of the hierarchical analyses. Second, it remains an open question to what extent the data collected in an inpatient setting reflect the symptoms and behaviour of AN patients in real-life. It should be kept in mind that the participants received intensive treatment. The changes between TP1 and TP2 can therefore not be attributed with certainty solely to weight-gain but are also influenced by other effects of the treatment. However, since psychotherapeutic treatment addressed rumination about food and rumination about weight/figure equally, possible additional effects would most likely also concern both aspects and therefore not confound the findings regarding the distinction between them. Nevertheless, we conducted additional analyses for TP2 including overall change of AN symptoms as a control variable (see Appendix B 7.2.2). The results did not differ in a noteworthy manner from the presented findings. Third, the time interval between TP1 and TP2 was based on weight-gain and therefore differed among the patients. Fourth, the results of the time-lagged analyses indicate that only at TP1 and only rumination about food had a longer-lasting effect on affect. This is compatible with our main findings, as we generally have found that rumination about food predicts affect to a greater extent

at TP1 than at TP2. However, no time-lagged effects were found for rumination about weight/figure, which appears to stand somewhat in contrast to our main findings, which indicate a stronger association between this type of rumination and affect. A speculative interpretation of these results might be that while generally no time-lagged effects between rumination and affect were found (indicating that the association is primarily momentary), the rumination about food might be experienced as particularly uncomfortable in patients with AN at the very acute state of the disorder (Serpell et al., 1999). Since rumination about food appears to be driven by physiological aspects of the disorder, it could be speculated that its effects are more enduring, are experienced as involuntary and therefore bothersome. However, more work, including interventional studies, is needed to draw firm conclusions. Fifth, while we found a strong link between food-related rumination and leptin at TP2, this association was not found at TP1. The most likely explanation for this is the lack of variance in leptin values at TP1, leading to a ceiling-effect (see Appendix B 7.2.2), which could explain why no association with other variables could be found. Last, it should also be noted that our analyses are unable to unravel causal mechanisms. While interpreting the results one should therefore keep in mind that it is possible that the presented statistical association between leptin and rumination about food is merely based on a shared association with other variables; e.g. hunger may lead to rumination about food (but not rumination about weight/figure) and is also reflected by leptin levels.

In sum, several important conclusions can be drawn from our longitudinal study. We suggest that rumination about bodyweight/figure is a pervasive aspect of AN as suggested by several cognitive-affective models of the disorder. Rumination about food should be considered not as a merely cognitive-affective aspect of the disorder, but also as a physiological aspect linked to undernutrition. To establish this framework as a concept for rumination in AN, further studies are necessary. The differences between the content-specific rumination may have implications not only for further research, but also for a clinical context, if confirmed by independent studies. While it is crucial to use all available cognitive-behavioural therapy methods to address rumination about bodyweight/figure as a cognitive-affective aspect of AN pathology, nutritional therapy might be most effective for food-related rumination. The information that disquieting ruminative thoughts about food are linked to undernutrition and decrease when weight is restored might represent an additional incentive for patients to gain weight.

4 Automatic and Controlled Processing: Implications for Eating Behaviour

4.1 Abstract

It is a widely held view that humans have control over their food choices and consumption. However, research also suggests that eating behaviour is often triggered by contextual cues and guided by automaticities and habits. Interestingly, the dichotomy between automatic and controlled processing has recently been challenged, suggesting that they may be intertwined. In a large female sample (n = 567), we investigated the hypothesis that task-based and self-reported measures of automatic and controlled processing would interact and impact self-reported eating behaviour. Results analysed via structural equation modelling suggest that automatic, but not controlled processing, during a modified flanker task, including a context-specific proportion congruent (CSPC) manipulation, was inversely associated with self-reported self-control. The influence of self-control on unhealthy eating behaviour (i.e., uncontrolled and emotional eating, heightened consumption of fat and sugar) was only indirect via habitual behaviour, which itself had a strong direct impact. Unhealthy eating was further associated with real-life outcomes (e.g., body mass index (BMI)). Our findings suggest that eating behaviour may indeed be guided primarily by automaticities and habits, whereas self-control might facilitate this association. Having self-control over eating might therefore be most effective by avoiding contextual cues eliciting undesired automatic behaviour and establishing habits that serve long-term goals.

4.2 Introduction

In times where food consumption is not a mere necessity for survival, but rather a topic of lifestyle and personal identity, research on eating behaviour has gained much attention. While most of us would like to believe that we deliberately choose the food we eat, it has been suggested that eating behaviour may often be more "automatic" than consciously controlled (Cohen & Farley, 2008; Köster, 2009). Studies assessing food consumption in laboratory settings have shown that eating behaviour can be independent from personal dietary goals (Hofmann, Rauch, & Gawronski, 2007). For example, chocolate consumption has been associated with automatic, stimulus-driven behaviour during classic reaction-time tasks, but not with snacking intentions (Allan et al., 2010; Hofmann et al., 2007). Corresponding findings from studies employing real-time diaries of food intake in daily life suggest that eating behaviour is largely guided by

situational cues instead of intention (Elliston et al., 2017). Similarly, eating behaviour has been found to be guided by habits (defined as a learned response that is activated by context in a "bottom-up" fashion and independent from short-term goals (Wood & Rünger, 2016)), such as customarily getting a pastry from the bakery on the way to work each morning (de Bruijn et al., 2007; de Bruijn, Kroeze, Oenema, & Brug, 2008; Lin et al., 2015). In this context, not only behavioural routines (longer sequences of actions habitually executed in the same contexts), but especially automaticities (an aspect of habit that is effortless, fast, and inflexible (Bargh & Chartrand, 1999; Wood & Rünger, 2016)) appear to play an important role in priming eating behaviour by the environment, e.g., reflexively putting ketchup on french fries (Wansink, 2004). It has been suggested that this may be a factor which has contributed to the worldwide increase in the prevalence of obesity (Hall, 2018; The GBD 2015 Obesity Collaborators (Institution), 2017).

Although the role of habits in eating behaviour is well-established (Cohen & Farley, 2008; van't Riet et al., 2011), the influence of "top-down" executive control processes, including self-control, also needs to be taken into consideration. For example, individuals high in self-control (which can be conceptualized as the ability to override or change responses, including the goal-directed inhibition of undesired behaviours (Nigg, 2017; Tangney, Baumeister, & Boone, 2004)) have been found to experience less conflict during choices between healthy and unhealthy foods (Georgii et al., 2019; Gillebaart et al., 2016) and to be more likely to maintain successful weight-loss (Bickel et al., 2018). Similar findings have been reported for individual differences in cognitive control (an umbrella term referring to multiple cognitive processes which orchestrate behaviour in a goal-directed manner (Cohen, 2017)). For example, elevated cognitive control, including superior inhibition of prepotent responses or resolution of "conflict" incited by irrelevant distractors (e.g., in a Stroop task), has been associated with succumbing to less food temptations in real life (Hofmann et al., 2014). Deficient cognitive control, on the other hand, has been linked with heightened snack consumption in laboratory settings and with unhealthy eating behaviour in general (Allom & Mullan, 2014; Hall, 2012). It has also been found to increase the likelihood of binge eating behaviour in real-life assessments of participants with eating disorders (Smith et al., 2020). However, meta-analytic data suggest that effects of control processes on eating behaviour are relatively small compared to effects of automaticity (de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). Nevertheless, the complexity of the impact of cognitive control on eating behaviour (Haynes, Kemps, & Moffitt, 2015; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Jasinska et al., 2012; Price, Lee, & Higgs, 2016) also needs to be appreciated. It could be argued that while eating behaviour might be relatively automatic in general, sufficient control capacities could strengthen the influence of other aspects

such as, for example, goals or intentions (de Bruijn et al., 2007; Haynes et al., 2015; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010).

The evidence reviewed above illustrates the involvement of both automatic or habitual processes on eating behaviour on the one hand, and controlled processes on the other. Importantly, recent research has challenged the traditional dichotomy between fast, effortless automatic, versus slow, effortful controlled processing (Shiffrin & Schneider, 1977), and suggested that the two may in fact be inextricably linked (Awh et al., 2012; Bugg & Crump, 2012). For example, laboratory experiments using adaptations of classic selective attention paradigms (e.g., Stroop or Eriksen flanker tasks) have shown that implicit contextual information can modulate performance in a manner suggestive of automatic priming of top-down control. In such tasks, so-called congruency effects (i.e., slower reaction times (RT) and increased error rates on incongruent relative to congruent trials) are generally taken as a measure of the capacity to override interference (or "conflict") between target and distractor stimulus features, reflecting controlled processing. The magnitude of such effects is significantly reduced or abolished for stimuli presented in contexts (e.g., locations) associated with frequent conflict—even though participants are unaware of any contextual variation in conflict frequency (Bugg, 2017; Bugg & Crump, 2012; Crump et al., 2006; Egner, 2014). This "context-specific proportion congruent" (CSPC) effect is thought to capture how strongly individuals rely on environmental information to automatically adjust top-down control in accordance with current contextual demands. Greater CSPC effects are thought to index a greater tendency to "relinquish the reins" and let contextual cues guide control adjustments (Bugg & Crump, 2012; Egner, 2014). For efficiency, we will refer to this phenomenon as automatic processing in the remainder of this article.

Regarding the interplay of automatic and controlled processing in determining eating behaviour, recent experimental evidence has shown that basic food attributes (tastiness) are processed earlier (and, arguably, more "automatically") than abstract attributes (healthfulness), and that this might explain a significant portion of individual differences in eating-related self-control capacity (Sullivan, Hutcherson, Harris, & Rangel, 2016). The literature discussed above also shows that there is involvement of both automatic and controlled processes in eating behaviour and that these processes are most likely intertwined (Haynes et al., 2015; Hofmann et al., 2014; Jasinska et al., 2012). However, the question of how these two aspects interact regarding eating behaviour has not been explicitly addressed in the research to date.

Against this background, we hypothesized that while a generally elevated amount of cognitive control might be associated with more self-controlled behaviour, including more controlled eating behaviour (as suggested by the literature discussed above (Allom & Mullan,

2014; Hofmann et al., 2014)), the reverse might be the case for automatic processing (gauged by the CSPC effect), as implied by the general association between automaticity and eating behaviour (Allan et al., 2010; Elliston et al., 2017). More specifically, in the current study, we aimed to test the prediction that individuals who show more pronounced automatic processing during performance of an established CSPC task would exhibit more self-reported automatic behavioural tendencies, which in turn impact eating behaviour. Our overarching aim was to answer the question of whether eating behaviour is primarily guided by automatic behavioural tendencies rather than by controlled processes, and whether this influence can be captured not only by self-report data but also by an experimental index of automatic processing. We investigated these associations in a large female population-based sample. By employing an online study design, we utilized the advantages of crowdsourcing (Buhrmester, Kwang, & Gosling, 2011; Crump, McDonnell, & Gureckis, 2013), which reaches the general population and allows for efficient collection of large amounts of data.

4.3 Methods

4.3.1 Participants

602 volunteers between the ages of 18 and 45 were recruited to participate in an online experiment via the crowdsourcing platform Clickworker (www.clickworker.de; clickworker GmbH, 2019). Given known differences in eating behaviour between men and women (e.g., women show more frequent dieting, men consume more meat, etc. (Rolls, Fedoroff, & Guthrie, 1991)) and a higher prevalence of sub-clinical disordered eating behaviour as well as eating disorders in women (Galmiche, Déchelotte, Lambert, & Tavolacci, 2019), we only recruited women to participate in this study. Better understanding of eating behaviour in females could provide an important contribution to further research addressing the question of when and why problematic eating behaviour develops into eating disorders. The mean self-reported body mass index (BMI) was 24.48 ± 6.30 and the socio-economic status was distributed normally (calculation according to “Gesundheit Deutschland aktuell” (GEDA; Lampert, Kroll, Müters, & Stolzenberg, 2013)). For more details on sample characteristics, see the Supplementary Material (Appendix C 7.3.1).

4.3.2 Materials

4.3.2.1 Conflict Control

For the experimental assessment of controlled and automatic processing (i.e., conflict control and automatic conflict control adjustments), we employed a modified version of the flanker task with a context-specific proportion congruent (CSPC) manipulation adopted from King et al. (King, Donkin, Korb, & Egner, 2012; King, Korb, & Egner, 2012) (see *Figure 4.1*). The task was implemented as an online study on the Labvanced platform (www.labvanced.com; Goeke & Finger, 2018). Labvanced is an online research tool, which has shown to reliably and precisely record participants' responses in a wide range of web-based studies (Goeke, Finger, Standvoss, & König, 2017; Kolyasnikov et al., 2019). In each of the 224 trials, participants had to rapidly and accurately indicate the viewpoint direction (left vs. right) of a trial-unique target stimulus face flanked by four distracting stimuli faces. In half of the trials, the target and distractors were congruent, and in the other half, incongruent. Participants were instructed to indicate their response via keystroke. Stimuli randomly appeared either on the left or the right side of a fixation cross. To assess automatic conflict control adjustment, a location-specific manipulation of conflict frequency was employed. One side featured mainly incongruent trials (75% of trials shown on this side), and the other side mainly featured congruent trials (75% of trials shown on that side). Which side was associated with the high vs. low conflict context was counterbalanced across the participants. For more details on the apparatus and task procedure, see the Supplementary Material (Appendix C 7.3.3).

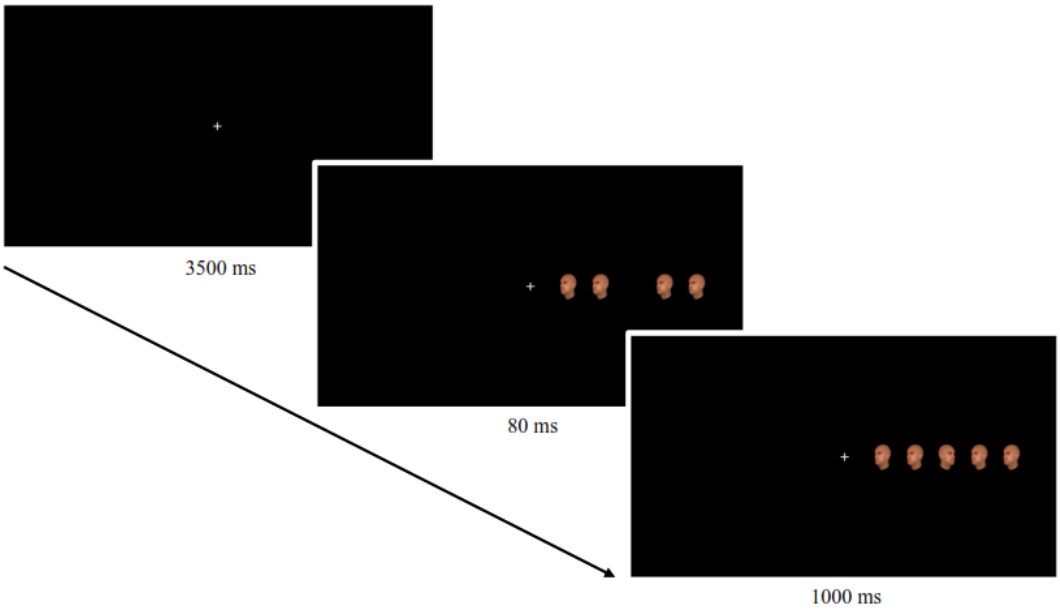


Figure 4.1. Exemplary trial of the flanker task. Each unique trial consisted of a fixation cross, followed by the presentation of four flanker faces shown for 80 ms before the identical target face appeared in the centre. Participants indicated the viewpoint direction of the target face via keystroke. Half of the 224 trials were congruent (i.e., identical viewpoint direction of flankers and target face), the other half were incongruent (as shown here). Proportion of conflict frequency was manipulated according to context depending on stimulus location: one side of the fixation cross was associated with 75% congruent trials (low conflict condition), the other side with 75% incongruent trials (high conflict condition). Which side of the fixation featured which condition was balanced across participants.

4.3.2.2 Self-Control and Habitual Behaviour

The Brief Self-Control Scale (BSCS; Tangney et al., 2004) was used to measure two aspects of trait self-control: (low) impulsivity and (high) restraint (Cronbach's α = .50 and .70). Habitual behaviour was assessed via the two scales of the Creature of Habit Scale (COHS; Ersche, Lim, Ward, Robbins, & Stochl, 2017), which assesses automatic responses to situations and behavioural patterns (automaticity scale; Cronbach's α = .83) as well as a tendency to routine behaviour (routine scale; Cronbach's α = .83).

4.3.2.3 Eating Behaviour

We used two scales of the short version of the Three Factor Eating Questionnaire (TFEQ-R18; Karlsson, Persson, Sjöström, & Sullivan, 2000) to assess the extent of emotional and uncontrolled eating behaviour (Cronbach's α = .87 and .89). The third scale of the TFEQ-R18, cognitive restraint, was not used in this study to ensure that eating behaviour would be represented in terms of actual behaviour (i.e., consumption), not restrictive tendencies. To address nutritional

intake as an aspect of eating behaviour, we therefore additionally employed the German version of the Dietary Free Fat and Sugar Short Questionnaire (DFS; Cronbach's α = .77; Francis & Stevenson, 2013; Fromm & Horstmann, 2019). This questionnaire assesses dietary intake of saturated fat and free sugar and has been validated as a self-report instrument reflecting the actual consumption of these nutrients that can be used instead of extensive 24 h food recall instruments (Fromm & Horstmann, 2019). Participants also gave information on whether they followed a specific style of diet (e.g., vegetarianism) and on current and anamnestic weight-loss diets.

4.3.3 Procedure

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the TU Dresden (135042018). Participants found the study by browsing the clickworker website. The study appeared only for registered female members between the ages of 18 and 45 who lived in Germany. After selecting the study, they were informed about the content and duration of the study, gave consent, and were asked to keep the study displayed on full-screen and eliminate distractions (e.g., turn off mobile phone). Via a customized link, the participants were then routed to the Labvanced web platform, where the study was conducted. In the first part of the study, participants answered questions regarding demographics and filled out the self-report questionnaires. The second part started with detailed instructions of the flanker task and a brief training session (24 trials). Following a short reminder of the instructions, the task ran through until completion. When the task was completed, participants filled out a short questionnaire (as in King, Donkin, et al. 2012; King, Korb, et al., 2012) to assess awareness of the context-specific congruency frequency manipulation (see Appendix C 7.3.2 for details). All participants who successfully completed the study received an individual completion code by the Labvanced experiment software which allowed them to collect their monetary compensation via clickworker.

4.3.4 Data Analysis

4.3.4.1 Flanker Task Data Analysis

Trials were excluded from all analyses if the response was missing, RT was shorter than 200ms or was >/< 3 standard deviations (SD) from the participant's overall mean, leading to a mean exclusion of 4% of the trials. RT parameters were calculated only on the basis of trials with

correct responses. Seven participants whose overall performance (RT and/or error rate) could be considered extreme (>/< 3 SD of the sample mean) were excluded from analyses. Rigorous quality control revealed that several participants did not follow instructions correctly (i.e., used a reversed stimulus-response mapping), which lead to a further exclusion of 28 participants and a final sample-size of 567 participants. For efficiency, we evaluated task performance with a combined measure of speed and accuracy, the linear integrated speed-accuracy score (LISAS; Vandierendonck, 2017; see Appendix C 7.3.5 for more details). For each participant, we calculated both the overall flanker effect (LISAS incongruent – LISAS congruent) as a global measure of controlled processing, and the CSPC effect (flanker congruency effect low conflict – flanker congruency effect high conflict) as a measure of automatic processing.

4.3.4.2 Structural Equation Modelling

We employed structural equation modelling (SEM) to investigate associations of task-based measures of conflict control and automatic adjustment of conflict control with self-report measures of self-control, habitual behaviour, and eating behaviour (see *Figure 4.2*). Three latent variables representing eating behaviour (estimated from both scales of the TFEQ-R18 and DFS), habitual behaviour (estimated from both scales of the COHS), and self-control (estimated from both scales of the BSCS) were built into the model. In a simple baseline model, eating behaviour was predicted through self-control and habitual behaviour, self-control was predicted through conflict control (flanker congruency effect), and habitual behaviour was predicted through automatic conflict control adjustments (CSPC effect). This baseline model was compared to two more complex models via nested model comparison. The first model (model A) additionally included an association between self-control and habitual behaviour, between conflict control (flanker congruency effect) and habitual behaviour, and between automatic conflict control adjustment (CSPC effect) and self-control. In the second model (model B, also referred to as "full" model), additional direct effects of conflict control (flanker congruency effect) and automatic conflict control adjustment (CSPC effect) on eating behaviour were also included (see *Figure 4.2* for a visual representation). Model estimation was conducted using the software AMOS version 21 (IBM Corporation, 2012).

To follow up on possible associations with real-life outcomes, we further analysed the association of eating behaviour as measured by the TFEQ-R18 and DFS with self-reported success of weight-loss diets and BMI via logistic and linear regression analyses.

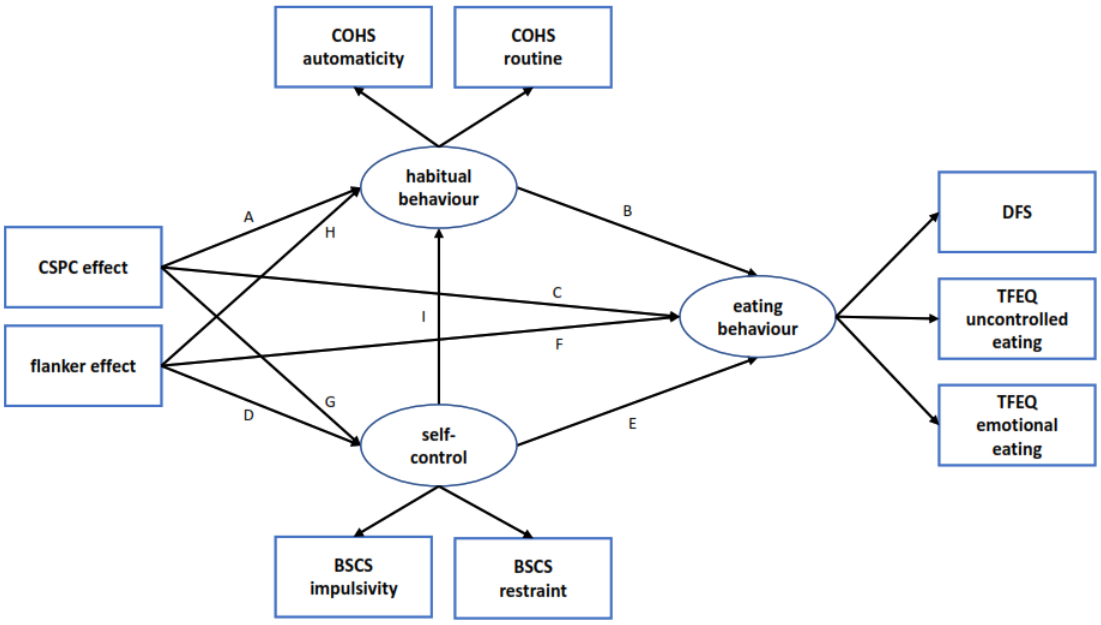


Figure 4.2. Visual representation of the structural equation modeling (SEM) analyses. Via nested model comparison, a full model (complex model B) was compared to a slightly simpler model (complex model A, paths C and F dropped) and a baseline model (paths C, F, G, H, I dropped). CSPC = context-specific proportion congruent, COHS = Creature of Habits Scale, BSCS = Brief Self-Control Scale, DFS = Dietary Fat and Free Sugar Short Questionnaire, TFEQ = Three Factor Eating Questionnaire.

4.4 Results

4.4.1 Sample, Self-Report Data, and Task Performance

The sample demographic characteristics and self-report data are displayed in *Table 4.1*. The mean scores of the self-report measures are similar to those reported in previous studies of the general population (Fromm & Horstmann, 2019; Kong et al., 2013; Lange & Dewitte, 2019; Tangney et al., 2004). The descriptive and inferential statistics of flanker task performance are summarized in *Table 4.2*. Mirroring previous findings with the employed task (King, Donkin, et al., 2012; King, Korb, et al., 2012), the overall flanker congruency effect was significant, and interference was reduced in the high-conflict context relative to the low-conflict context, indicating a significant CSPC effect. Participants' responses in the post-test questionnaire confirmed the absence of awareness for contextual variation in conflict frequency (see Appendix C 7.3.3 for more details).

Table 4.1. Demographics and questionnaires

	M	**SD**	**range**
age	29.25	7.05	18 – 45
BMI	24.48	6.30	14.9 – 67.2
BSCS:			
impulsivity	12.05	2.72	4-20
restraint	11.00	3.03	4-20
COHS:			
routine	54.00	10.06	21 – 80
automaticity	31.03	8.52	11 – 55
TFEQ-R18:			
uncontrolled eating	19.76	5.84	9 – 36
emotional eating	6.48	2.75	3 – 12
DFS	54.67	10.52	29 – 100

Notes. N = 602. Age is given in years. BMI = body mass index. BSCS = Brief Self-Control Scale. COHS = Creature of Habit Scale. TFEQ-R18 = Three Factor Eating Questionnaire – Revised. DFS = Dietary Fat and free Sugar Short Questionnaire. Results for the questionnaires are given as raw values.

Table 4.2. Flanker task: flanker and CSPC effect

	high conflict condition		**low conflict condition**	
	congruent trials	incongruent trials	congruent trials	incongruent trials
M ± *SD* (LISAS)	772.46 ± 132.03	892.20 ± 132.30	764.03 ± 126.98	920.51 ± 148.15
Flanker effect	119.74 ± 98.20		156.47 ± 112.13	
	t = -29.03**		t = -33.23**	
CSPC effect	36.73 ± 139.50			
	t = -6.27**			

Notes. *n* = 567. ** = significant at α ≤ .01. t = value of dependent t-test. LISAS = linear integrated speed-accuracy score. The flanker effect is calculated as the difference between incongruent vs. incongruent trials. CSPC = context-specific proportion congruent. The CSPC effect is calculated as the difference between the flanker effect in the high vs. low conflict condition.

4.4.2 Structural Equation Modelling

The results of the final structural equation model are depicted in *Figure 4.3*. All three latent variables could be estimated as expected. As can be derived from the measures of fit in *Table 4.3*, the more complex models can be considered a good fit for the data according to generally accepted standards (West, Taylor, & Wu, 2012). Given the significant ($p < .01$) change in $\chi 2$, the fit of the two complex models was considerably better than the simple baseline model. The difference of fit between the complex models A and B was nonsignificant. The additional direct effects of model B were nonsignificant and model fit was not improved by adding these effects, therefore the simpler model, model A, was our accepted explanatory model.

The weights in this model show that conflict control per se is not directly related to (self-reported) self-control or habitual behaviour, i.e., the overall flanker congruency effect showed no significant associations with these variables (estimated based on the BSCS and COHS). In contrast, greater automatic conflict control adjustment assessed via the CSPC effect was linked to lower self-control and via this association, also indirectly to more habitual behaviour. This suggests that a stronger tendency to outsource control to the environment is associated with lower self-reported self-control and more habitual behaviour. Self-reported habitual behaviour was associated with unhealthy eating behaviour (as assessed using the TFEQ and DFS), i.e., more pronounced routine and automatic behaviour was linked to more uncontrolled and emotional eating and higher consumption of fat and sugar. Self-reported self-control had no direct association with eating behaviour but showed an indirect influence mediated via a shared association with habitual behaviour. In line with this, the total estimated impact of habitual behaviour on eating behaviour (β = .75) was stronger than the total effect of self-control (β = -.57). Mediated via these associations, automatic conflict control adjustment was also significantly associated with eating behaviour (as estimated based on the TFEQ and DFS). Specifically, it was indirectly related to more emotional and uncontrolled eating and increased consumption of fat and sugar.

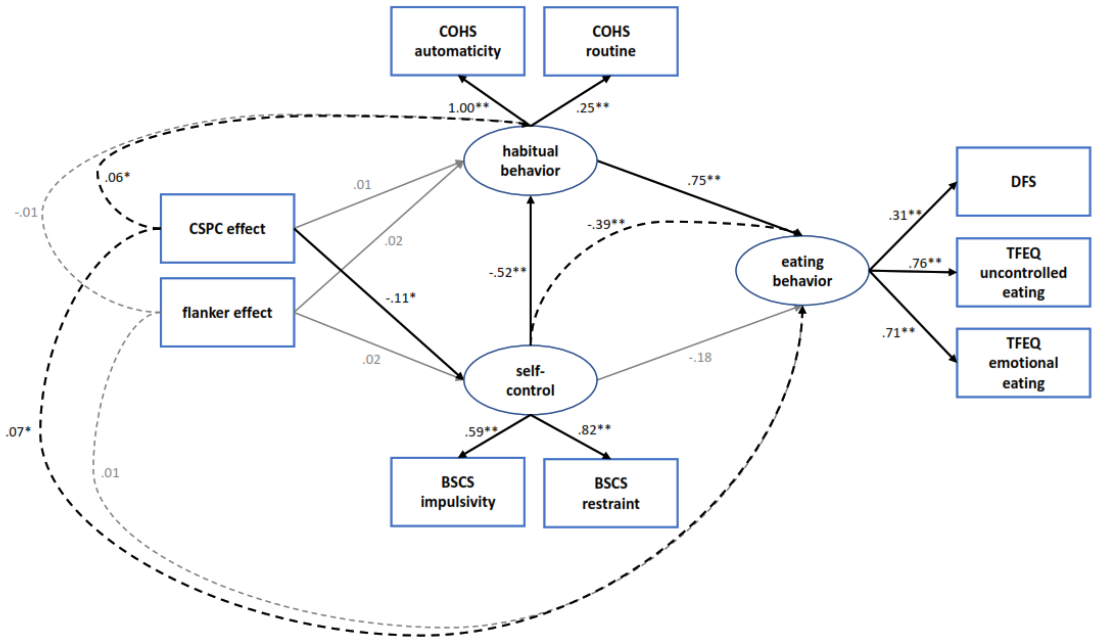


Figure 4.3. Visual representation of the results of the final SEM model. Values are standardized betas. * = significant at α ≤ .05, ** = significant at α ≤ .01. Continuous lines represent direct effects, dashed lines represent indirect effects. CSPC = context-specific proportion congruent, COHS = Creature of Habits Scale, BSCS = Brief Self-Control Scale, DFS = Dietary Fat and Free Sugar Short Questionnaire, TFEQ = Three Factor Eating Questionnaire.

Table 4.3. Model fit of the SEM analyses

	baseline model	complex model A	complex model B
df	24	21	19
χ^2	178.33	53.24	52.84
χ^2/df	7.43	2.54	2.78
CFI	.85	.97	.97
RMSEA	.11	.05	.06
AIC	238.33	119.24	122.84

Notes. df = degrees of freedom; CFI = comparative fit index. RMSEA = root mean square error of approximation. AIC = Akaike information criterion. For χ^2/df, RMSEA, and AIC lower values indicate a better fit. For CFI higher values indicate a better fit.

4.5 Discussion

By using self-report as well as experimental indices, the current study addressed the question of whether eating behaviour is generally more automatic in nature, triggered by bottom-up environmental cues, or more controlled, guided by endogenous top-down goal representations, and to what extent these processes interact. In a large female sample from diverse socioeconomical backgrounds with a broad distribution of BMI values, participants who tended to let their responses be guided automatically by contextual cues during flanker task performance also reported less self-controlled behaviour. Via this connection, such participants also indirectly showed both more automatic and habitual behaviour as well as more uncontrolled, emotional, and unhealthy eating. Such eating behaviour was in turn associated with a higher BMI. More specifically, individuals who frequently rely on automatic reactions report eating as a reaction to unpleasant emotions, experiencing a lack of control over their eating behaviour, and heightened consumption of fat and sugar. In contrast, self-control showed no direct associations with eating behaviour, but had an indirect influence via habitual behaviour. Together, these results provide novel evidence underlining previous accounts of strong associations between eating behaviour and automatic behavioural tendencies (de Bruijn et al., 2008; Lin et al., 2015; van't Riet et al., 2011). The results regarding the self-report measures suggest that eating behaviour might be largely guided by habits and automatic reactions to contextual cues. In contrast, self-control, as investigated here, seems to have a relatively limited impact. The associations of the self-report instruments with task-based measures of controlled and automatic processing also reflect this pattern. Our findings integrate task-based measures of controlled and automatic processing with self-report data as well as real-life outcomes such as BMI, which offers a novel perspective to previous research.

Our findings suggest that people who rely on contextual cues and automatic behavioural tendencies do so both in cognitive processing as well as in their everyday life, which includes

uncontrolled and emotional eating behaviour and heightened consumption of fat and sugar. Unhealthy eating behaviour could be partly due to contextual cues such as foods high in fat and sugar presented at cash registers or easily available fast food and inviting advertisements. Especially in an environment where unhealthy food is easily available and circumstances invite snacking behaviour, the tendency to react automatically when circumstances invite such behaviour might make it more difficult for some people to establish or maintain healthy eating behaviour. On the other hand, if a specific automatic behaviour (which allows for efficient processing) is beneficial, it could yield desirable long-term effects (e.g., following habitual routines in areas such as exercise). Our study complements a line of research highlighting the costs and merits of habitual behaviour. While beneficial habits have been found to function as the mediator between self-control and positive life outcomes (de Ridder & Gillebaart, 2017; de Ridder et al., 2012; Galla & Duckworth, 2015), we were able to demonstrate possible disadvantages of automatic behaviour in the context of eating. Acknowledging that many daily activities are primarily guided by habits and automatic reactions to contextual cues can help to promote a healthy lifestyle. Paradoxically, achieving sufficient self-control might be most efficient via establishing beneficial habits (e.g., a healthy breakfast) that serve long-term goals (e.g., maintaining healthy bodyweight) via pre-commitment. Furthermore, creating situations and contextual surroundings which cue behaviour that is in line with those goals (e.g., placing fresh fruit instead of chocolate on your living-room table or changing your daily route to work to avoid the pastry shop) could aid self-control (Galla & Duckworth, 2015). Studies reporting such moderating associations between habits, self-control, and real-life outcomes (e.g., Quinn, Pascoe, Wood, & Neal, 2010) are supported by our findings showing that these associations are already present in cognitive processes that exist outside of awareness, which might translate into behaviour in everyday life.

The relevance of this interplay between controlled and automatic processes in the context of eating behaviour is highlighted by our findings regarding BMI and diets: more unhealthy eating behaviour was associated with higher BMI and lower success of weight-loss diets. These findings suggest that the factors found to contribute to unhealthy eating, i.e., habitual and automatic (as opposed to self-controlled) behavioural tendencies, present an obstacle for people who strive to reach or maintain a healthy bodyweight. However, this might also present a starting point for possible solutions. Targeting behavioural automaticities and habits as key factors in weight-loss programs and obesity prevention campaigns might be more effective than fostering self-control. Promising results of habit-based weight-loss programs support this notion (Cleo et al., 2017).

Our findings and interpretations should be considered in the light of some limitations. First, the sample came from the female German-speaking population. Therefore, the results and

conclusions may not be generalizable to males or to populations from a different (eating) culture. It should also be noted that the sample included participants who self-reported a history of or current eating disorders (ca. 14% and ca. 5%). Close inspection of the data revealed that these individuals did not cause outliers in the employed measures. Because it was our goal to investigate a sample representative of the general (female) population, we did not exclude these participants from analyses. Second, we did not find any clear associations between task-based cognitive control (as gauged by flanker congruency effects) and self-control or eating behaviour, which stands somewhat in contrast to other accounts (Dohle, Diel, & Hofmann, 2018; Whitelock, Nouwen, van den Akker, & Higgs, 2018). However, this discrepancy is not entirely surprising considering that associations between cognitive control as captured by laboratory tasks and self-report measures as well as real-life outcomes are generally small and not particularly reliable (Duckworth & Kern, 2011; Enkavi et al., 2019; Nęcka, Gruszka, Orzechowski, Nowak, & Wójcik, 2018). Furthermore, associations between cognitive control and eating behaviour are most often reported as moderating or mediating effects (Haynes et al., 2015; Nederkoorn et al., 2010; Price et al., 2016). Third, our findings are limited to the CSPC effect, as observed in our specific task. It has been critiqued that the CSPC effect might not (as generally proposed) reflect automatic adjustment of control, but rather contingency learning (Schmidt & Lemercier, 2019). However, our task adheres well to an expert consensus on how to minimize potential confounds in the study of conflict control adjustments (Braem et al., 2019) and this measure is well-suited to address our research question regarding the complex interplay of automatic and controlled processing. Nevertheless, the findings might not generalize to other related experimental measures (Bugg & Crump, 2012) or paradigms (Verbruggen & Logan, 2009). Lastly, data regarding BMI and success of weight-loss diets was self-reported. We cannot rule out that participants might have reported their height and bodyweight inaccurately. However, since the data is distributed normally and appears to be representative of the general population, we consider the risk of inaccurate data to be low. The self-reported data on success of weight-loss diets might also not be entirely reliable, and this should be kept in mind when interpreting the associations between eating behaviour and success of weight-loss diets.

The present study has shown that reliance on situational cues and automatic tendencies can be measured both via performance during a cognitive laboratory task as well as via self-report. This style of information processing and decision-making influences eating behaviour, which was found to be strongly associated with automatic behavioural tendencies (as opposed to self-control). These findings highlight the importance of environmental cues and habits as guiding aspects of eating behaviour, which has further consequences for real-life outcomes, such as BMI. People wanting to change their eating behaviour might therefore consider approaching this

challenge via implementing environmental cues triggering healthy behaviour (e.g., fruit instead of sweets placed on the desk) and establishing habits that facilitate the desired behaviour (e.g., prepping a healthy lunch to take to work the next day every evening right after dinner). Our findings also support policies aiming to reduce cueing unhealthy food choices through, for example, advertisements or placement of unhealthy items at the top of menus.

5 General Discussion

5.1 Summary of Key Findings

The overarching aim of this work was to provide and discuss empirical investigations regarding the central role of self-control and need for control in AN to allow for a better understanding of the associations between a) inefficiency, rumination, and negative affect, and b) self-control, habitual behaviour, and restrictive eating. The objective was to develop a broad perspective on disorder-specific mechanisms which might contribute to development and maintenance of AN. The main conjectures outlined at the beginning of this thesis suggested that a) the constant rumination about food and bodyweight or figure in AN arises from both physiological aspects of the disorder as well as from feelings of inefficiency or lack of control, leading to negative affect, and b) the restrictive eating behaviour in AN is achieved via an interaction of controlled as well as automatic processes. These associations might contribute to the development and maintenance of AN.

Study 1 (Fürtjes, Seidel, et al., 2020) explored the associations between inefficiency, rumination, and negative affect in AN, demonstrating how elevated feelings of inefficiency in AN compared with HC might contribute to dysfunctional cognitive-affective processes. Feelings of inefficiency were elevated in individuals with a history of AN compared to HC, confirming the first main hypothesis of Study 1. As proposed by the GPT and the further research hypotheses of Study 1, it was found that this heightened inefficiency was associated with increased ruminative thoughts and negative affect. Additionally, the relationship between ruminative thoughts and negative affect was found to be more pronounced in AN, suggesting that feelings of inefficiency and lack of control might trigger dysfunctional cognitive-affective processes in AN. It could therefore be suggested that inefficiency might function as a vulnerability and/or maintenance factor in AN by reinforcing dysfunctional cognitive-affective processes.

The findings of Study 2 (Fürtjes et al., 2018) confirmed the need for a differentiation between rumination about food vs. bodyweight and figure with a detailed investigation of associations between rumination, negative affect, and neuroendocrinological aspects of AN. In line with the central research hypothesis of Study 2, rumination about food was found to be associated with leptin and ruminative thoughts of this content were found to decline with weight gain. Rumination about bodyweight and figure on the other hand was unrelated to nutritional status and persisted after weight gain. Ruminative thoughts of this content showed the close associations with negative affect which were also found in Study 1, highlighting their relevance in the context of cognitive-affective dysfunction in AN.

Study 3 (Fürtjes, King, et al., 2020) demonstrated the involvement of both controlled and automatic processing in human eating behaviour. Individuals who rely on automatic tendencies and let their behaviour be guided by contextual cues show this pattern both in cognitive processing and self-reported behaviour in everyday life. This includes eating behaviour, which appears to be largely guided by such mechanisms. The influence of controlled processes on eating behaviour was found to be indirect, mediated via habits and automaticity. These findings confirmed the proposed hypotheses of Study 3. The associations between control, automaticity, and eating behaviour were found to have further implications for BMI and success of weight-loss diets, confirming the relevance of the mechanisms behind human eating behaviour for real-life consequences.

5.2 Integration and Implications

5.2.1 Integration of Key Findings

The superordinate goal of this thesis was to shed light on mechanisms regarding cognitive, affective, and behavioural aspects of AN which might contribute to the development and maintenance of the disorder.

Studies 1 and 2 addressed the role of rumination in AN. In Study 1, individuals with a history of AN who had recovered from the disorder in terms of bodyweight and eating behaviour still reported heightened levels of rumination about bodyweight/figure compared with HC – but not about food, suggesting that a differentiation between these two kinds of rumination might be indicated. Study 2 took on a closer investigation of the differences between rumination about food vs. figure, demonstrating that rumination about food is primarily linked to physiological aspects of the disorder during the acute state of undernourishment and declines during weight gain. Rumination about bodyweight and figure on the other hand was found to be closely linked to negative affect in both studies, constituting dysfunctional cognitive-affective processes which were found to be relatively persistent during weight rehabilitation (Study 2) and even after recovery in terms of bodyweight and eating behaviour (Study 1). Study 1 provided a closer investigation of these dysfunctional processes. As is suggested by the GPT, the dysfunctional cognitive-affective processes regarding rumination about bodyweight/figure were found to be associated with feelings of inefficiency and lack of control – which were found to be elevated in AN compared to HC. Taken together, Studies 1 and 2 highlight the relevance of need for control and feelings of inefficiency in AN: subjective lack of control and inefficiency appear to trigger dysfunctional cognitive-affective processes which keep ruminative

thoughts about AN-related topics active and lead to negative affect. This most likely makes it difficult for individuals with AN to disengage from their weight-goals and restrictive eating behaviour.

Building on these findings placing need for control in a central position within AN, Study 3 addressed the question of how the excessive control over eating behaviour might be attained. The results of preliminary investigations in the general female population suggest that eating behaviour is guided by automaticity and habits to a large extent, while the impact of self-control is mediated via this association – a pattern which presents itself both in self-reported behaviour as well as during cognitive processing. These findings hint at the possibility of similar behavioural mechanisms in AN: individuals with AN might exercise control over their eating behaviour by developing restrictive eating habits and establishing contextual cues for automatic behaviour favouring food restriction. Future research investigating such processes in patients with AN is needed to show whether the findings obtained with a sample of the general female population in Study 3 can be replicated in a similar manner in a study with an AN sample. As suggested by Study 1, being able to exercise high levels of control via these rigid, habitual behaviours might consequently lead to a decrease in ruminative thoughts and negative affect. This is also a possibility which presents an intriguing starting point for future research.

In sum, the results of the three studies lend support to a perspective integrating several aspects into a framework of mechanisms which might contribute to the development and maintenance of AN: individuals with AN experience a high need for control, which is associated with rumination and negative affect. Feelings of control might be obtained by establishing rigid habitual behaviour in the context of restrictive eating, possibly lessening the strain of negative affect and ruminative thoughts.

5.2.2 Implications: Need for Control and Cognitive-Affective Dysfunction in AN

The results of Studies 1 and 2 demonstrate that the close link between rumination about bodyweight/figure and negative affect in AN contributes to the cognitive-affective dysfunction that is typical for the disorder, as is suggested by theoretical models of AN (Cooper, 2005; Fairburn & Harrison, 2003; Treasure & Schmidt, 2013). They are also in line with research regarding the RST, which has shown that ruminative thoughts and negative affect are connected in a reciprocal manner in everyday life (Moberly & Watkins, 2008). Such dysfunctional cognitive-affective processes have previously been reported to play an important role in AN. For example, naturalistic investigations have established the relevance of the associations between rumination, negative affect, and restrictive eating behaviour in the everyday life of patients with AN (Naumann et al., 2015, 2014; Rawal et al., 2010; Seidel et al., 2016). The findings of Studies 1 and 2 extend this line of research by not only

confirming the cognitive-affective dysfunction in AN, but also addressing possible underlying mechanisms which trigger the maladaptive processes. It could be demonstrated that especially rumination about bodyweight and figure (in contrast to rumination about food) plays an important role in the cognitive-affective dysfunction in AN. Considered in the context of further typical aspects of AN, namely body-dissatisfaction and extreme weight-goals, it is likely that such thoughts are linked to self-criticism, feelings of insufficient progress towards individual weight-goals, and inefficiency – which points into the direction of the GPT as a useful framework for explaining the role of rumination in AN. Inefficiency and feelings of lack of control in AN might trigger dysfunctional cognitive-affective processes which manifest themselves in everyday life of the patients. These associations were found to be persistent during weight-rehabilitation in patients with acute AN (Study 2) and to still impact the daily life of individuals with a history of AN who have recovered from the disorder in terms of weight and eating behaviour (Study 1). It could therefore be argued that inefficiency might present a vulnerability and/or maintenance factor of the disorder by triggering and amplifying dysfunctional cognitive-affective processes in AN. Inefficiency and feelings of lack of control might make it difficult for patients with AN to disengage from their weight-goals and their restrictive eating behaviour, because they prime ruminative thoughts about these concerns. The subsequent maladaptive relations between ruminative thoughts and negative affect (which in Study 1 were found only in AN, not HC) might also contribute to the maintenance of the disorder by interfering with interoceptive function and corrective learning (Duffy et al., 2019; Reilly et al., 2019). This is in line with previous research demonstrating the importance of inefficiency for duration and outcome of treatment in AN (Olatunji et al., 2018; Pinto et al., 2008; Surgenor et al., 2007). Regarding the encumbering ruminative thoughts about food on the other hand, the results of Study 2 suggest that in this context physiological aspects of the disorder should be taken into consideration, as leptin levels appear to play an important role for rumination about food. In fact, recent research was able to demonstrate that off-label drug treatment with leptin was associated with a decrease in rumination in patients with acute AN (Milos et al., 2020), supporting this suggestion.

Taken together, the findings of Study 1 and 2 highlight the relevance of both the GPT and the RST in the context of AN as discussed at the beginning of this work, while also taking into account physiological aspects of the disorder. The results support the proposal that the typical feelings of inefficiency and lack of control in AN trigger ruminative thoughts and negative affect (GPT), leading to dysfunctional cognitive-affective processes (RST).

5.2.3 Implications: Self-Control and Automaticity in Eating Behaviour

The findings of Study 3 present preliminary evidence for the general relevance of automaticity and habits in eating behaviour, providing a basis for further investigations of mechanisms behind restrictive eating in AN. The insight that eating behaviour in general appears to be influenced mainly by automatic behavioural tendencies and reactions to contextual cues adds to a growing body of research supporting this proposal (Cohen & Farley, 2008; Elliston, Ferguson, & Schüz, 2017; Köster, 2009). However, further (indirect) associations with controlled processes also showed some support for opposing research, demonstrating the impact of cognitive and self-control on eating behaviour as discussed at the beginning of this work (Allom & Mullan, 2014; Bickel et al., 2018; Hall, 2012; Hofmann et al., 2014). The integration of measures of both automatic and controlled processing in Study 3 showed that both perspectives appear to be valid. When brought into context with each other, a more comprehensive framework of the mechanisms guiding eating behaviour can be provided. Because the impact of controlled processes on eating behaviour appears to work via the shared association with automatic processes, it could be speculated that control of eating behaviour does not primarily happen during tempting situations, requiring effortful resistance – but instead is achieved via the establishment of goal-serving habits and avoidance of temptations through the reduction of tempting contextual cues (and possibly increase of contextual cues for desired, controlled behaviour). While this is in line with previous research proposing that the impact of self-control on real-life outcomes is mediated via habits and routines (de Ridder & Gillebaart, 2017; de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012; Galla & Duckworth, 2015), further research is needed to investigate whether such processes can indeed be found in eating behaviour during everyday life. In the specific context of eating behaviour, this might be reflected in behaviour such as e.g. establishing a morning routine including a breakfast of yoghurt and fresh fruit instead of sweet pastries, prepping healthy meals ahead of time to avoid succumbing to fast-food, or throwing out the stash of chocolate bars in the desk-drawer to avoid unconscious snacking. While this might seem desirable and health-promoting for the general population, it could be argued that such processes reach an undesirable and health-harming level in AN. The rigid restriction of food intake in AN could reflect such processes of self-control working via the establishment of habits and automatic behaviours such as e.g. drinking a lot of coffee in the morning instead of breakfast, prepping the same low-calorie meals at the same time every day, always sticking to a certain order while eating (e.g. “filling” up on vegetables first) etc. This proposal is supported by theoretical frameworks of AN including rigid behavioural patterns and comorbid symptoms of OCD (Schmidt & Treasure, 2006; Treasure & Schmidt, 2013). Patients with AN are prone to rigid routines and struggle with set shifting (Halmi et al., 2003; Treasure & Schmidt, 2013) – which might therefore also be reflected in the restrictive eating behaviour, which often shows characteristics of habits or even compulsions. If

the extreme control of food intake in AN is achieved via the establishment of according habits, the automaticity of this behaviour could also explain the strong perseverance and its resistance to change even when consequences have become severely harmful. Study 3 was able to provide preliminary support for such associations between automatic and controlled processes and eating behaviour in the general population, which provides a basis for further investigations in AN.

5.3 Limitations

The research presented in this work is subject to several limitations, which should be taken into consideration when interpreting the findings of the three studies. Limitations of each study have been discussed individually in the respective publications, but several general limitations should be considered again against the background of the complete work. Limiting aspects due to the design and methods of the studies need to be addressed, as well as aspects regarding interpretation and generalisability of the presented findings. These limitations are discussed in detail below.

5.3.1 Limitations Regarding Methods and General Study Design

5.3.1.1 EMA Method

Studies 1 and 2 utilized EMA in their longitudinal design to assess rumination and affect in everyday life over a period of two weeks. This method has several advantages compared with laboratory assessments (e.g. reducing memory bias, foregoing undesired effects of the situational surroundings of a laboratory setting, ability to assess not only inter- but also intraindividual differences), but also drawbacks. The repeated assessment of a specific topic could lead to reactive effects due to increased sensitivity, which could influence the data. While this possibility was addressed by controlling for day of study and time of day in all hierarchical analyses, such reactive effects cannot be ruled out with certainty. However, previous research indicates that the advantages of EMA outweigh such drawbacks and that data on cognitive and affective processes collected via this method is valid and reliable (Csikszentmihalyi & Larson, 1987; Ebner-Priemer & Trull, 2009; Shiffman et al., 2008).

5.3.1.2 Crowdsourcing

The online data collection for Study 3 took place via crowdsourcing. Therefore, the truthfulness of self-reported data regarding e.g. age, bodyweight, success of weight-loss diets etc. cannot be ascertained. Undesirable variation in the data due to e.g. contextual aspects of the different surroundings of participants during the assessment can also not be ruled out. Previous research has

addressed such possible drawbacks of online (as opposed to lab-based) studies since data collection via crowdsourcing has gained popularity, providing empirical evidence that data acquired via crowdsourcing is of high quality and generally comparable to laboratory studies (Buhrmester et al., 2011; Miller, Schmidt, Kirschbaum, & Enge, 2018; Paolacci, Chandler, & Ipeirotis, 2010). To nevertheless address possible influences of the crowdsourcing design on the data, the design of Study 3 included IMCs included in the self-report measures as well as algorithms verifying understanding of instructions and constant task-performance during the flanker task to ensure that participants were attentive during the assessment. All in all, the risk of data quality having been impacted due to aspects related to crowdsourcing can be considered to be very low.

5.3.1.3 Samples

The AN sample of Study 1 consisted of former patients recovered from the disorder in terms of bodyweight and eating behaviour, not of acute patients. Therefore, all interpretations regarding the results of Study 1 cannot be directly transferred to processes and aspects of acute AN.

In Study 2 the sample consisted of patients with acute AN. Participants received inpatient treatment during the time of the assessments, which means that results might not reflect the everyday life of individuals with AN in their home without intensive care and therapy. This should be kept in mind when interpreting the results of Study 2.

Lastly, the large sample of Study 3 consisted of females between the ages of 18 and 45 from a German speaking population. This should be kept in mind when interpreting the findings of Study 3, which might not be generalizable to males or populations from a different cultural background.

5.3.2 Limitations Regarding Interpretations and Conclusions

5.3.2.1 Correlation vs. Causation

Because data analysis was based on regression-based approaches (HLM, CPM, SEM) in all three studies, causality cannot be derived from the presented results.

The interpretations rumination about bodyweight/figure is triggered by feelings of inefficiency and lack of control (Study 1), that rumination about food is triggered by physiological aspects of AN related to undernourishment (Study 2), and that rumination about bodyweight increases negative affect (Studies 1 and 2) are somewhat speculative. When interpreting the findings regarding associations between rumination and negative affect presented in Studies 1 and 2, it should additionally be kept in mind that the reported effects were only found for momentary associations. Time-lagged analyses predicting affect at *t* through rumination at *t-1* did not yield significant results. Therefore, causal interpretations regarding the directionality of the relationship between rumination

and affect cannot be made, only close momentary associations could be established with certainty. Whether rumination causes negative effect (as would be suggested by the GPT), or whether the relation is reciprocal (as postulated by the RST) cannot be unravelled by the findings presented in the two studies. Neither can be said whether indeed physiological aspects of AN cause rumination about food and feelings of inefficiency cause rumination about bodyweight/figure – or whether the associations stem from shared connections to further variables (such as e.g. hunger or perfectionism).

The same considerations apply to Study 3. The onetime assessment of controlled and automatic processing, self-control and automatic behaviour, eating behaviour, and further outcomes such as BMI does not allow for conclusions regarding causal relationships between these variables. The interpretations regarding the directionality of the associations between control, automaticity, and eating behaviour discussed in Study 3 should therefore be treated carefully and it should be kept in mind that suggested ideas regarding causality are speculative.

5.3.2.2 Further Aspects

Apart from the limitations stemming from regression-based analyses, some additional aspects should be considered in the interpretation of the findings of the presented research.

The findings of Study 1 and 2 are based on rumination regarding specific topics with relevance for AN (i.e. food and bodyweight/figure). It was decided to focus on ruminative thoughts about these two aspects because asking for all possible topics of rumination seemed unfeasible. Nevertheless, it should be kept in mind that the results presented in Studies 1 and 2 are specific to ruminative thoughts about AN-related topics and might not be generalizable to rumination with a different content.

A further aspect that needs to be considered regards Study 1. The interpretation of the presented findings that was offered, proposed that inefficiency and lack of control might function as a factor increasing vulnerability and/or risk of relapse of AN. However, since the AN sample of Study 1 consisted of AN patients who had recovered from the disorder in terms of bodyweight and eating behaviour, it could also be argued that inefficiency might rather be a scar of the disorder.

5.4 Future Directions and Clinical Applications

5.4.1 Directions for Future Research

The limitations discussed above could provide a starting point for future research to continue the investigation of the relationships between self-control, need for control, habitual or automatic behaviour, rumination, and affect in AN.

Study 1 was able to highlight the role of inefficiency and lack of control in AN. However, as stated above further research is needed to clarify the functionality of these aspects within the aetiology of the disorder. Especially research comparing acute and recovered AN with HC and risk-groups (such as e.g. professional dancers) could provide answers to the question whether these variables function as a vulnerability, a maintenance factor, a scar of the disorder, or maybe all of the above. It should also be considered that in Study 1 inefficiency was treated as a trait-variable and therefore data was collected only once instead of consistently over the course of the study. To obtain deeper insight into the impact of inefficiency on rumination and affect, future research might consider assessing feelings of inefficiency and lack of control not only once, but also on the situational level at the same time with rumination and affect.

As discussed above, the findings presented in Study 1 and 2 do not allow for clear interpretations regarding the causality of the associations between inefficiency, rumination, and affect. A possibility to address this matter would be to conduct interventional studies comparing AN and HC participants in different experimental conditions. Different levels of inefficiency or feelings of control could be experimentally induced, e.g. via manipulated feedback or procedures asking participants to recall previous successes vs. failures (Fisher & Johnston, 1996; Weinberg, Hughes, Critelli, England, & Jackson, 1984). Groups with high vs. low induced inefficiency could then be compared regarding associations with subsequent ruminative thoughts and affect to draw causal conclusions about the effect of inefficiency on rumination and affect. In a similar manner, rumination and negative affect could be experimentally induced (e.g. via film sequences, autobiographical recall, reflection tasks, etc. (Jallais & Gilet, 2010; Watkins & Teasdale, 2001; Westermann, Spies, Stahl, & Hesse, 1996)) to investigate associations with subsequent levels of these variables.

Regarding the relationship of controlled and automatic processes with eating behaviour investigated in Study 3, future research could build on the preliminary findings presented in this work. Assessment of self-control, habitual behaviour, and eating behaviour in real-life via EMA procedures would allow for a closer inspection of the proposed associations and minimize recall bias. It could be investigated whether individuals with high levels of automatic behaviour in everyday life also show more automatic eating behaviour, and whether a high level of self-controlled behaviour in everyday life influences eating behaviour via habits and automatic behaviour. In a possible interventional approach to address the question of causality regarding this topic, longitudinal studies might investigate whether establishing specific eating-related habits has an effect on eating behaviour. Such interventions could be compared to interventions based on e.g. inhibitory self-control training to compare the impact of establishing habits vs. training inhibitory self-control on eating behaviour. This would allow for a deeper understanding of the mechanisms guiding eating behaviour by untangling the different contributions of automatic and controlled processes.

The insight that eating behaviour in the general population appears to be largely guided by automatic processes, with self-control working via this association, should also be transferred to future AN research. The strategies by which AN patients achieve their extremely restrictive eating behaviour could be assessed via EMA procedures in which individuals with AN report when and how they avoid food intake to investigate whether these strategies include habits or rituals as well as inhibitory self-control. Similar studies including participants from risk-groups and individuals who have recovered from AN could provide insight into the question whether individuals at risk of AN show higher levels of automaticity and habits regarding eating behaviour, whether they show higher levels of control regarding eating behaviour – or whether they utilize habits and routines to achieve controlled eating behaviour.

5.4.2 Clinical Applications

Apart from providing a starting point for further research, the findings presented in this thesis also carry implications for possible application in clinical and health-related contexts.

The insight that need for control and feelings of inefficiency play an important role in AN by fuelling dysfunctional cognitive-affective processes is relevant for the clinical domain. It might be promising to target feelings of inefficiency and high need for control in therapy to treat mechanisms which possibly contribute to disorder maintenance. Subjective feelings of progress and control could be increased through e.g. interventions targeting self-esteem (Adamson, Ozenc, Baillie, & Tchanturia, 2019), which could help to achieve a decline in distressing ruminative thoughts and negative effect, contributing to treatment success. Such approaches might also prove helpful for preventative interventions in risk groups, where individuals could be coached to build and strengthen subjective feelings of efficiency and control via non-pathological behavioural strategies that are independent from eating or bodyweight and figure – e.g. via positive self-verbalisations and further established methods of self-esteem training. Apart from AN, the same applications mentioned above could also be transferred into the context of other psychiatric disorders in which rumination and negative affect present important symptoms, e.g. depressive disorders.

A further application for the clinical context can be derived from the likely possibility that eating behaviour is guided by habits and automatic behavioural tendencies. It was speculated that patients with AN might achieve and maintain their extremely restrictive eating behaviour by following rigid habits and routines. Interventions aiming to re-establish a healthy eating behaviour could tap into those processes by explicitly assessing previous pathological eating habits and substituting them through new, healthy routines. The relevance of habits and routines for eating

behaviour could also be considered in the clinical context of non-psychiatric disorders in which eating behaviour plays an important role, such as e.g. Diabetes mellitus. Treatment of illnesses or disorders which require a specific diet could be supported by nutrition counselling including information about the impact of habits and routines on eating behaviour. This could encourage patients to establish eating habits which contribute to successful treatment of their illnesses. In a non-clinical context the importance of habits and automaticity for eating behaviour could be used to encourage healthy eating behaviour in the general population, which might contribute to prevention and reduction of obesity and associated health risks (e.g. cardiovascular diseases). Campaigns for healthy eating could include strategies such as implementing environmental cues that encourage healthy eating behaviour (e.g. placing low-calorie meals on the top of menus, including water instead of sugary drinks with meal-deals, displaying fruit instead of candy bars at the cash register, etc.). Programs for weight-loss might improve their success by targeting eating habits and encouraging participants to establish healthy routines regarding eating behaviour.

5.5 Conclusion

The research described and discussed in this thesis was able to lend support to an integrative perspective on different mechanisms contributing to AN pathology. Against the backdrop of the GPT, it was demonstrated how feelings of inefficiency and lack of control as a core aspect of AN are related to cognitive-affective symptoms of the disorder. By triggering ruminative thoughts and negative affect, subjective lack of progress and control might lead to dysfunctional cognitive-affective processes which could play a part in the development and maintenance of AN. A broader view on such processes was enabled by addressing similarities between theoretical models of AN placing need for control and feelings of inefficiency in the centre of the disorder (e.g. Fairburn et al., 1999) and the GPT. These considerations carry implications for the clinical context, suggesting that it might be beneficial to target need for control and feelings of inefficiency in therapy. The question of how the extreme control over eating behaviour in AN could be achieved was further explored against the backdrop of a line of research proposing interactive associations between controlled and automatic processes (as opposed to a dichotomous perspective) in the guidance of human behaviour. The presented research provided preliminary evidence for the proposal that eating behaviour is mainly guided by habits and automatic reactions to contextual cues, but that self-control works via this association to influence food choices and consumption. It is possible that such processes guiding eating behaviour in the general (female) population could be elevated to an extreme level in AN, enabling patients to exercise control over eating and restrict food intake by establishing rigid

behavioural routines regarding eating behaviour. Further research is needed to investigate this question and to enable a deeper understanding of the mechanisms by which AN patients achieve and maintain their extremely restrictive eating behaviour.

6 References

Adamson, J., Ozenc, C., Baillie, C., & Tchanturia, K. (2019). Self-Esteem Group: Useful Intervention for Inpatients with Anorexia Nervosa? *Brain Sciences*, *9*(12), 1–11. https://doi.org/10.3390/brainsci9010012

Adriaanse, M. A., Kroese, F. M., Gillebaart, M., & de Ridder, D. T. D. (2014). Effortless inhibition: habit mediates the relation between self-control and unhealthy snack consumption. *Frontiers in Psychology*, *5*, 10–15. https://doi.org/10.3389/fpsyg.2014.00444

Aldao, A., & Nolen-Hoeksema, S. (2010). Specificity of cognitive emotion regulation strategies: A transdiagnostic examination. *Behaviour Research and Therapy*, *48*, 974–983. https://doi.org/10.1016/j.brat.2010.06.002

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review*, *30*, 217–237. https://doi.org/10.1016/j.cpr.2009.11.004

Allan, J. L., Johnston, M., & Campbell, N. (2010). Unintentional eating. What determines goal-incongruent chocolate consumption? *Appetite*, *54*(2), 422–425. https://doi.org/10.1016/j.appet.2010.01.009

Allom, V., & Mullan, B. (2014). Individual differences in executive function predict distinct eating behaviours. *Appetite*, *80*, 123–130. https://doi.org/10.1016/j.appet.2014.05.007

Aster, M. (2006). *Wechsler Intelligenztest für Erwachsene: WIE - Übersetzung und Adaption der WAIS-III*. Frankfurt: Harcourt Test Services.

Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: a failed theoretical dichotomy. *Trends in Cognitive Sciences*, *16*(8), 437–443. https://doi.org/10.1016/j.tics.2012.06.010.Top-down

Bargh, J. A., & Chartrand, T. L. (1999). The unbearable automaticity of being. *American Psychologist*, *54*(7), 462–479. https://doi.org/10.1037/0003-066X.54.7.462

Beeken, R. J., Leurent, B., Vickerstaff, V., Wilson, R., Croker, H., Morris, S., … Wardle, J. (2016). A brief intervention for weight control based on habit-formation theory delivered through primary care: results from a randomised controlled trial. *International Journal of Obesity*, *41*, 246–254. https://doi.org/10.1038/ijo.2016.206

Bernardoni, F., King, J. A., Geisler, D., Stein, E., Jaite, C., Nätsch, D., … Ehrlich, S. (2016). Weight restoration therapy rapidly reverses cortical thinning in anorexia nervosa: A longitudinal study. *NeuroImage*, *130*, 214–222. https://doi.org/10.1016/j.neuroimage.2016.02.003

Bickel, W. K., Moody, L. N., Koffarnus, M., Thomas, J. G., & Wing, R. (2018). Self-control as measured by delay discounting is greater among successful weight losers than controls. *Journal of Behavioral Medicine*, *41*, 891–896. https://doi.org/10.1007/s10865-018-9936-5

Braem, S., Bugg, J. M., Schmidt, J. R., Crump, M. J. C., Weissman, D. H., Notebaert, W., & Egner, T. (2019). Measuring Adaptive Control in Conflict Tasks. *Trends in Cognitive Sciences*, *23*(9), 769–783. https://doi.org/10.1016/j.tics.2019.07.002

Brans, K., Koval, P., Verduyn, P., Lim, Y. L., & Kuppens, P. (2013). The regulation of negative and positive affect in daily life. *Emotion*, *13*(5), 926–939. https://doi.org/10.1037/a0032400

Brockmeyer, T., Holtforth, M. G., Bents, H., Kämmerer, A., Herzog, W., & Friederich, H.-C. (2012). Starvation and emotion regulation in anorexia nervosa. *Comprehensive Psychiatry*, *53*(5), 496–501. https://doi.org/10.1016/j.comppsych.2011.09.003

Bruch, H. (1978). *The golden cage. The enigma of anorexia nervosa.* Cambridge: Harvard University Press.

Bugg, J. M. (2017). Context, Conflict, and Control. In T. Egner (Ed.), *The Wiley Handbook of Cognitive Control*. Chichester, UK: John Wiley and Sons Ltd.

Bugg, J. M., & Crump, M. J. C. (2012). In support of a distinction between voluntary and stimulus-driven control: A review of the literature on proportion congruent effects. *Frontiers in Psychology*, *3*(SEP), 1–16. https://doi.org/10.3389/fpsyg.2012.00367

Buhrmester, M., Kwang, T., & Gosling, S. D. (2011). Amazon's Mechanical Turk: A New Source Of Inexpensive, Yet High-Quality, Data? *Perspectives on Psychological Science*, *6*(1), 3–5. https://doi.org/10.1177/1745691610393980

Carver, C. S., & Scheier, M. F. (1990). Origins and Functions of Positive and Negative Affect: A Control-Process View. *Psychological Review*, *97*(1), 19–35. https://doi.org/10.1037/0033-295X.97.1.19

Casper, R. C. (1998). Behavioral Activation and Lack of Concern, Core Symptoms of Anorexia Nervosa? *International Journal of Eating Disorders*, *24*(4), 381–393. https://doi.org/10.1002/(SICI)1098-108X(199812)24:4<381::AID-EAT5>3.0.CO;2-Q

Cleo, G., Isenring, E., Thomas, R., & Glasziou, P. (2017). Could habits hold the key to weight loss maintenance? A narrative review. *Journal of Human Nutrition and Dietetics*, *30*(5), 655–664. https://doi.org/10.1111/jhn.12456

clickworker GmbH. (2018). www.clickworker.de.

Cohen, D. A., & Farley, T. A. (2008). Eating as an Automatic Behavior. *Preventing Chronic Disease*, *5*(1).

Cohen, J. D. (2017). Cognitive Control. Core Constructs and Current Considerations. In T. Egner (Ed.), *The Wiley Handbook of Cognitive Control*. Chichester, UK: John Wiley and Sons Ltd.

Coniglio, K. A., Becker, K. R., Franko, D. L., Zayas, L. V., Plessow, F., Eddy, K. T., & Thomas, J. J. (2017). Won't stop or can't stop? Food restriction as a habitual behavior among individuals with anorexia nervosa or atypical anorexia nervosa. *Eating Behaviors*, *26*, 144–147. https://doi.org/10.1016/j.eatbeh.2017.03.005

Cooper, M. J. (2005). Cognitive theory in anorexia nervosa and bulimia nervosa: Progress, development and future directions. *Clinical Psychology Review*, *25*, 511–531. https://doi.org/10.1016/j.cpr.2005.01.003

Cooper, M. J., Wells, A., & Todd, G. (2004). A cognitive model of bulimia nervosa. *British Journal of Clinical Psychology*, *43*, 1–16. https://doi.org/10.1348/014466504772812931

Cowdrey, F. A., & Park, R. J. (2011). Assessing rumination in eating disorders: Principal component analysis of a minimally modified ruminative response scale. *Eating Behaviors*, *12*, 321–324. https://doi.org/10.1016/j.eatbeh.2011.08.001

Cowdrey, F. A., & Park, R. J. (2012). The role of experiential avoidance, rumination and mindfulness in eating disorders. *Eating Behaviors*, *13*, 100–105. https://doi.org/10.1016/j.eatbeh.2012.01.001

Crump, M. J. C., Gong, Z., & Milliken, B. (2006). The context-specific proportion congruent Stroop effect: Location as a contextual cue. *Psychonomic Bulletin & Review*, *13*(2), 316–321. https://doi.org/https://doi.org/10.3758/BF03193850

Crump, M. J. C., McDonnell, J. V., & Gureckis, T. M. (2013). Evaluating Amazon's Mechanical Turk as a Tool for Experimental Behavioral Research. *PLoS ONE*, *8*(3), 1–18. https://doi.org/10.1371/journal.pone.0057410

Csikszentmihalyi, M., & Larson, R. (1987). Validity and Reliability of the Experience-Sampling Method. *The Journal of Nervous and Mental Disease*, *175*(9), 526–536. https://doi.org/https://doi.org/10.1007/978-94-017-9088-8_3

D'Anci, K. E., Watts, K. L., Kanarek, R. B., & Taylor, H. A. (2009). Low-carbohydrate weight-loss diets. Effects on cognition and mood. *Appetite*, *52*(1), 96–103. https://doi.org/10.1016/j.appet.2008.08.009

de Bruijn, G. J., Kremers, S. P. J., de Vet, E., de Nooijer, J., van Mechelen, W., & Brug, J. (2007). Does habit strength moderate the intention-behaviour relationship in the Theory of Planned Behaviour? The case of fruit consumption. *Psychology and Health*, *22*(8), 899–916. https://doi.org/10.1080/14768320601176113

de Bruijn, G. J., Kroeze, W., Oenema, A., & Brug, J. (2008). Saturated fat consumption and the Theory of Planned Behaviour: Exploring additive and interactive effects of habit strength. *Appetite*, *51*, 318–323. https://doi.org/10.1016/j.appet.2008.03.012

de Ridder, D., & Gillebaart, M. (2017). Lessons learned from trait self-control in well-being: making the case for routines and initiation as important components of trait self-control. *Health*

Psychology Review, *11*(1), 89–99. https://doi.org/10.1080/17437199.2016.1266275

de Ridder, D. T. D., Lensvelt-Mulders, G., Finkenauer, C., Stok, F. M., & Baumeister, R. F. (2012). Taking stock of self-control: A meta-analysis of how trait self-control relates to a wide range of behaviors. *Personality and Social Psychology Review*, *16*(1), 76–99. https://doi.org/10.1177/1088868311418749

Dohle, S., Diel, K., & Hofmann, W. (2018). Executive functions and the self-regulation of eating behavior: A review. *Appetite*, *124*, 4–9. https://doi.org/10.1016/j.appet.2017.05.041

Duckworth, A. L., & Kern, M. L. (2011). A meta-analysis of the convergent validity of self-control measures. *Journal of Research in Personality*, *45*, 259–268. https://doi.org/10.1016/j.jrp.2011.02.004

Duffy, M. E., Rogers, M. L., Joiner, T. E., Bergen, A. W., Berrettini, W., Bulik, C. M., … Keel, P. K. (2019). An investigation of indirect effects of personality features on anorexia nervosa severity through interoceptive dysfunction in individuals with lifetime anorexia nervosa diagnoses. *International Journal of Eating Disorders*, *52*, 200–205. https://doi.org/10.1002/eat.23008

Ebner-Priemer, U. W., & Trull, T. J. (2009). Ecological Momentary Assessment of Mood Disorders and Mood Dysregulation. *Psychological Assessment*, *21*(4), 463–475. https://doi.org/10.1037/a0017075

Egner, T. (2014). Creatures of habit (and control): A multi-level learning perspective on the modulation of congruency effects. *Frontiers in Psychology*, *5*, 1–11. https://doi.org/10.3389/fpsyg.2014.01247

Ehrlich, S., Burghardt, R., Schneider, N., Hein, J., Weiss, D., Pfeiffer, E., … Salbach-Andrae, H. (2009). Leptin and its associations with measures of psychopathology in patients with anorexia nervosa. *Journal of Neural Transmission*, *116*, 109–115. https://doi.org/10.1007/s00702-008-0151-3

Ehrlich, S., Geisler, D., Ritschel, F., King, J. A., Boehm, I., Breier, M., … Kroemer, N. B. (2015). Elevated cognitive control over reward processing in recovered female patients with anorexia nervosa. *Journal of Psychiatry & Neuroscience*, *40*(5), 307–315. https://doi.org/10.1503/jpn.140249

Elliston, K. G., Ferguson, S. G., & Schüz, B. (2017). Personal and situational predictors of everyday snacking: An application of temporal self-regulation theory. *British Journal of Health Psychology*, *22*(4), 854–871. https://doi.org/10.1111/bjhp.12259

Engel, S. G., Wonderlich, S. A., Crosby, R. D., Mitchell, J. E., Crow, S., Peterson, C. B., … Gordon, K. H. (2013). The Role of Affect in the Maintenance of Anorexia Nervosa: Evidence From a Naturalistic Assessment of Momentary Behaviors and Emotion. *Journal of Abnormal Psychology*, *122*(3), 709–719. https://doi.org/10.1037/a0034010

Enkavi, Z. A., Eisenberg, I. W., Bissett, P. G., Mazza, G. L., MacKinnon, D. P., Marsch, L. A., & Poldrack, R. A. (2019). Large-scale analysis of test–retest reliabilities of self-regulation measures. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(12), 5472–5477. https://doi.org/10.1073/pnas.1818430116

Ersche, K. D., Lim, T. V., Ward, L. H. E., Robbins, T. W., & Stochl, J. (2017). Creature of Habit: A self-report measure of habitual routines and automatic tendencies in everyday life. *Personality and Individual Differences*, *116*, 73–85. https://doi.org/10.1016/j.paid.2017.04.024

Fairburn, C. G., Cooper, Z., & Shafran, R. (2003). Cognitive behaviour therapy for eating disorders: a "transdiagnostic" theory and treatment. *Behavior Research and Therapy*, *41*, 509–528. https://doi.org/10.1016/S0005-7967(02)00088-8

Fairburn, C. G., & Harrison, P. J. (2003). Eating disorders. *The Lancet*, *361*, 407–416. https://doi.org/10.1016/S0140-6736(03)12378-1

Fairburn, C. G., Shafran, R., & Cooper, Z. (1999). A cognitive behavioural theory of anorexia nervosa. *Behaviour Research and Therapy*, *37*, 1–13. https://doi.org/10.1016/S0005-7967(98)00102-8

Fichter, M., & Quadflieg, N. (2001). The structured interview for anorexic and bulimic disorders for DSM-IV and ICD-10 (SIAB-EX): reliability and validity. *European Psychiatry*, *16*, 38–48.

https://doi.org/10.1016/S0924-9338(00)00534-4
Fisher, K., & Johnston, M. (1996). Experimental manipulation of perceived control and its effect on disability. *Psychology and Health*, *11*, 657–669. https://doi.org/10.1080/08870449608404995
Forestier, C., Sarrazin, P., Allenet, B., Gauchet, A., Heuzé, J. P., & Chalabaev, A. (2018). "Are you in full possession of your capacity?". A mechanistic self-control approach at trait and state levels to predict different health behaviors. *Personality and Individual Differences*, *134*, 214–221. https://doi.org/10.1016/j.paid.2018.05.044
Francis, H., & Stevenson, R. (2013). Validity and test–retest reliability of a short dietary questionnaire to assess intake of saturated fat and free sugars: a preliminary study. *Nutritional Science*, *26*(3), 234–242. https://doi.org/https://doi.org/10.1111/jhn.12008
Fromm, S. P., & Horstmann, A. (2019). Psychometric Evaluation of the German Version of the Dietary Fat and Free Sugar – Short Questionnaire. *Obesity Facts*, *12*(5), 518–528. https://doi.org/10.31232/osf.io/w9xny
Froreich, F. V., Vartanian, L. R., Grisham, J. R., & Touyz, S. W. (2016). Dimensions of control and their relation to disordered eating behaviours and obsessive-compulsive symptoms. *Journal of Eating Disorders*, *4*(1), 1–9. https://doi.org/10.1186/s40337-016-0104-4
Fürtjes, S., King, J. A., Goeke, C., Seidel, M., Goschke, T., Horstmann, A., & Ehrlich, S. (2020). Automatic and Controlled Processing: Implications for Eating Behavior. *Nutrients*, *12*(4), 1097. https://doi.org/https://doi.org/10.3390/nu12041097
Fürtjes, S., Seidel, M., King, J. A., Biemann, R., Roessner, V., & Ehrlich, S. (2018). Rumination in Anorexia Nervosa: Cognitive-Affective and Neuroendocrinological Aspects. *Behavior Research and Therapy*, *111*, 92–98. https://doi.org/10.1016/j.brat.2018.10.001
Fürtjes, S., Seidel, M., King, J. A., Boehm, I., Jaite, C., Roessner, V., & Ehrlich, S. (2020). A naturalistic investigation of cognitive-affective dysfunction in Anorexia nervosa: The role of inefficiency. *International Journal of Eating Disorders*, *53*(2), 239–247. https://doi.org/https://doi.org/10.1002/eat.23189
Galla, B. M., & Duckworth, A. L. (2015). More than Resisting Temptation: Beneficial Habits Mediate the Relationship between Self-Control and Positive Life Outcomes. *Journal of Personality and Social Psychology*, *109*(3), 508–525. https://doi.org/10.1016/j.clinbiochem.2015.06.023.Gut-Liver
Galmiche, M., Déchelotte, P., Lambert, G., & Tavolacci, M. P. (2019). Prevalence of eating disorders over the 2000 – 2018 period: a systematic literature review. *American Journal Od Clinical Nutrition*, (109), 1402–1413. https://doi.org/https://doi.org/10.1093/ ajcn/nqy342
Georgii, C., Schulte-Mecklenbeck, M., Richard, A., van Dyck, Z., & Blechert, J. (2019). The dynamics of self-control: within-participant modeling of binary food choices and underlying decision processes as a function of restrained eating. *Psychological Research*. https://doi.org/10.1007/s00426-019-01185-3
Gilboa-Schechtman, E., Avnon, L., Zubery, E., & Jeczmien, P. (2006). Emotional Processing in Eating Disorders: Specific Impairment or General Distress Related Deficiency? *Depression and Anxiety*, *23*, 331–339. https://doi.org/10.1002/da
Gillebaart, M., & de Ridder, D. T. D. (2015). Effortless Self-Control: A Novel Perspective on Response Conflict Strategies in Trait Self-Control. *Social and Personality Psychology Compass*, *9*(2), 88–99. https://doi.org/10.1111/spc3.12160
Gillebaart, M., Schneider, I. K., & de Ridder, D. T. D. (2016). Effects of Trait Self-Control on Response Conflict About Healthy and Unhealthy Food. *Journal of Personality*, *84*(6), 789–798. https://doi.org/10.1111/jopy.12219
Goeke, C., & Finger, H. (2018). www.labvanced.com.
Goeke, C. M., Finger, H., Standvoss, K., & König, P. (2017). LabVanced: A Unified JavaScript Framework for Online Studies. In *International Conference on Computational Social Science IC^{2}S^2*.
Goldschmidt, A. B., Wonderlich, S. A., Crosby, R. D., Engel, S. G., Lavender, J. M., Peterson, C. B., … Mitchell, J. E. (2014). Ecological momentary assessment of stressful events and negative affect in bulimina nervosa. *Journal of Consulting and Clinical Psychology*, *82*(1), 30–39.

https://doi.org/10.1371/journal.pone.0178059
Haedt-Matt, A., & Keel, P. K. (2011). Revisiting the Affect Regulation Model of Binge Eating: A Meta-Analysis of Studies using Ecological Momentary Assessment. *Psychological Bulletin*, *137*(4), 660–681. https://doi.org/10.1037/a0023660.Revisiting
Hall, K. D. (2018). Did the Food Environment Cause the Obesity Epidemic? *Obesity*, *26*, 11–13. https://doi.org/10.1002/oby.22073
Hall, P. A. (2012). Executive control resources and frequency of fatty food consumption: Findings from an age-stratified community sample. *Health Psychology*, *31*(2), 235–241. https://doi.org/10.1037/a0025407
Halmi, K. A., Sunday, S. R., Klump, K. L., Strober, M., Leckman, J. F., Fichter, M., … Kaye, W. H. (2003). Obsessions and compulsions in anorexia nervosa subtypes. *International Journal of Eating Disorders*, *33*, 308–319. https://doi.org/10.1002/eat.10138
Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2010). Emotional functioning in eating disorders: attentional bias, emotion recognition and emotion regulation. *Psychological Medicine*, *40*(11), 1887–1897. https://doi.org/10.1017/S0033291710000036
Hauser, D. J., & Schwarz, N. (2016). Attentive Turkers: MTurk participants perform better on online attention checks than do subject pool participants. *Behavior Research Methods*, *48*(1), 400–407. https://doi.org/10.3758/s13428-015-0578-z
Hautzinger, M., Keller, F., & Kühne, C. (2009). *Beck Depressions Inventar: Revision*. Bern: Huber.
Hayes, A. F. (2013). *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*. New York: The Guilford Press.
Haynes, A., Kemps, E., & Moffitt, R. (2015). Inhibitory self-control moderates the effect of changed implicit food evaluations on snack food consumption. *Appetite*, *90*, 114–122. https://doi.org/10.1016/j.appet.2015.02.039
Hebebrand, J., Muller, T. D., Holtkamp, K., & Herpetz-Dahlmann, B. (2007). The role of leptin in anorexia nervosa: clinical implications. *Molecular Psychiatry*, *12*, 23–35. https://doi.org/10.1038/sj.mp.4001909
Hemmelmann, C., Brose, S., Vens, M., Hebebrand, J., & Ziegler, A. (2010). Perzentilen des Body-Mass-Index auch für 18- bis 80-Jährige? Daten der Nationalen Verzehrsstudie II. *Deutsche Medizinische Wochenschrift*, *135*, 848–852. https://doi.org/10.1055/s-0030-1253666
Higgins, S. C., Gueorguiev, M., & Korbonits, M. (2007). Ghrelin, the peripheral hunger hormone. *Annals of Medicine*, *39*, 116–136. https://doi.org/10.1080/07853890601149179
Hofmann, W., Adriaanse, M., Vohs, K. D., & Baumeister, R. F. (2014). Dieting and the self-control of eating in everyday environments: An experience sampling study. *British Journal of Health Psychology*, *19*, 523–539. https://doi.org/10.1111/bjhp.12053
Hofmann, W., Gschwendner, T., Friese, M., Wiers, R. W., & Schmitt, M. (2008). Working memory capacity and self-regulatory behavior: toward an individual differences perspective on behavior determination by automatic versus controlled processes. *Journal of Personality and Social Psychology*, *95*(4), 962–977. https://doi.org/10.1037/a0012705
Hofmann, W., Rauch, W., & Gawronski, B. (2007). And deplete us not into temptation: Automatic attitudes , dietary restraint , and self-regulatory resources as determinants of eating behavior ☪. *Journal of Experimental Social Psychology*, *43*, 497–504. https://doi.org/10.1016/j.jesp.2006.05.004
Holtkamp, K., Herpertz-Dahlmann, B., Mika, C., Heer, M., Heussen, N., Fichter, M., … Hebebrand, J. (2003). Elevated Physical Activity and Low Leptin Levels Co-occur in Patients With Anorexia Nervosa. *The Journal of Clinical Endocrinology & Metabolism*, *88*(11), 5169–5174. https://doi.org/10.1210/jc.2003-030569
Houben, K. (2011). Overcoming the urge to splurge: Influencing eating behavior by manipulating inhibitory control. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*, 384–388. https://doi.org/10.1016/j.jbtep.2011.02.008
Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite*, *56*, 345–349. https://doi.org/10.1016/j.appet.2010.12.017

Hox, J. (2010). *Multilevel Analysis: Techniques and Applications*. New York: Routledge.

Hudson, J. I., Hiripi, E., Pope Jr., H. G., & Kessler, R. C. (2007). The Prevalence and Correlates of Eating Disorders in the National Comorbidity Survey Replication. *Biological Psychiatry*, *61*(3), 348–358. https://doi.org/10.1038/jid.2014.371

IBM Corporation. (2012). IBM SPSS AMOS for Windows. Armonk, NY: IBM Corp.

Jacobi, C., Paul, T., de Zwaan, M., Nutzinger, D. O., & Dahme, B. (2004). Specificity of Self-Concept Disturbances in Eating Disorders. *International Journal of Eating Disorders*, *35*, 204–210. https://doi.org/10.1002/eat.10240

Jallais, C., & Gilet, A. L. (2010). Inducing changes in arousal and valence: Comparison of two mood induction procedures. *Behavior Research Methods*, *42*(1), 318–325. https://doi.org/10.3758/BRM.42.1.318

Jasinska, A. J., Yasuda, M., Burant, C. F., Gregor, N., Khatri, S., Sweet, M., & Falk, E. B. (2012). Impulsivity and inhibitory control deficits are associated with unhealthy eating in young adults. *Appetite*, *59*(3), 738–747. https://doi.org/10.1016/j.appet.2012.08.001

Jones, N. P., Papadakis, A. A., Hogan, C. M., & Strauman, T. J. (2009). Over and over again: Rumination, reflection, and promotion goal failure and their interactive effects on depressive symptoms. *Behaviour Research and Therapy*, *47*, 254–259. https://doi.org/10.1016/j.brat.2008.12.007

Karlsson, J., Persson, L.-O. O., Sjöström, L., & Sullivan, M. (2000). Psychometric properties and factor structure of the Three-Factor Eating Questionnaire (TFEQ) in obese men and women. Results from the Swedish Obese Subjects (SOS) study. *International Journal of Obesity and Related Metabolic Disorders : Journal of the International Association for the Study of Obesity*, *24*(12), 1715–1725. https://doi.org/10.1038/sj.ijo.0801442

Karpowicz, E., Skärsäter, I., & Nevonen, L. (2009). Self-esteem in patients treated for anorexia nervosa. *International Journal of Mental Health Nursing*, *18*(5), 318–325. https://doi.org/10.1111/j.1447-0349.2009.00621.x

Kemps, E., & Tiggemann, M. (2005). Working memory performance and preoccupying thoughts in female dieters: Evidence for a selective central executive impairment. *British Journal of Clinical Psychology*, *44*, 357–366. https://doi.org/10.1348/014466505X35272

Keys, A., Brozek, J., Henschel, A., Mickelsen, O., & Taylor, H. L. (1950). *The biology of human starvation. (2 vols)*. Oxford: University of Minnesota Press.

King, G. A., Polivy, J., & Herman, C. P. (1991). Cognitive aspects of dietary restraint: Effects on person memory. *International Journal of Eating Disorders*, *10*(3), 313–321. https://doi.org/10.1002/1098-108X(199105)10:3<313::AID-EAT2260100307>3.0.CO;2-0

King, J. A., Donkin, C., Korb, F. M., & Egner, T. (2012). Model-based analysis of context-specific cognitive control. *Frontiers in Psychology*, *3*(SEP), 1–13. https://doi.org/10.3389/fpsyg.2012.00358

King, J. A., Geisler, D., Ritschel, F., Boehm, I., Seidel, M., Roschinski, B., … Ehrlich, S. (2015). Global cortical thinning in acute anorexia nervosa normalizes following long-term weight restoration. *Biological Psychiatry*, *77*, 624–632. https://doi.org/10.1016/j.biopsych.2014.09.005

King, J. A., Korb, F. M., & Egner, T. (2012). Priming of control: Implicit contextual cuing of top-down attentional set. *Journal of Neuroscience*, *32*(24), 8192–8200. https://doi.org/10.1523/JNEUROSCI.0934-12.2012

Kolyasnikov, P., Nikulchev, E., Belov, V., Silaeva, A., Kosenkov, A., Malykh, A., … Malykh, S. (2019). Analysis of software tools for longitudinal studies in psychology. *International Journal of Advanced Computer Science and Applications*, *10*(8), 21–33. https://doi.org/10.14569/ijacsa.2019.0100804

Kong, F., Zhang, Y., You, Z., Fan, C., Tian, Y., & Zhou, Z. (2013). Body Dissatisfaction and Restrained Eating: Mediating Effects of Self-Esteem. *Social Behavior and Personality*, *41*(7), 1165–1170. https://doi.org/10.2224/sbp.2013.41.7.1165

Koole, S. L., Smeets, K., van Knippenberg, A., & Dijksterhuis, A. (1999). The cessation of rumination through self-affirmation. *Journal of Personality and Social Psychology*, *77*(1), 111–

125. https://doi.org/10.1037/0022-3514.77.1.111

Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, *20*, 70–82. https://doi.org/10.1016/j.foodqual.2007.11.002

Kromeyer-Hauschild, K., Wabitsch, M., Kunze, D., Geller, F., Geiß, H. C., Hesse, V., … Hebebrand, J. (2001). Perzentile für den Body-mass- Index für das Kindes- und Jugend- alter unter Heranziehung verschiedener deutscher Stichproben. *Monatsschrift Kinderheilkunde*, *149*, 807–818. https://doi.org/10.1007/s001120170107

Lampert, T., Kroll, L. E., Müters, S., & Stolzenberg, H. (2013). Messung des sozioökonomischen Status in der Studie "gesundheit in Deutschland aktuell" (GEDA). *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz*, *56*(1), 131–143. https://doi.org/10.1007/s00103-012-1583-3

Lange, F., & Dewitte, S. (2019). Cognitive Flexibility and Pro-environmental Behaviour: A Multimethod Approach. *European Journal of Personality*, *33*, 488–505. https://doi.org/10.1002/per.2204

Lavender, J. M., De Young, K. P., Wonderlich, S. A., Crosby, R. D., Engel, S. G., Mitchell, J. E., … Le Grange, D. (2013). Daily Patterns of Anxiety in Anorexia Nervosa: Associations with Eating Disorder Behaviours in the Natural Environment. *Journal of Abnormal Psychology*, *122*(3), 672–683. https://doi.org/10.1177/1043454210368532.Analysis

Lavender, J. M., Wonderlich, S. A., Engel, S. G., Gordon, K. H., Kaye, W. H., & Mitchell, J. E. (2015). Dimensions of emotion dysregulation in anorexia nervosa and bulimia nervosa: A conceptual review of the empirical literature. *Clinical Psychology Review*, *40*, 111–122. https://doi.org/10.1016/j.cpr.2015.05.010

Lin, P. Y., Wood, W., & Monterosso, J. (2015). Healthy eating habits protect against temptations. *Appetite*, *103*, 432–440. https://doi.org/10.1016/j.appet.2015.11.011

Maloney, P. W., Grawitch, M. J., & Barber, L. K. (2012). The multi-factor structure of the Brief Self-Control Scale: Discriminant validity of restraint and impulsivity. *Journal of Research in Personality*, *46*(1), 111–115. https://doi.org/10.1016/j.jrp.2011.10.001

Marsh, R., Steinglass, J., Graziano, K., Peterson, B., & Walsh, B. T. (2007). Self-Regulatory Control and Habit Learning in the Development of Eating Disorders. *Current Psychiatry Reviews*, *3*, 73–83. https://doi.org/10.2174/157340007779815691

Martin, L. L., & Tesser, A. (1996). Some Ruminative Thoughts. In R. S. Wyer (Ed.), *Advances in Social Cognition, Volume IX: Ruminative Thoughts*. Mahwah, New Yersey: Lawrence Erlbaum Associates.

McEvoy, P. M., Watson, H., Watkins, E. R., & Nathan, P. (2013). The relationship between worry, rumination, and comorbidity: Evidence for repetitive negative thinking as a transdiagnostic construct. *Journal of Affective Disorders*, *151*, 313–320. https://doi.org/10.1016/j.jad.2013.06.014

McLaughlin, K. A., & Nolen-Hoeksema, S. (2011). Rumination as a transdiagnostic factor in depression and anxiety. *Behaviour Research and Therapy*, *49*, 186–193. https://doi.org/10.1016/j.brat.2010.12.006

Miller, R., Schmidt, K., Kirschbaum, C., & Enge, S. (2018). Comparability, Stability, and Reliability of Internet-Based Mental Chronometry in Domestic and Laboratory Settings. *Behavior Research Methods*, *50*(4), 1345–1358. https://doi.org/10.3758/s13428-018-1036-5

Milos, G., Antel, J., Kaufmann, L. K., Barth, N., Koller, A., Tan, S., … Hebebrand, J. (2020). Short-term metreleptin treatment of patients with anorexia nervosa: rapid on-set of beneficial cognitive, emotional, and behavioral effects. *Translational Psychiatry*, *10*(303). https://doi.org/10.1038/s41398-020-00977-1

Moberly, N. J., & Watkins, E. R. (2008). Ruminative Self-Focus and Negative Affect: An Experience Sampling Study. *Journal of Abnormal Psychology*, *117*(2), 314–323. https://doi.org/10.1037/0021-843X.117.2.314

Moberly, N. J., & Watkins, E. R. (2010). Negative affect and ruminative self-focus during everyday goal pursuit. *Cognition and Emotion*, *24*(4), 729–739. https://doi.org/10.1080/02699930802696849

Naumann, E., Tuschen-Caffier, B., Voderholzer, U., Caffier, D., & Svaldi, J. (2015). Rumination but Not Distraction Increases Eating-Related Symptoms in Anorexia and Bulimia Nervosa. *Journal of Abnormal Psychology*, *124*(2), 412–420. https://doi.org/10.1037/abn0000046

Naumann, E., Tuschen-Caffier, B., Voderholzer, U., Schäfer, J., & Svaldi, J. (2016). Effects of emotional acceptance and rumination on media-induced body dissatisfaction in anorexia and bulimia nervosa. *Journal of Psychiatric Research*, *82*, 119–125. https://doi.org/10.1016/j.jpsychires.2016.07.021

Naumann, E., Tuschen-Caffier, B., Voderholzer, U., & Svaldi, J. (2014). On the role of sadness in the psychopathology of anorexia nervosa. *Psychiatry Research*, *215*, 711–717. https://doi.org/10.1016/j.psychres.2013.12.043

Nęcka, E., Gruszka, A., Orzechowski, J., Nowak, M., & Wójcik, N. (2018). The (In)significance of Executive Functions for the Trait of Self-Control: A Psychometric Study. *Frontiers in Psychology*, *9*(1139), 1–12. https://doi.org/10.3389/fpsyg.2018.01139

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control Yourself or Just Eat What You Like? Weight Gain Over a Year is Predicted by an Interactive Effect of Response Inhibition and Implicit Preference for Snack Foods. *Health Psychology*, *29*(4), 389–393.

Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *58*(4), 361–383. https://doi.org/10.1111/jcpp.12675

Nolen-Hoeksema, S. (1991). Responses to Depression and Their Effects on the Duration of Depressive Episodes. *Journal of Abnormal Psychology*, *100*(4), 569–582. https://doi.org/10.1037/0021-843X.100.4.569

Nolen-Hoeksema, S. (2004). The Response Styles Theory. In C. Papageorgiou & A. Wells (Eds.), *Depressive Rumination. Nature, Theory and Treatment2*. Chichester, UK: John Wiley and Sons Ltd.

Nolen-Hoeksema, S., Stice, E., Wade, E., & Bohon, C. (2007). Reciprocal Relations Between Rumination and Bulimic, Substance Abuse, and Depressive Symptoms in Female Adolescents. *Journal of Abnormal Psychology Psychology*, *116*(1), 198–207. https://doi.org/10.1037/0021-843X.116.1.198

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking Rumination. *Perspectives on Psychological Science*, *3*(5), 400–424. https://doi.org/0.1111/j.1745-6924.2008.00088.x

Olatunji, B. O., Levinson, C., & Calebs, B. (2018). A network analysis of eating disorder symptoms and characteristics in an inpatient sample. *Psychiatry Research*, *262*, 270–281. https://doi.org/10.1016/j.psychres.2018.02.027

Oldershaw, A., Lavender, T., Sallis, H., Stahl, D., & Schmidt, U. (2015). Emotion generation and regulation in anorexia nervosa: A systematic review and meta-analysis of self-report data. *Clinical Psychology Review*, *39*, 83–95. https://doi.org/10.1016/j.cpr.2015.04.005

Oppenheimer, D. M., Meyvis, T., & Davidenko, N. (2009). Instructional manipulation checks: Detecting satisficing to increase statistical power. *Journal of Experimental Social Psychology*, *45*, 867–872. https://doi.org/10.1016/j.jesp.2009.03.009

Paolacci, G., Chandler, J., & Ipeirotis, P. G. (2010). Running experiments on Amazon Mechanical Turk. *Judgment and Decision Making*, *5*(5), 411–419. https://doi.org/10.2139/ssrn.1626226

Park, R. J., Dunn, B. D., & Barnard, P. J. (2011). Schematic Models and Modes of Mind in Anorexia Nervosa I: A Novel Process Account. *International Journal of Cognitive Therapy*, *4*(4), 415–437. https://doi.org/10.1521/ijct.2011.4.4.415

Petermann, F., & Petermann, U. (2008). HAWIK-IV. *Kindheit Und Entwicklung*, *17*, 71–75.

Pinto, A. M., Heinberg, L. J., Coughlin, J. W., Fava, J. L., & Guarda, A. S. (2008). The Eating Disorder Recovery Self-Efficacy Questionnaire (EDRSQ): Change with treatment and prediction of outcome. *Eating Behaviors*, *9*, 143–153. https://doi.org/10.1016/j.eatbeh.2007.07.001

Polivy, J. (1996). Psychological consequences of food restriction. *Journal of the American Dietetic Association*, *96*(6), 589–592. https://doi.org/10.1016/S0002-8223(96)00161-7

Powell, D. J. H., McMinn, D., & Allan, J. L. (2017). Does real time variability in inhibitory control drive snacking behavior? An intensive longitudinal study. *Health Psychology*, *36*(4), 356–364. https://doi.org/10.1037/hea0000471

Price, M., Lee, M., & Higgs, S. (2016). Food-specific response inhibition, dietary restraint and snack intake in lean and overweight/obese adults: A moderated-mediation model. *International Journal of Obesity*, *40*, 877–882. https://doi.org/10.1038/ijo.2015.235

Quinn, J. M., Pascoe, A., Wood, W., & Neal, D. T. (2010). Can't control yourself? Monitor those bad habits. *Personality and Social Psychology Bulletin*, *36*(4), 499–511. https://doi.org/10.1177/0146167209360665

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park, CA: Sage.

Raudenbush, S. W., Bryk, A. S., & Congdon, R. T. (2017). HLM 7 for Windows. Lincolnwood: Scientific Software International Inc.

Rawal, A., Park, R. J., & Williams, J. M. G. (2010). Rumination, experiential avoidance, and dysfunctional thinking in eating disorders. *Behaviour Research and Therapy*, *48*, 851–859. https://doi.org/10.1016/j.brat.2010.05.009

Reilly, E. E., Lavender, J. M., Berner, L. A., Brown, T. A., Wierenga, C. E., & Kaye, W. H. (2019). Could repetitive negative thinking interfere with corrective learning? The example of anorexia nervosa. *International Journal of Eating Disorders*, *52*(1), 36–41. https://doi.org/10.1002/eat.22997

Rivière, J., & Douilliez, C. (2017). Perfectionism, rumination, and gender are related to symptoms of eating disorders: A moderated mediation model. *Personality and Individual Differences*, *116*, 63–68. https://doi.org/10.1016/j.paid.2017.04.041

Roberts, H., Watkins, E. R., & Wills, A. J. (2013). Cueing an unresolved personal goal causes persistent ruminative self-focus: An experimental evaluation of control theories of rumination. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(4), 449–455. https://doi.org/10.1016/j.jbtep.2013.05.004

Rolls, B. J., Fedoroff, I. C., & Guthrie, J. F. (1991). Gender Differences in Eating Behavior and Body Weight Regulation. *Health Psychology*, *10*(2), 133–142. https://doi.org/https://doi.org/10.1037/0278-6133.10.2.133

Russell, J. A. (2003). Core Affect and the Psychological Construction of Emotion. *Psychological Review*, *110*(1), 145–172. https://doi.org/10.1037/0033-295X.110.1.145

Schmidt, J. R., & Lemercier, C. (2019). Context-Specific Proportion Congruent Effects: Compound-Cue Contingency Learning in Disguise. *Quarterly Journal of Experimental Psychology*, *72*(5), 119–1130. https://doi.org/https://doi.org/10.1177/1747021818787155

Schmidt, U., & Treasure, J. (2006). Anorexia nervosa: Valued and visible. A cognitive-interpersonal maintenance model and its implications for research and practice. *British Journal of Clinical Psychology*, *45*, 343–366. https://doi.org/10.1348/014466505X53902

Segerstrom, S. C., Tsao, J. C. I., Alden, L. E., & Craske, M. G. (2000). Worry and rumination: Repetitive thought as a concomitant and predictor of negative mood. *Cognitive Therapy and Research*, *24*(6), 671–688. https://doi.org/10.1023/A:1005587311498

Seidel, M., King, J. A., Ritschel, F., Boehm, I., Geisler, D., Bernardoni, F., … Ehrlich, S. (2018). The real-life costs of emotion regulation in anorexia nervosa: a combined ecological momentary assessment and fMRI study. *Translational Psychiatry*, *8*(28), 1–11. https://doi.org/10.1038/s41398-017-0004-7

Seidel, M., Petermann, J., Ritschel, F., Boehm, I., King, J. A., Geisler, D., … Ehrlich, S. (2016). A naturalistic examination of negative affect and disorder-related rumination in anorexia nervosa. *European Child & Adolescent Psychiatry*, *25*(11), 1207–1216. https://doi.org/10.1007/s00787-016-0844-3

Serpell, L., Treasure, J., Teasdale, J., & Sullivan, V. (1999). Anorexia Nervosa: Friend or Foe? *International Journal of Eating Disorders*, *25*, 177–186. https://doi.org/10.1002/(SICI)1098-108X(199903)25:2

Shafran, R., Fairburn, C. G., Robinson, P., & Lask, B. (2004). Body Checking and its Avoidance in

Eating Disorders. *International Journal of Eating Disorders*, *35*(1), 93–101. https://doi.org/10.1002/eat.10228

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological Momentary Assessment. *Annual Review of Clinical Psychology*, *4*, 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415

Shiffrin, R. M., & Schneider, W. (1977). Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending, and a General Theory. *Psychological Review*, *84*(2), 127–190. https://doi.org/10.1037/0033-295X.84.2.127

Smith, J. M., & Alloy, L. B. (2009). A roadmap to rumination: A review of the definition, assessment, and conceptualization of this multifaceted construct. *Clinical Psychology Review*, *29*, 116–128. https://doi.org/10.1016/j.cpr.2008.10.003

Smith, K. E., Mason, T. B., & Lavender, J. M. (2018). Rumination and eating disorder psychopathology: A meta-analysis. *Clinical Psychology Review*, *61*, 9–23. https://doi.org/10.1016/j.cpr.2018.03.004

Smith, K. E., Mason, T. B., Schaefer, L. M., Juarascio, A., Dvorak, R., Weinbach, N., … Wonderlich, S. A. (2020). Examining intra-individual variability in food-related inhibitory control and negative affect as predictors of binge eating using ecological momentary assessment. *Journal of Psychiatric Research*, *120*, 137–143. https://doi.org/10.1016/j.jpsychires.2019.10.017

Startup, H., Lavender, A., Oldershaw, A., Stott, R., Tchanturia, K., Treasure, J., & Schmidt, U. (2013). Worry and Rumination in Anorexia Nervosa. *Behavioural and Cognitive Psychotherapy*, *41*, 301–316. https://doi.org/10.1017/S1352465812000847

Stein, K., & Corte, C. M. (2003). Ecological Momentary Assessment of Eating-Disordered Behaviors. *International Journal of Eating Disorders*, *34*, 349–360. https://doi.org/10.1002/eat.10194

Steyer, R., Schwenkmezger, P., Notz, P., & Eid, M. (1997). *Der mehrdimensionale Befindlichkeitsfragebogen (MDBF). Handanweisung [The multidimensional affect rating scale (MDBF). Manual]*. Göttingen: Hogrefe.

Sullivan, N., Hutcherson, C., Harris, A., & Rangel, A. (2016). Dietary self-control is related to the speed with which health and taste attributes are processed. *Psychological Science*, *26*(2), 122–134. https://doi.org/10.1177/0956797614559543.Dietary

Surgenor, L. J., Horn, J., Plumridge, E. W., & Hudson, S. M. (2002). Anorexia nervosa and psychological control: A reexamination of selected theoretical accounts. *European Eating Disorders Review*, *10*(2), 85–101. https://doi.org/10.1002/erv.457

Surgenor, L. J., Maguire, S., Russell, J., & Touyz, S. (2007). Self-liking and self-competence: Relationship to symptoms of anorexia nervosa. *European Eating Disorders Review*, *15*(2), 139–145. https://doi.org/10.1002/erv.734

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High Self-Control Predicts Good Adjustment, Less Pathology, Better Grades, and Interpersonal Success. *Journal of Personality*, *72*(2), 271–324. https://doi.org/https://doi.org/10.1111/j.0022-3506.2004.00263.x

The GBD 2015 Obesity Collaborators (Institution). (2017). Health effects of overweight and obesity in 195 countries over 25 years. *New England Journal of Medicine*, *377*(1), 13–27. https://doi.org/10.1056/NEJMoa1614362

Thiel, A., Jacobi, C., Horstmann, S., Paul, T., Nutzinger, D. O., & Schüßler, G. (1997). Eine deutschsprachige Version des Eating Disorder Inventory EDI-2. *Psychotherapie, Psychosomatik, Medizinische Psychologie*, *47*, 365–376.

Tian, A. D., Schroeder, J., Häubl, G., Risen, J. L., Norton, M. I., & Gino, F. (2018). Enacting Rituals to Improve Self-Control. *Journal of Personality and Social Psychology*, *114*(6), 851–876. https://doi.org/10.1037/pspa0000113

Tiggemann, M., & Raven, M. (1998). Dimensions of control in bulimia and anorexia nervosa: Internal control, desire for control, or fear of losing self-control? *Eating Disorders*, *6*(1), 65–71. https://doi.org/10.1080/10640269808249248

Treasure, J., & Schmidt, U. (2013). The cognitive-interpersonal maintenance model of anorexia nervosa revisited: a summary of the evidence for cognitive, socio-emotional and interpersonal

predisposing and perpetuating factors. *Journal of Eating Disorders*, *1*(13), 1–10. https://doi.org/https://doi.org/10.1186/2050-2974-1-13

Treasure, J., Zipfel, S., Micali, N., Wade, T., Stice, E., Claudino, A., … Wentz, E. (2015). Anorexia nervosa. *Nature Reviews*, *1*, 1–21. https://doi.org/10.1038/nrdp.2015.74

Treynor, W., Gonzalez, R., & Nolen-Hoeksema, S. (2003). Rumination Reconsidered: A Psychometric Analysis. *Cognitive Therapy and Research*, *27*(3), 247–259. https://doi.org/10.1023/A:1023910315561

Troop, N. A., Holbrey, A., & Treasure, J. L. (1998). Stress, Coping, and Crisis Support in Eating Disorders. *International Journal of Eating Disorders*, *24*, 157–166. https://doi.org/10.1002/(SICI)1098-108X(199809)24:2<157::AID-EAT5>3.0.CO;2-D

van't Riet, J., Sijtsema, S. J., Dagevos, H., & de Bruijn, G. J. (2011). The importance of habits in eating behaviour. An overview and recommendations for future research. *Appetite*, *57*, 585–596. https://doi.org/10.1016/j.appet.2011.07.010

Vandierendonck, A. (2017). A comparison of methods to combine speed and accuracy measures of performance: A rejoinder on the binning procedure. *Behavior Research Methods*, *49*, 653–673. https://doi.org/10.3758/s13428-016-0721-5

Verbruggen, F., & Logan, G. D. (2009). Automaticity of cognitive control: Goal priming in response-inhibition paradigms. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *35*(5), 1381–1388. https://doi.org/10.1017/CBO9781107415324.004

Wade, T. D., Wilksch, S. M., Paxton, S. J., Byrne, S. M., & Austin, S. B. (2015). How perfectionism and ineffectiveness influence growth of eating disorder risk in young adolescent girls. *Behaviour Research and Therapy*, *66*, 56–63. https://doi.org/10.1016/j.brat.2015.01.007

Wansink, B. (2004). Environmenal Factors that Increase the Food Intake and Consumption Volume of Unknowing Consumers. *Annual Review of Nutrition*, *24*, 455–479. https://doi.org/10.1146/annurev.nutr.24.012003.132140

Watkins, E. R. (2008). Constructive and Unconstructive Repetitive Thought. *Psychological Bulletin*, *134*(2), 163–206. https://doi.org/10.1037/0033-2909.134.2.163

Watkins, E., & Teasdale, J. D. (2001). Rumination and overgeneral memory in depression: Effects of self-focus and analytic thinking. *Journal of Abnormal Psychology*, *110*(2), 353–357. https://doi.org/10.1037/0021-843X.110.2.333

Weinberg, R. S., Hughes, H. H., Critelli, J. W., England, R., & Jackson, A. (1984). Effects of preexisting and manipulated self-efficacy on weight loss in a self-control program. *Journal of Research in Personality*, *18*, 352–358. https://doi.org/10.1016/0092-6566(84)90019-9

West, S. G., Taylor, A. B., & Wu, W. (2012). Model Fit and Model Selection in Structural Equation Modeling. In R. H. Hoyle (Ed.), *Handbook of Structural Equation Modeling* (pp. 209–231). New York: The Guilford Press.

Westermann, R., Spies, K., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology*, *26*, 557–580. https://doi.org/10.1002/(SICI)1099-0992(199607)26:4<557::AID-EJSP769>3.0.CO;2-4

Whitelock, V., Nouwen, A., van den Akker, O., & Higgs, S. (2018). The role of working memory sub-components in food choice and dieting success. *Appetite*, *124*, 24–32. https://doi.org/10.1016/j.appet.2017.05.043

Wood, W., & Rünger, D. (2016). Psychology of Habit. *Annual Review of Psychology*, *67*, 289–314. https://doi.org/10.1146/annurev-psych-122414-033417

Wundt, W. (1896). *Grundriss der Psychologie.* Leipzig: Engelmann.

7 Appendix

7.1 Appendix 1 (Supplementary Material Study 1)

7.1.1 Methods

7.1.1.1 Participants

HC participants were recruited via recruitment letters, flyers on bulletin boards, and online advertisements. Participants of the AN sample were former patients with AN who had received treatment at the university hospital's child and adolescent psychiatric or psychosomatic department or at similar treatment facilities within Germany. All participants with a history of AN had to provide physician letters documenting their treatment history. To be included in the AN group of the study participants had to have been previously diagnosed with acute AN according to the DSM-5. Of the 32 participants with a history of AN $n = 24$ fulfilled the criteria of the restrictive subtype of AN, $n = 8$ of the binge-purge subtype at the time of acute illness. The mean age of onset was 15 years. Participants had to show maintenance of a BMI higher than 18.5 for the last six months (18 years and older) or of a BMI higher than the tenth age percentile (younger than 18 years), menses had to be constant. Exclusion criteria were binging, purging or restrictive eating patterns. Participants of the AN as well as the HC group were excluded if they had a lifetime history of any of the following clinical diagnoses: organic brain syndrome, schizophrenia, substance dependence, psychosis NOS, bipolar disorder, bulimia nervosa, or binge-eating disorder (or "regular" binge eating - defined as bingeing at least once weekly for 3 or more consecutive months). In the AN sample, four participants reported having suffered from comorbid psychiatric disorders at the time of treatment (depressive disorder $n = 4$, anxiety disorder $n = 2$; and four of those had taken antidepressant medication). Further exclusion criteria were adipositas (BMI over 28 for 18 years and older or over the 94^{th} age percentile for participants younger than 18); IQ lower than 85; current substance abuse; current inflammatory, neurologic, or metabolic illness; chronic medical or neurological illness that could affect appetite, eating behaviour, or bodyweight (e.g., diabetes); clinical relevant anaemia; pregnancy; breast feeding. Psychotropic medication within four weeks prior to the study was also an exclusion criterion. However, participants with a history of AN could be included in the study while taking antidepressants (only SSRI, $n = 4$) after the prescribing psychiatrist confirmed that the depressive disorder was in remission. The relevant information (including possible confounding variables such as menstrual cycle and use of contraceptive medication) was obtained from all participants using the structured interview for anorexic and bulimic disorders (SIAB-EX Fichter & Quadflieg, 2001)

conducted by clinically experienced and trained research assistants under the supervision of the attending child and adolescent psychiatrist. The 87-item interview systematically assesses the prevalence and severity of specific eating-related as well as -unrelated psychopathology and provides diagnoses according to ICD-10 and DSM-IV. This information was supplemented by our in-house semi-structured interview. This interview has been used continuously in our ongoing studies on AN (Ehrlich et al., 2015; Fürtjes et al., 2018; J. A. King et al., 2015; Seidel et al., 2018).The goal of this procedure is a comprehensive description of our participant groups. Using the semi-structured interview, trained interviewers assess demographic and clinical data in the following domains: Socio-economic status, family history, detailed information on bodyweight, including highest and lowest lifetime-BMI and weight changes over the past six weeks, detailed information on menstrual cycle and contraceptives intake, current and past medical problems, current and past psychiatric or psychological treatments, current and past medication intake and nicotine abuse.

7.1.1.2 Ecological Momentary Assessment

Participants were provided with a study smartphone (Samsung Galaxy Ace, 5831i) running the application which coordinated alarms, questionnaires, and answers. The study-procedure for the application was designed via an online platform (XS.Movisens, Karlsruhe, Germany), which also managed data collection and immediate server upload for constant monitoring of compliance. Participants received a detailed tutorial on how to handle the smartphone, the application, and the content of the questionnaire. In addition to verbal and a written instruction (which was handed out) participants completed two test-runs of the procedure (receiving an alarm – opening the questionnaire – filling out the questionnaire). They were instructed to answer the questionnaire as soon as the alarm appeared but were given a maximum of additional 30 minutes after the prompt when unable to reply (e.g., during class or work) or safety was a concern (e.g., while driving). Recordings during the first days of sampling were closely monitored in terms of compliance to ensure that instructions were understood. If compliance appeared to be low (<70%), participants were contacted to address possible questions or problems. Compensation was provided at the end of the study, in accordance with compliance rates. Participants received a fixed amount and additional bonus payment according to the rate of filled out questionnaires. Data collection occurred via the signal-contingent assessment method: alarms occurred at six semi-random times during a 14-hour period that was adapted for each individual to suit different daily routines. Prompts were anchored within six smaller intervals of two 2 ½ hour intervals (before midday) and four 1 ½ hour intervals (after midday). Between the intervals were 30-minutes breaks, and the maximum delay between alarm and response was also 30min. E.g., in the 14-hour period of 09:00 to 23:00, one alarm was sent randomly in each of the six time-intervals 09:0-11:30, 12:00-14:30, 15:15-16:45, 17:15-18:45, 19:15-20:45, 21:15-22:45.

Several contextual variables were assessed additionally to the variables of interest with each alarm. Participants were asked whether they had been mainly alone vs. in company, and at home vs. in public since the last alarm. They also indicated their main occupation during the time since the last alarm, choosing from six categories (leisure, eating, waiting, therapy, sleep, other).

7.1.1.3 Statistics

As described in the main manuscript, we employed a combination of hierarchical linear modelling (HLM) and conditional process modelling (CPM) to analyse the data according to our hypotheses. To provide sufficient clarity as to which analyses address which hypothesis, an overview can be found below in *Table A2*.

The general hierarchical linear model used as the basis for all HLM analyses included dummy-coded control variables for the situational factors described above and composed as follows:

$$y_{tij} = \gamma_{000} + \gamma_{010}*\text{DAYOFSTUDY}_{ij} + \gamma_{100}*TIMEOFDAY_{tij} + \gamma_{200}*COMPANY_{tij} + \gamma_{300}*\text{ACTIVITY01}_{tij} + \gamma_{400}*ACTIVITY02_{tij} + \gamma_{500}*ACTIVITY03_{tij} + \gamma_{600}*ACTIVITY04_{tij} + \gamma_{700}*ACTIVITY05_{tij} + \gamma_{800}*ACTIVITY06_{tij} + \gamma_{700}*ACTIVITY07_{tij} + \gamma_{800}*ACTIVITY08_{tij} + r_{0ij} + u_{00j} + e_{tij}$$

The variance components for these "empty" models are presented below in *Table A1*. All HLM analyses were conducted with the software HLM7.03 (Raudenbush et al., 2017). In addition to the results presented in the main manuscript, the complete multilevel estimates of the full HLM models can be found in section 2 (*Table A3 + Table A4*). Furthermore, in *Figure A1* below we show a distribution of the frequency with which each category of main activity was reported, split for participants under 18 vs. 18 and older since one might assume that the frequency of activities might differ due to circumstances related to age (school vs. work etc.). As can be seen, there are only slight differences between the groups. Both groups (age under 18 vs. 18 and older) also showed no difference in the reported amount of time spent in company vs. alone (time mainly spent in company was reported in $M = 60\%$ of all situations in both groups).

The CPM analyses predicting affect through inefficiency included rumination about weight as a mediator variable and group as a moderator variable on the effect of rumination about weight on affect as well as the indirect effect of inefficiency on affect mediated via rumination about weight. The general statistical model used as a basis for the analyses was as follows:

$$y_j = i_j + c_j'*INEFFICIENCY + (b_{1j} + b_{3j}*GROUP)*RUMINATIONWEIGHT + b_{2j}*GROUP + e_{yj}$$

All CPM analyses were conducted using the PROCESS macro for SPSS version 3.1 (Hayes, 2013). In addition to the results presented in the main manuscript, the full estimates of the calculated models can be found below in *Table A5*.

Table A1. Variance components of the empty HLM models (models 1a-c)

	Level 1 and 2			Level 3		
Outcome	***SD***	***Variance***	***p***	***SD***	***Variance***	***p***
Rumination about Food	4.52	20.44	< .001	14.15	200.28	< .001
Rumination about Weight	8.03	64.52	< .001	17.10	292.41	< .001
Valence of affect	16.92	286.15	< .001	25.97	674.31	< .001
Energetic Arousal	16.61	275.76	< .001	23.61	557.26	< .001
Calmness	16.52	272.75	< .001	25.51	650.55	< .001

Notes. SD = standard deviation.

Table A2. Statistical approach: overview

Calculated Model	**Outcome**	**Variables**			**Targeted Hypotheses**
		Predictors	**Mediators**	**Moderators**	
HLM 1a HLM 1b	Rumination about Food Rumination about Weight	*Level1:* Valence of Affect Energetic Arousal Calmness *Level 3:* Group Inefficiency		*cross-level:* Group Inefficiency	Hypothesis 1 + 2
HLM 2a HLM 2b HLM 2c	Valence of Affect Energetic Arousal Calmness	*Level 1:* Rumination about Food Rumination about Weight *Level 3:* Group Inefficiency		*cross-level:* Group Inefficiency	Hypothesis 1 + 2
CPM 1 CPM 2 CPM 3	Valence of Affect Energetic Arousal Calmness	Inefficiency	Rumination about Weight	Group	Hypothesis 2 + 3

Notes. HLM = Hierarchichal Linear Model. CPM = Conditional Process Model. See *Tables B3-5* for further details on included variables.

7.1.2 Additional Tables and Figures

Table A3. Multilevel estimates for HLM models 1a-b

	Model 1a: Rumination about Food			Model 1b: Rumination about Weight		
Effect	**β**	***SE***	***p***	**β**	***SE***	***p***
Intercept	42.09	22.45	.07	48.29	18.24	.01
Level 1 - Affect:						
Valence of Affect	.01	.03	n.s.	-.03	.03	n.s.
Energetic Arousal	.03	.02	n.s.	.04	.02	.02
Calmness	-.05	.02	.05	-.01	.02	n.s.
Level 1- Control Variables:						
Time of Day	-.11	.22	n.s.	.09	.18	n.s.
Company/Alone	.42	.79	n.s.	.51	.67	n.s.
Activity: school	-4.23	22.25	n.s.	-28.55	18.00	n.s.
Activity: leisure	-2.56	22.25	n.s.	-25.93	18.00	n.s.
Activity: exercise	-6.30	22.30	n.s.	-18.22	18.03	n.s.
Activity: eating	18.95	22.26	n.s.	-22.15	18.01	n.s.
Activity: traffic	-1.56	22.26	n.s.	-24.83	18.01	n.s.
Activity: waiting	-2.83	22.38	n.s.	-25.07	18.11	n.s.
Activity: therapy	-10.91	24.06	n.s.	-25.29	19.45	n.s.
Activity: sleeping	-14.57	22.28	n.s.	-32.15	18.02	.08
Activity: other	-3.89	22.26	n.s.	-25.37	18.00	n.s.
Level 2 – Control Variables:						
Day of Study	-.27	.10	.004	.04	.10	n.s.
Level 3:						
Group	-6.31	3.76	.10	7.26	3.89	.07
Inefficiency	.56	.19	.01	.83	.20	< .001
Cross-Level Interaction:						
Group x Valence of Affect	-.13	.04	.001	-.10	.04	.02
Group x Energetic Arousal	.01	.03	n.s.	.01	.03	n.s.
Group x Calmness	.03	.04	n.s.	-.01	.03	n.s.
Inefficiency x Valence of Affect	.00	.00	n.s.	.00	.00	n.s.
Inefficiency x Energetic Arousal	.00	.00	n.s.	.00	.00	n.s.
Inefficiency x Calmness	.00	.00	n.s.	.00	.00	n.s.

Notes. Non-standardized beta-values of the hierarchical linear models. *SE* = standard error. n.s. = not significant. Group was coded 0 = healthy control participant; 1 = recovered individual with a history of Anorexia nervosa.

Table A4. Multilevel estimates for HLM models 2c-e

	Model 2a: Valence			**Model 2b: Arousal**			**Model 2c: Calmness**		
Effect	**β**	***SE***	***p***	**β**	***SE***	***p***	**β**	***SE***	***p***
Intercept	150.51	28.96	< .001	158.25	36.54	< .001	109.54	30.68	< .001
Level 1 – Rumination:									
Thoughts about Food	-.03	.03	n.s.	-.05	.05	n.s.	-.11	.04	< .01
Thoughts about Weight	-.03	.07	n.s.	.17	.05	< .001	-.02	.06	n.s.
Level 1 – Control Variables:									
Time of Day	-.36	.27	n.s.	-1.21	.35	< .001	.75	.30	.01
Company/Alone	-5.97	1.04	< .001	-3.31	1.32	.01	-3.19	1.14	.01
Activity: school	-8.97	28.65	n.s.	-31.61	36.21	n.s.	13.11	30.34	n.s.
Activity: leisure	2.41	28.64	n.s.	-26.65	36.20	n.s.	25.57	30.33	n.s.
Activity: exercise	4.91	28.69	n.s.	-.59	36.26	n.s.	16.74	30.39	n.s.
Activity: eating	2.08	28.66	n.s.	-28.60	36.22	n.s.	27.97	30.35	n.s.
Activity: traffic	-3.49	28.66	n.s.	-27.96	36.22	n.s.	19.60	30.35	n.s.
Activity: waiting	-8.55	28.81	n.s.	-34.93	36.41	n.s.	1.12	30.52	n.s.
Activity: therapy	-25.52	30.88	n.s.	-39.76	39.15	n.s.	5.49	32.88	n.s.
Activity: sleeping	-6.67	28.65	n.s.	-78.95	36.23	.03	29.48	30.35	n.s.
Activity: other	-5.15	28.65	n.s.	-34.96	36.20	n.s.	20.52	30.33	n.s.
Level 2 – Control Variables:									
Day of Study	.25	.18	n.s.	-.05	.19	n.s.	.45	.19	.02
Level 3:									
Group	-.65	5.45	n.s.	3.54	6.23	n.s.	8.54	5.95	n.s.
Inefficiency	-1.80	.28	< .001	-1.04	.32	< .01	-1.66	.31	< .001
Cross-Level Interaction:									
Group x Rumination about Food	-.06	.05	n.s.	.03	.09	n.s.	.05	.06	n.s.
Group x Rumination about Weight	-.22	.11	.04	-.17	.08	.03	-.12	.09	n.s.
Inefficiency x Rumination about Food	.00	.00	n.s.	-.01	.00	.01	-.01	.00	.03
Inefficiency x Rumination about Weight	.00	.01	n.s.	.01	.00	n.s.	.00	.00	n.s.

Notes. Non-standardized beta-values of the hierarchical linear models. *SE* = standard error. n.s. = not significant. Group was coded 0 = healthy control participant; 1 = recovered individual with a history of Anorexia nervosa.

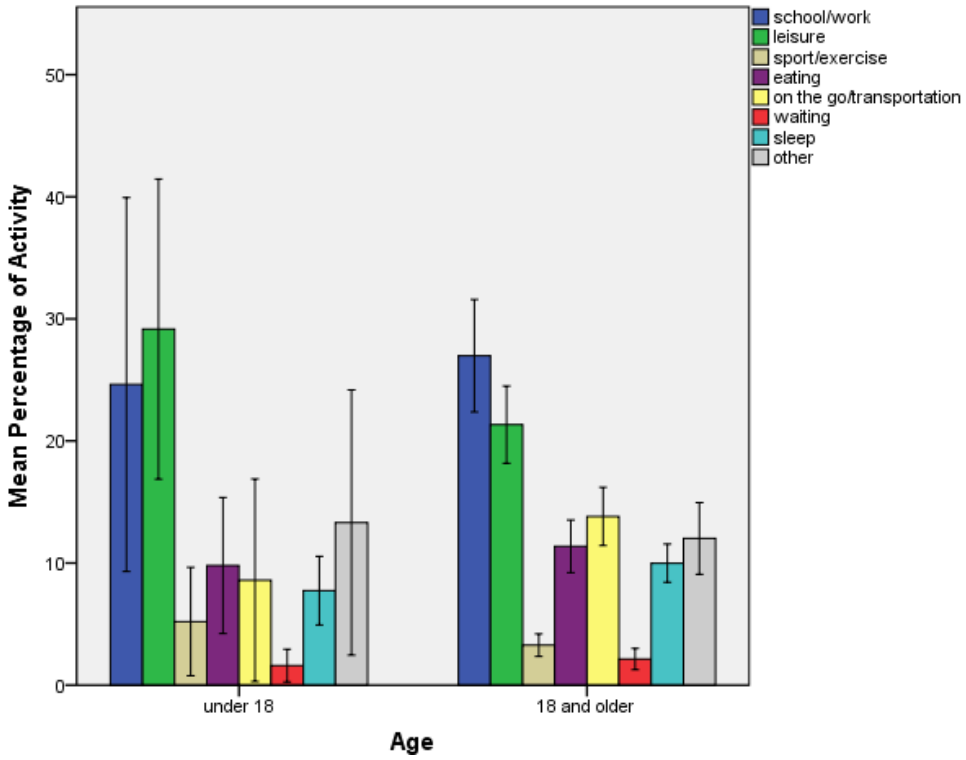


Figure A1. Distribution of the percentage of each category of main activity reported by the participants if separated by age – underage vs. 18 and older.

Table A5. Estimates of the CPM models: direct and indirect associations between inefficiency and affect

	Model a: Valence				**Model b: Arousal**				**Model 2: Calmness**			
Preditors	**β**	***SE***	***p***	**CI**	**β**	***SE***	***p***	**CI**	**β**	***SE***	***p***	**CI**
direct effects:												
Inefficiency	-.81	.31	.00	[-1.43; -.20]	-.52	.35	n.s.	[-1.22; .18]	-.93	.31	.00	[-1.54; -.32]
Rumination about Weight	-.35	.28	n.s.	[-.92; .22]	-.03	.32	n.s.	[-.68; .62]	-.64	.28	.03	[-1.21; -.07]
moderated direct effects:												
Group x Rumination about Weight	-.57	.34	.10	[-1.25; .12]	-.64	.39	n.s.	[-1.43; .14]	-.26	.34	n.s.	[-.95; .42]
direct effect for HC	-.35	.28	n.s.	[-.92; .22]	-.03	.32	n.s.	[-.68 .62]	-.64	.28	.03	[-1.21; -.07]
direct effect for AN	-.92	.20	.00	[-1.32; -.51]	-.67	.23	.01	[-1.14; -.21]	-.91	.20	.00	[-1.31; -.50]
moderated indirect effect of inefficiency via rumination about weight												
indirect effect for HC	-.28	.28		[-.09; .22]	-.02	.34		[-.72; .68]	-.52	.30		
indirect effect for AN	-.74	.30		[-1.37; -.29]	-.55	.27		[-1.13; -.95]	-.74	.26		

Notes. Standardized β-values of the conditional process models. $N = 64$. HC = healthy control participant; AN = recovered individual with a history of Anorexia nerovsa. *SE* = standard error; CI = confidence interval; n.s. = not significant. Rumination and affect are given as measured by the EMA questionnaire and aggregated on the person level. Inefficiency is given as measured by the EDI-2. Group was coded 0 = HC; 1 = AN. Predictors were always entered simultaneously.

7.1.3 Additional Analyses and Results

7.1.3.1 HLM Models without Inefficiency

To ensure that the results of the HLM analyses could not be explained in an easier way by group instead of inefficiency, we calculated all models again without inefficiency as a predictor and conducted deviance tests to compare these models to the full models presented in the main manuscript. The results of these analyses can be found below in *Table A6* and *Table A7*. As can be seen, for all models the deviance tests showed a significantly better fit of the model including inefficiency as a predictor.

7.1.3.2 Further Variables of Interest

To ensure that the findings presented in the main manuscript were not influenced by further variables, we calculated further HLM analyses with age, BMI-SDS, time since recovery of weight and eating behavior, AN-subtype at the time of acute illness, and current antidepressant medication as person-level predictors of rumination and affect. None of the variables had a significant direct influence on rumination or affect with the exception of age, which was significantly associated with less calmness ($\beta = -1.60$; $p < .05$). While this is an interesting aspect, our main findings remained unaltered and therefore its relevance was not considered high enough to justify increasing the complexity of the original HLM analyses by including more control variables on the person level.

Table A6. Results of the additional HLM models: associations between rumination and affect without inefficiency as a predictor

	Models 1a+b: Rumination		**Model 2a-c: Affect**		
Predictor	**Food**	**Weight/Figure**	**Valence**	**Energetic Arousal**	**Calmness**
Level 1:					
Valence of affect	.01	-.03			
Energetic Arousal	.04	.04*			
Calmness	-.04	.00			
Level 3:					
Group	-1.63	14.18**			
Cross-Level Interaction:					
Group x Valence of Affect	-.12**	-.10**			
Group x Energetic Arousal	.00	.01			
Group x Calmness	.01	-.02			
Level 1:					
Rumination about Food			.-.01	.01	-.08*
Rumination about Weight			-.02	.15**	-.01
Level 3:					
Group			-15.52*	-5.07	-5.28
Cross-Level Interaction:					
Group x Rumination about Food			-.09	-.09	-.02
Group x Rumination about Weight			-.24**	-.13	-.16*

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$; ** = significant at $\alpha \leq .01$. $N = 64$. Rumination and affect are given as measured by the EMA questionnaire. Predictors were always entered simultaneously. Group was coded 0 = healthy control participant; 1 = recovered individual with a history of Anorexia nervosa. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for activity and company

*Table A7.*Results of the deviance tests comparing model fit of the HLM models with vs. without inefficiency as predictor

	Models 1a+b: Rumination		**Model 2a-c: Affect**		
Predictor	**Food**	**Weight/Figure**	**Valence**	**Energetic Arousal**	**Calmness**
deviance of model without inefficiency	38371.76	36915.03	40818.83	42720.06	41564.89
deviance of model including inefficiency	38360.30	36897.40	40782.77	42703.04	41508.71
χ^2	11.45*	17.63**	36.07**	17.03**	56.18**

Notes: Deviance of the hierarchical linear models. $N = 64$. χ^2 = Chi-Test to compare fit of nested models; significant values indicate a better fit of the model with the lower deviance. * = significant at $\alpha \leq .05$; ** = significant at $\alpha \leq .01$.

7.2 Appendix B (Supplementary Material Study 2)

7.2.1 Methods

7.2.1.1 Participants

To be included in the study subjects had to be diagnosed with acute AN according to the DSM-5. Participants were excluded if they had a lifetime history of any of the following clinical diagnoses: organic brain syndrome, schizophrenia, substance dependence, psychosis NOS, bipolar disorder, bulimia nervosa, or binge-eating disorder (or "regular" binge eating - defined as bingeing at least once weekly for 3 or more consecutive months). Further exclusion criteria were IQ lower than 85; psychotropic medication within 4 weeks prior to the study; current substance abuse; current inflammatory, neurologic, or metabolic illness; chronic medical or neurological illness that could affect appetite, eating behaviour, or body weight (e.g., diabetes); clinical relevant anaemia; pregnancy; breast feeding. The relevant information (including possible confounding variables such as menstrual cycle and use of contraceptive medication) was obtained from all participants using the SIAB-EX semi-structured interview (Fichter & Quadflieg, 2001) conducted by clinically experienced and trained research assistants under the supervision of the attending child and adolescent psychiatrist. The 87-item interview systematically assesses the prevalence and severity of specific eating-related as well as -unrelated psychopathology and provides diagnoses according to ICD-10 and DSM-IV. This information was supplemented by our in-house semi-structured interview. Out of the 33 participants, one patient was of the binge-purge subtype. The rest of the sample was of the restrictive subtype. Two patients reported having been in psychotherapeutic treatment for other psychiatric disorders than the eating disorder. Both patients reported having had a depressive episode, one also an anxiety disorder.

There was an overlap between the current sample and that of (Seidel et al., 2018, 2016); data from 26 patients has previously been published there. This regards only EMA data collected at TP1 of our study. The TP2 data as well as the analyses regarding endocrinological data have not been published before. There is also a sample overlap with other publications (Bernardoni et al., 2016; J. A. King et al., 2015), which focused on neuroimaging data.

7.2.1.2 Clinical Measures

We used a short version of the German adaptation of the Wechsler Intelligence Scale for Children (Petermann & Petermann, 2008), which included the following subtests: vocabulary, letter number sequencing, matrix reasoning, and symbol search. The short version of the German adaptation of the Wechsler Adult Intelligence Scale (Aster, 2006) included the subtests: picture

completion, digit symbol coding, similarities, and arithmetics. To complement the information obtained with the clinical interviews, eating disorder-specific psychopathology was assessed with the German version of the Eating Disorders Inventory (EDI-2; Thiel et al., 1997); here we focused on the EDI-2 total score. Depressive symptoms were explored using the German version of the Beck Depression Inventory (BDI-II; Hautzinger et al., 2009).

The nutritional status of the subject was operationalized using the body mass index standard deviation score (BMI-SDS) and plasma Leptin levels. For details on the reference sample for the calculation of the BMI-SDS see Hemmelmann et al., (2010) and Kromeyer-Hauschild et al. (2001). Plasma Leptin was measured by a commercially available enzyme-linked immunosorbent assay at the Institute for Clinical Chemistry and Pathobiochemistry Otto-von-Guericke-University Magdeburg according to the manufacturer's instructions (BioVendor, Czech Republic) with an intra-assay coefficient of variation (CV) of 4,2%, inter-assay CV of 6,7%, and a lower limit of detection of 0.2 ng/ml.

7.2.1.3 Ecological Momentary Assessment

Participants were given a study smartphone (Samsung Galaxy Ace, 5831i). The application-based questionnaire was designed via an online platform (XS.Movisens, Karlsruhe, Germany), which also managed data collection and immediate server upload for constant monitoring of compliance. Participants were initially screened, weighed, and interviewed, before they received detailed instruction on how to handle the smartphone, the application and the content of the questionnaire. They were instructed to answer the questionnaire as soon as the alarm appeared, but were given an additional 30 minutes after the prompt when unable to reply (e.g., during class or work, during meal times or therapy session) or safety was a concern (e.g., while driving). Recordings during the first days of sampling were closely monitored in terms of compliance, to ensure that instructions were understood. Compensation was provided at the end of the study, in accordance with compliance rates. Data collection occurred via the signal-contingent assessment method: Alarms occurred at six semi-random times during a 14-hour period that was adapted for each individual to suit different daily routines. Prompts were anchored within six smaller intervals of two 2 ½ hour intervals (before midday) and for 1 ½ hour intervals (after midday). Between the intervals were 30-minutes breaks, to ensure that three of the six meals provided during inpatient therapy were not included in the sampling.

In addition to the variables of interest with each alarm several contextual control variables were retrieved. Participants were asked whether they had been mainly alone vs. in company, and at

home vs. in public since the last alarm. They also indicated their main occupation during the time since the last alarm, choosing from six categories (leisure, eating, waiting, therapy, sleep, other).

7.2.1.4 Statistics

The general hierarchical linear model used as the basis for all multilevel analyses included dummy-coded control variables for the situational factors described above and composed as follows:

$$y_{tij} = \gamma_{000} + \gamma_{010}*\text{DAYOFSTUDY}_{ij} + \gamma_{100}*TIMEOFDAY_{tij} + \gamma_{200}*COMPANY_{tij} + \gamma_{300}*\text{ACTIVITY01}_{tij} + \gamma_{400}*ACTIVITY02_{tij} + \gamma_{500}*ACTIVITY03_{tij} + \gamma_{600}*ACTIVITY04_{tij} + \gamma_{700}*ACTIVITY05_{tij} + \gamma_{800}*ACTIVITY06_{tij} + r_{0ij} + u_{00j} + e_{tij}$$

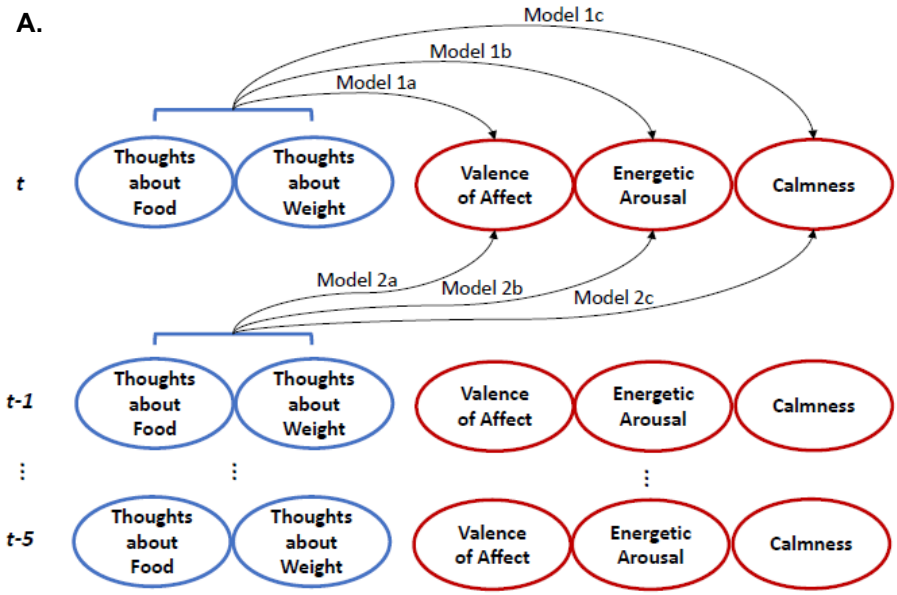
The variance components for the basic models are presented below in *Table B1*.

Table B1. Variance components of the basic HLM models (models 1a-c)

	Level 1 and 2			Level 3		
Outcome	***SD***	***Variance***	***p***	***SD***	***Variance***	***p***
TP1:						
Valence	18.29	334.34	< .001	34.06	1160.28	< .001
Energetic Arousal	11.61	134.76	< .001	36.00	1295.89	< .001
Calmness	16.56	274.09	< .001	39.58	1585.09	< .001
TP2:						
Valence	15.21	231.24	< .001	40.36	1628.92	< .001
Energetic Arousal	10.08	101.61	< .001	30.90	955.11	< .001
Calmness	14.87	221.00	< .001	37.87	1434.11	< .001

Notes. SD = standard deviation.

As described in the paper, we calculated hierarchical models with rumination as predictor for valence of affect, calmness, and energy (models 1a-c). These models were calculated once for TP1 and again for TP2. Further models regarding time-lagged associations were analysed in a similar manner; in addition to the variables at *t* time-lagged variables for *t-1* were included as predictors (models 2a-c). The models predicting valence of affect through rumination are presented in the main manuscript (models 1a and 2a). The results of the additional models with calmness resp. energetic arousal as outcome (models 1b+c and 2b+c) are displayed here in *Table B2*. For a better visualization of these complex analyses, *Figure B2* depicts all the hierarchical linear models that were calculated. *Figure B3* depicts the additional analyses (t-tests).


A.
Model 1c
Model 1b
Model 1a
t
Thoughts about Food
Thoughts about Weight
Valence of Affect
Energetic Arousal
Calmness
Model 2a
Model 2b
Model 2c
t-1
t-5


B.
TP1
TP2
Thoughts about Food
Thoughts about Weight
Valence of Affect
Energetic Arousal
Calmness
BMI-SDS
Leptin
BMI-SDS change
Leptin change
Model 3a
Model 3b
Model 3c
Model 3d

Figure B2. Schematic visualization of the calculated hierarchical linear models **A:** Models 1 and 2 (a-c). Affect was predicted through rumination, all variables were entered into the general model on Level 1 (momentary). Models of the class 1 represent the momentary analyses, Models of the class 2 included time-lagged variables of the predictors. Models of the class 2 also included rumination and the outcome variable at *t* to control for the momentary association between the variables and therefore correctly estimate the time-lagged effects Predictors were always included simultaneously. Models were calculated in the exact same way for TP1 and TP2. **B:** Models 3 (a-d). Rumination (resp. change in rumination between TP1 and TP2) was predicted through nutritional status (resp. change in nutritional status between TP1 and TP2). The predictor variables were entered into the general model on Level 3 (person). Predictors were included simultaneously. Models 3a+b were calculated in the exact same way for TP1 and TP2.

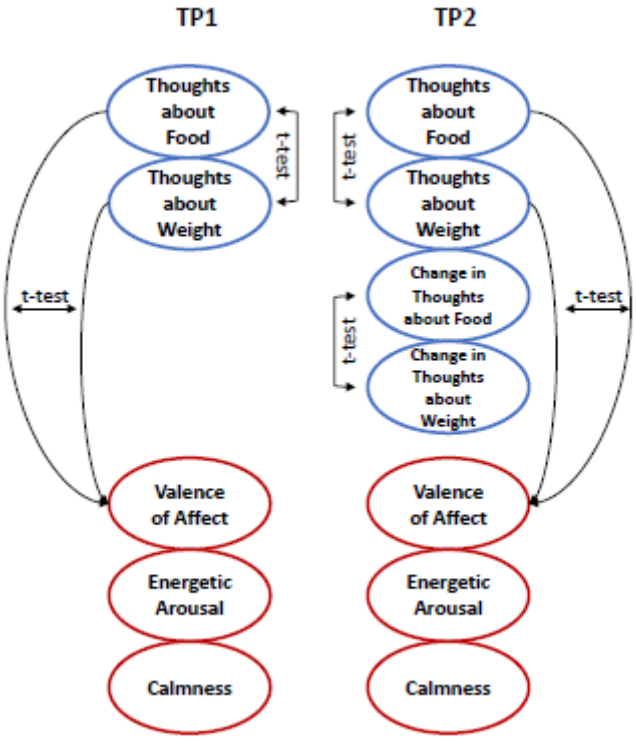


Figure B3. Schematic visualization of further analyses. Dependent t-tests were calculated contrasting the mean values for rumination about food vs. rumination about weight for both TP1 and TP2 and for the change in these two variables between TP1 and TP2. Further dependent t-tests contrasted the slopes for the effect of rumination on valence of affect extracted from the HLM model 1a, these analyses were also conducted for values of both TP1 and TP2.

7.2.2 Additional Tables and Results

Table B2. Momentary and time-lagged relationship between rumination and affect

Outcome	Predictor	TP1: β	TP2: β
Models 1a-c - momentary association:			
Valence of Affect (*t*)	Rumination about Food (*t*)	-.24**	-.13*
	Rumination about Weight (*t*)	-.50**	-.31**
Energetic Arousal (*t*)	Rumination about Food (*t*)	-.07	-.11*
	Rumination about Weight (*t*)	-.06	.02
Calmness (*t*)	Rumination about Food (*t*)	-.18*	-.11
	Rumination about Weight (*t*)	-.40**	-.30**
Models 2a-c - time-lagged association:			
Valence of Affect (*t*)	Valence of Affect (*t-1*)	-.07**	-.13**
	Rumination about Food (*t-1*)	-.10*	-.05
	Rumination about Weight (*t-1*)	.05	.02
	Rumination about Food (*t*)	-.28**	-.17*
	Rumination about Weight (*t*)	-.46**	-.36**
Energetic Arousal (*t*)	Energetic Arousal (*t-1*)	-.09**	-.07*
	Rumination about Food (*t-1*)	.03	.07
	Rumination about Weight (*t-1*)	-.01	.01
	Rumination about Food (*t*)	-.09	-.09
	Rumination about Weight (*t*)	-.11*	-.10
Calmness (*t*)	Calmness (*t-1*)	-.16**	-.12**
	Rumination about Food (*t-1*)	-.16**	-.03
	Rumination about Weight (*t-1*)	.03	-.08
	Rumination about Food (*t*)	-.17*	-.16
	Rumination about Weight (*t*)	-.36**	-.31**

Notes: Non-standardized β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$, ** = significant at $\alpha \leq .01$. $N = 33$. Rumination and Affect are given as measured by the EMA questionnaire. Predictors were always entered simultaneously. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for activity and company.

Table B3. Dependent t-tests contrasting variables concerning Rumination about Food vs. Rumination about Weight

	Rumination about Food	**Rumination about Weight**	***t***
crossectional: TP1			
mean ± standard deviation	57.30 ± 21.55	59.10 ± 23.59	-.76
effect on Valence of Affect (β)	-.24 ± .11	-.50 ± .24	6.38**
crossectional: TP2			
mean ± standard deviation	41.28 ± 21.84	49.35 ± 24.81	-3.26**
effect on Valence of Affect (β)	-.13 ± .03	-.31 ± .19	5.05**
longitudinally: TP2 – TP1			
mean ± standard deviation	-16.02 ± 23.59	-9.75 ± 24.34	-2.27*
effect on Valence of Affect (β)	.11 ± .10	.20 ± .28	-1.89^{+}

Notes. * = significant at $\alpha \leq .05$, ** = significant at $\alpha \leq .01$, $^{+}$ = significant at $\alpha \leq .10$. $N = 33$. Rumination and Affect were entered as measured by the EMA questionnaire. Individual Slopes (β) were extracted from the hierarchical analyses presented in *Table 2* (model 1a).

Table B4. Momentary relationship between rumination and affect at TP2, controlled for change in AN symptoms

Outcome	**Predictor**	**TP2: β**
Valence of Affect (*t*)	Rumination about Food (*t*)	-.21*
	Rumination about Weight (*t*)	-.44**
Energetic Arousal (*t*)	Rumination about Food (*t*)	.01
	Rumination about Weight (*t*)	-.01
Calmness (*t*)	Rumination about Food (*t*)	-.23**
	Rumination about Weight (*t*)	-.35**

Notes. β-values of the hierarchical linear models. * = significant at $\alpha \leq .05$, ** = significant at $\alpha \leq .01$. $N = 33$. Rumination and Affect are given as measured by the EMA questionnaire. Predictors were always entered simultaneously. Included control variables on Level 3: change in EDI-2 total score from TP1 to TP2. Included control variables on Level 2: day of study. Included control variables on Level 1: time of day, dummy-coded variables for activity and company.

Table B5. Multilevel estimates for HLM models of the momentary relationship between rumination and affect at TP1

	Valence			Energetic Arousal			Calmness		
Effect	**β**	***SE***	***p***	**β**	***SE***	***p***	**β**	***SE***	***p***
Intercept	105.51	10.47	< .001	140.43	8.60	< .001	118.98	10.68	< .001
Rumination:									
Thoughts about Food	-.24	.06	< .001	-.07	.05	n.s.	-.13	.07	.06
Thoughts about Weight	-.50	.08	< .001	-.06	.05	n.s.	-.38	.07	< .001
Control Variables:									
Day	-7.34	3.78	.05	-11.25	5.21	.03	-2.99	2.79	n.s.
Trigger	1.06	.55	.06	1.70	.75	.02	.44	.41	n.s.
Company	-4.01	3.33	n.s.	-4.11	3.00	n.s.	-6.81	2.80	.02
Activity: leisure	-7.86	5.27	n.s.	-8.39	3.58	.02	-.57	5.47	n.s.
Activity: eating	-19.09	5.89	.001	-14.25	3.91	< .001	-10.73	5.51	.05
Activity: waiting	-19.77	5.87	< .001	-21.17	4.31	< .001	-9.87	5.82	.09
Activity: therapy	-11.87	5.75	.04	-6.10	4.23	n.s.	-6.29	5.36	n.s.
Activity: sleeping	-8.45	6.33	n.s.	-39.40	6.35	< .001	1.34	6.27	n.s.
Activity: other	-3.31	6.71	n.s.	-7.98	3.88	.04	1.63	5.87	n.s.

Notes. SE = standard error. n.s. = not significant.

Table B6. Multilevel estimates for HLM models of the momentary relationship between rumination and affect at TP2

	Valence			Energetic Arousal			Calmness		
Effect	**β**	***SE***	***p***	**β**	***SE***	***p***	**β**	***SE***	***p***
Intercept	120.39	7.84	< .001	144.46	7.64	< .001	120.37	7.55	< .001
Rumination:									
Thoughts about Food	-.13	.05	.02	-.11	.05	.02	-.11	.06	.09
Thoughts about Weight	-.31	.07	< .001	.02	.06	n.s.	-.29	.04	< .001
Control Variables:									
Day	-1.90	2.91	n.s.	-3.02	3.34	n.s.	-5.62	2.19	.01
Trigger	.29	.43	n.s.	.43	.49	n.s.	.82	.33	.01
Company	-3.12	2.53	n.s.	-7.30	4.71	n.s.	3.10	3.41	n.s.
Activity: leisure	5.41	2.31	.02	-1.20	2.99	n.s.	3.90	1.97	.05
Activity: eating	-1.82	2.25	.03	-5.53	3.15	.08	-.96	2.45	n.s.
Activity: waiting	-10.80	3.68	< .01	-7.92	5.17	n.s.	-9.03	5.19	.08
Activity: therapy	.23	2.57	n.s.	-2.89	4.15	n.s.	-.17	2.78	n.s.
Activity: sleeping	2.83	3.89	n.s.	-36.42	6.53	< .001	4.15	3.33	n.s.
Activity: other	-3.85	2.04	.06	-9.48	3.56	.01	-6.29	2.28	.01

Notes. SE = standard error. n.s. = not significant.

Table B7. Variance coefficients of the leptin data

	TP1	**TP2**
Variance (*SD*)	6.49 (2.55)	79.41 (8.91)

Notes. $n = 22$. These results indicate that as opposed to TP2, at TP1 subjects showed less variance in their leptin levels possibly limiting our ability to detect significant associations between leptin and rumination measures at TP1

7.3 Appendix C (Supplementary Material Study 3)

7.3.1 Participants

To be included in the study subjects had to be female, between the ages of 18 and 45, and fluent in the German language. Registered users of the crowdsourcing platform Clickworker who met these criteria found a short description of the study on the website and could then decide to participate. The socioeconomic characteristics of the 602 participants are displayed below in *Table C1*.

Table C1. Socioeconomic characteristics of the sample

	M* ± *SD	**percentage (%)**
lower education:		
abitur		80%
degree lower than abitur		20%
higher education:		
no higher education		9%
apprenticeship/college education		30%
currently in college/training		24%
Bachelor's degree		19%
Master's degree		17%
ISCED	3.77 ± 1.15	
occupation:		
unemployed		24%
full-time		30%
art-time/marginally employed		35%
other		6%
employee		60%
manual worker		7%
self-employed/freelance		10%
monthly income	2.552 ± 2.225	
SES	13.51 ± 3.04	

Notes. *N* = 602. Abitur = highest degree in Germany, comparable to a high school degree. ISCED = International Standard Classification of Education; score calculated according to Schroedter, Lechert, & Lüttinger (2006). Monthly income is given in Euro (€). SES = socio-economic status; score calculated according to Lampert, Kroll, Müters, & Stolzenberg (2013).

10% of the participants reported currently being in treatment for psychiatric disorder: 47 participants indicated suffering from depression, 17 from an anxiety disorder, 11 from a personality

disorder (mainly Borderline), 4 from an eating disorder, 4 from posttraumatic stress disorder, and 49 reported other or combined diagnoses (e.g. depression and anxiety, depression and personality disorder). In a separate question specifically asking for eating disorders, 5% of the participants (28 individuals) reported currently suffering from an eating disorder (while not necessarily being formally diagnosed or in treatment) and 15% (88 individuals) responded with having suffered from an eating disorder in the past. Of these 116 participants, 23% reported suffering or having suffered from Anorexia nervosa, 28% from Bulimia nervosa, 15% from binge eating disorder, and the remaining 34% from an unspecified eating disorder.

When asked about their diet, 19.3% of the participants reported following a specific style of diet: 62 participants were vegetarian, 21 vegan, and 35 followed other specific diets such as e.g. low-carb or paleo. 13.8% of the participants reported currently being on a weight-loss diet, 35% reported never having been on a weight-loss diet, and 9% reported being regularly or constantly on weight-loss diets.

7.3.2 General Study Details

The programming, presentation, and recording of the study was carried out with the software of the online experiment platform Labvanced (Goeke & Finger, 2018). Participants were free to take part in the study at the time and location of their convenience but were asked to eliminate distracting factors such as noisy surroundings to their best abilities beforehand. A desktop computer or notebook running Microsoft Windows, Apple OS, or Linux was required to start the study. Mobile devices such as tablets were not enabled to run the study. Participants could start the study in a web-browser of their choosing among Chrome (40%), Safari (8%), Firefox (42%), MS Edge (7%), or Opera (3%) – Internet Explorer was excluded due to compatibility problems. Starting the study launched full-screen mode, which participants were instructed to keep activated for the duration of the study. To ensure that participants were paying close attention during the reaction-time task, the number of continuous missing responses was counted and the study was terminated (after a previous warning) if participants gave no response for 10 trials in a row. Experiment sessions which were rejected by this control-check were re-opened for new participants immediately. This fully automated procedure enabled the recording of a high number of valid datasets in a relatively short time.

To assess the commitment of the participants, we used instructional manipulation checks (IMC; Oppenheimer, Meyvis, & Davidenko, 2009). A total of five questions to test attentiveness were distributed across the study, disguised as multiple choice questions mixed in with the assessment of demographics or as items of the questionnaires. The vast majority of the participants

was very attentive: 406 of the 602 participants answered every IMC correctly, 155 four out of the five. Only 26 participants (4.3%) gave wrong answers to two of the five questions, further 10 participants (1.7%) to three. Four participants (< 1%) only answered one IMC correctly and one participant gave wrong answers to all five IMCs. These results are similar to those in studies on IMC (Hauser & Schwarz, 2016; Oppenheimer et al., 2009; Paolacci et al., 2010). To rule out possible influence of attentiveness on our findings, we investigated associations between number of correct IMCs and all questionnaires, parameters of the flanker task, and age. There were no significant correlations. We also repeated all SEM analyses under exclusion of all individuals with less than three correct IMCs—results did not differ from the reported model.

7.3.3 Flanker Task

To ensure understanding of the task, participants had to answer two multiple choice questions (*"Which faces are you supposed to focus on?—(a) all; (b) only the one in the middle; (c) only the ones on the sides"* and *"Which key are you supposed to press for "views to the left"?—(a) T; (b) S; (c) B"*) after the instructions, before the pre-run. They were looped back to the instructions until they gave the correct answers. The face stimuli used for the flanker task were generated with FaceGen software (Singular Inversions; Toronto, ON, Canada). We used an equal number of left- and right-looking male and female faces with unique identities form various ethnic groups (448 faces total). The viewpoint angles were 45-50°. The task was presented in full-screen mode with a black backdrop and a white fixation cross. Answers were logged via keystroke. To keep possible spatial stimulus-response conflicts minimal, participants were instructed to use "T" and "B" on a QWERTZ keyboard as response keys. For the same reason the response associated with the two keys was randomly assigned to be spatially compatible (left index finger on "T" for left viewpoint direction) for half of the participants vs. incompatible (left index finger on "T" for right viewpoint direction) for the other half. Which of the two keys should be used for which answer ("left" vs. "right" viewpoint-direction of the target) was balanced across participants within each of the two location-based context-specific proportion congruency (CSPC) conditions (right vs. left side of the screen as high conflict context).

To ensure that participants were unaware of the CSPC manipulation, a short questionnaire was filled out after the experiment. Participants indicated the difficulty of congruent and incongruent trials on a visual analogue scale from 1 (very easy) to 10 (very difficult) and answered the question whether they had noticed a pattern in the frequency of congruent vs. incongruent trials (yes/no). If the answered yes, they were asked to answer more fully via free input. Regardless of whether participants indicated having noticed a pattern, all participants were asked to indicate the frequency

of incongruent trials on visual analogue scales from 0 (never) to 100 (always) for left side of the screen, right side of the screen, white target faces, dark-skinned target faces, female target faces, and male target faces.

Results revealed that of the 567 participants whose flanker task data was evaluated, only 29 reported having noticed a pattern in the frequency of congruent vs. incongruent trials. They described patterns in the order of trials (e.g. 3 congruent, then 2 incongruent, then 4 congruent etc.), a higher frequency of congruent trials depending on viewpoint direction (e.g. more trials with the target face looking to the right), or a higher frequency of congruent trials depending on skin color (e.g. more trials with a dark-skinned target face). No participant described a pattern depending on the side of the screen. The suspected frequency of incongruent trials for the six variables (right side, left side, white, dark-skinned, female, male) can be found below in *Table C2*. As can be seen, there was significantly less incongruency suspected for dark-skinned and for female faces, but not for right or left side of the screen. Separate t-tests for the two groups according to manipulation condition (high conflict right vs. high conflict left) were conducted for mean suspected frequency of incongruent trials on the right vs. left side. In both groups there was no significant difference ($t = 0.00$, $p = 1.00$ for high conflict right; $t = .52$, $p = .60$ for high conflict left).

Taken together, the results of the post-experiment questionnaire show that participants were unaware of the manipulation, which makes it highly unlikely that performance differences between the two conditions were caused by conscious processes.

*Table C*2. Results of the post-experiment questionnaire

	right side	**left side**	**white**	**dark-skinned**	**female**	**male**
suspected frequency of incongruent trials ($M \pm SD$)	50.94 ± 18.38	50.57 ± 18.88	50.40 ± 19.62	46.03 ± 20.59	48.32 ± 19.40	49.73 ± 19.44
difference to "right side" (t)		.37	.59	4.50**	2.68**	1.20
difference to "left side" (t)	.37		.17	4.44**	2.28*	.81

Notes. n = 567. * = significant at $\alpha \leq .05$; ** = significant at $\alpha \leq .01$.

7.3.4 Self-Report Measures

The Brief Self-Control Scale (BSCS; Tangney et al., 2004) was evaluated via calculation of sum-scores for two scales: impulsivity (four items reflecting intuitive and spontaneous behavior; e.g. *"I often act without thinking through all the alternatives."*) and restraint (four items reflecting self-

discipline and engagement in effortful control; e.g. *"I am good at resisting temptation."*). This structure has been established and validated (Maloney, Grawitch, & Barber, 2012).

For the evaluation of the Creature of Habit Scale (COHS; Ersche et al., 2017) sum-scores for the two sub-scales automaticity (11 items reflecting the tendency to show automatic reactions and behavioral patterns; e.g. *"Whenever I go into the kitchen, I typically look in the fridge."*) and routine (16 items reflecting the tendency to follow routines and establish regularity in daily life; e.g. *"I always try to get the same seat in places such as on the bus, in the cinema, or in church."*) were calculated.

For the two scales of the short version of the Three Factor Eating Questionnaire (TFEQ-R18; Karlsson et al., 2000) also sum-scores were calculated: uncontrolled eating (9 times reflecting subjective loss of control over eating behavior; e.g. *"When I see a real delicacy, I often get so hungry that I have to eat it right away."*) and emotional eating (3 items reflecting the tendency to eat as a response to (negative) emotional states; e.g. *"When I feel blue, I often overeat."*).

The Dietary Free Fat and Sugar Short Questionnaire (DFS; Fromm & Horstmann, 2019) was evaluated via the sum-score of the 26 items assessing the frequency of dietary intake of specific foods rich in saturated fat and free sugar (e.g. cured meats) over the last 12 months.

Self-reported body mass index (BMI) was assessed via free number input items for current height and weight and calculated as BMI = kg/m2. Specific style of diet was assessed via two items: a multiple choice question *"Do you follow a specific style of diet (vegetarianism, veganism, lowcarb, paleo…)?"* with the possible answers yes or no and (if applicable) a follow-up question *"Which specific style of diet do you follow?"* with a free text input format. Weight loss diets were assessed via a modified multiple choice item of the TFEQ: *"How often have you been on a weight-loss diet?"* with the answer options 1 to 3 times, 4 to 8 times, 9 to 15 times, more than 15 times, regularly, almost constantly, never. If any answer other than never was chosen, a follow-up question assessed success of weight-loss diets in a multiple choice format: *"Did those weight-loss diets have the desired success?"* with the answer options yes, no, sometimes.

7.3.5 Statistics

To circumvent difficulties in data evaluation due to the speed-accuracy trade-off that is frequently present in reaction-time tasks, performance in the flanker task was evaluated via the linear integrated speed-accuracy score (LISAS). This score estimates performance by correcting reaction time for error rate in a linear manner with equal weighing of both aspects (Vandierendonck, 2017).

The score was calculated for each participant and each condition (high vs. low conflict) according to Vandierendonck (2017) through the following equation:

$$\text{LISAS} = RT_j + \frac{S_{RT}}{S_{PE}} \times PE_j$$

with: RT_j = meand reaction time in condition j; PE_j = error rate in condition j; S_{RT} = overall standard deviation of reaction time; S_{PE} = overall standard deviation of error rate

Declaration of Authorship

Die vorliegende Arbeit wurde im Zeitraum zwischen Oktober 2015 und September 2020 im Bereich Psychosoziale Medizin und Entwicklungsneurowissenschaften der medizinischen Fakultät der technischen Universität Dresden und des Universitätsklinikums Carl Gustav Carus (Technische Universität Dresden) angefertigt. Die wissenschaftliche Betreuung fand durch Prof. Dr. med. Stefan Ehrlich statt. Frühere erfolglose Promotionsverfahren haben nicht stattgefunden. Ich erkenne die Promotionsordnung des Bereichs Mathematik und Naturwissenschaften der Technischen Universität Dresden, in der Fassung vom 23. Februar 2011, letzte Änderung 18. Juni 2014, an. Ich versichere, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Aus fremden Quellen direkt oder indirekt übernommene Gedanken sind als solche kenntlich gemacht. Die Arbeit wurde weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegta.

Unterschrift:

Datum: