MASTERARBEIT / MASTER’S THESIS

Titel der Masterarbeit / Title of the Master‘s Thesis

„Reward Processing in Individuals with Anorexia Nervosa“

verfasst von / submitted by

Magdalena Schustereder, BSc

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2023 / Vienna 2023

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Psychologie UG2002
Betreut von / Supervisor:	>Assoz. Prof. Giorgia Silani, Privatdoz. PhD <

Table of Contents

Introduction 4
Theoretical Background 7
Anorexia nervosa 7
i. Classification 7
ii. Subtypes of AN 7
iii. Aetiology of AN 8
iv. Incidence, prevalence, mortality & recovery rates 10
v. Predominant personality factors in individuals with AN 11
vi. Altered neurobiology in individuals with Anorexia Nervosa 12
vii. Anorexia nervosa in times of the COVID-19 pandemic 14
viii. Anhedonia in individuals with Anorexia Nervosa 15
Reward Processing 17
i. Social touch as a reward 20
ii. Food reward processing 21
Reward processing in AN 22
i. Food reward processing in EDs 24
ii. Altered social reward processing in AN 25
iii. Facial muscles as an indicator of implicit liking or disliking 26
iv. Measurement of implicit wanting 28
Research Questions & Hypotheses 29
i. Clinical and social significance 29
ii. Research gap 29
iii. Research question 32
iv. Hypotheses 32
Methods 34
Participants 34
Stimuli 34
i. Social rewards 34
ii. Non-social rewards 35
Procedure 35
i. Explicit measures 36
ii. Implicit measures 36
Data Analysis 38
Statistical analysis 38
Results 39

Explicit measures of liking (VAS): 39
Explicit measures of wanting (VAS): 42
Implicit measures of wanting (effort): 45
Implicit measures of wanting and liking (facial EMG): 46
Discussion 55
Limitations 59
Current relevance of this research...61
List of Tables 62
List of Figures 63
List of Abbreviations...64
References 65
Appendix...81
Abstract (English) 81
Abstract (German)...82

Introduction

Anorexia Nervosa is a condition which is very easy to detect because it is outwardly visible compared to many other mental illnesses. However, this could lead to the fallacy that the challenges and problems faced by people with anorexia are also apparent and visible, which is not true. Many aspects of this complex disorder are not yet fully explained and further research is needed to develop therapeutic approaches and methods to better support and understand it. As this disorder also often affects very young people (Lucas & Holub, 1995; Micali et al., 2013) and also tends to become chronic in approximately 20% of the diagnosed patients (Steinhausen, 2009). It shows a high mortality of 3.4 up to 16% (Keel et al., 2003; Lee et al., 2003; Löwe et al., 2001; Steinhausen, 2009) , which is one of the highest within mental disorders (Birmingham et al., 2005; Keel et al., 2003). Therefore, the relevance of research in that area cannot be overestimated. The findings of this study contribute to the understanding of reward processing in AN patients compared to healthy control subjects.

Patients suffering from anorexia nervosa primarily pursue the goal of losing weight and this mainly through highly restrictive eating behaviour but also through other methods such as purging, the misuse of laxatives and excessive exercise (Fairburn & Harrison, 2003). The fear of food and weight gain as well as a distorted body image are the most striking traits in AN patients (Crucianelli et al., 2021; Davidovic et al., 2018; Eiber et al., 2002; Sanders et al., 2015).

There is considerable evidence that symptoms of anorexia nervosa are highly connected with reward processing (Davis & Woodside, 2002; Ehrlich et al., 2015; Giel et al., 2011; Nozoe et al., 1996; Via et al., 2015). Therefore, AN cannot be sufficiently understood without consideration of reward processing.

Reward processing is a topic that presents many research opportunities and is being investigated even in healthy control subjects (Berridge, 2009; Berridge & Kringelbach, 2015; Berridge & Robinson, 2003; Craske et al., 2016; Schultz, 2006; Tibboel et al., 2015). If we look more closely at reward processing concerning people with a psychiatric disorder such as anorexia nervosa, many open questions arise.

“Wanting” and “liking” are two distinct components of reward processing (Craske et al., 2016). Wanting is more connected to the motivational aspects of gaining a reward, whereas liking is rather described as the hedonistic aspect of reward processing (Berridge, 2009). Wanting and liking are examined in this work both in explicit and in implicit measurement methods to enable a complete representation of the described aspects.

To better understand reward processing in people with anorexia nervosa, this master thesis will compare certain aspects of reward behaviour (here: wanting and liking) with an age-matched healthy control group.

To achieve this goal, 31 women between 15 and 22 years of age were included in the sample, 19 of whom were in the experimental group suffering from anorexia. The 12 other subjects formed the healthy control group. These studies were conducted between April and October of 2022 at Vienna General Hospital in cooperation with the Medical University of Vienna as well as the Faculty of Psychology at the University of Vienna. The present work is quantitative in nature and therefore the exact procedures of the calculations are described in the data analysis part. Mixed variance analyses were used, as both between-subjects and within-subjects effects were investigated.

This thesis will start off with an overview of the theoretical background, primarily on the topics of anorexia nervosa, reward processing and then reward processing specifically in patients with anorexia nervosa. This broad theoretical overview aims to give a fundamental insight on anorexia nervosa, its epidemiology, its aetiology as well as the social and personal impact this mental illness entails. Also introduced as a symptom of anorexia is anhedonia, which is characterized as an altered hedonic system, reduced interest in activities and joylessness (Dolan et al., 2021; Eiber et al., 2002; Tchanturia et al., 2012) and is therefore another important component in understanding reward processing in the context of eating disorders.

Subsequently, the process of reward processing will be presented in broad terms, but then also particularly in relation to the distinct components of wanting and liking. To combine the topic of reward processing and anorexia, the current state of scientific research on anhedonia in a disorder of anorexia will be presented. Thereafter, a connection between the specific reward processing, i.e. wanting and liking in the context of anorexia will be outlined. The neurobiology of rewards is also briefly discussed, although this will not be part of the rest of this paper. Nevertheless, research in this area is significantly linked to research on behavioural data and provides many insights and findings. The focus of most scientific papers on the combination of the two topics is in the field of neurobiology and should therefore not be overlooked.

This is followed by a thorough description of the procedure, the patients and the measurement methods. Afterwards the results of the statistical analyses are described and in the last part, the discussion, an integration of these results in the existing literature is attempted and limitations of this study are outlined.

Theoretical Background

Anorexia nervosa

i. Classification

Anorexia nervosa classified according to F.50 and F.50.01 of the International Classification of Diseases 10 (ICD-10) is an eating disorder (ED) characterized by a persistent restriction of energy intake, which subsequently leads to low body weight in relation to health norms. According to the Diagnostic and Statistical Manual of Mental Disorders 5 (DSM-5), restrictive eating behaviour is also accompanied by fear of weight gain, as well as disturbed perception of body weight, and physical appearance (DSM-V, 2020). In the DSM-5 a threshold of <17.5 has been established in terms of body mass index. This interpretation is criticised for having too low a specificity and for being insufficiently effective, especially in very young affected patients (Herpertz-Dahlmann et al., 2005; Tuschen-Caffier & Svaldi, 2014). The BMI as a criterion in the age group in which AN occurs most frequently, would, in purely practical terms, then also include many healthy children (Herpertz-Dahlmann et al., 2005). It was removed in the ICD-10 as a criterion, and it was decided to use the 10th age percentile as a weight limit instead (Herpertz-Dahlmann et al., 2005).

ii. Subtypes of AN

As noted above, the AN diagnosis in the ICD-10 is divided into typical F.50 and atypical F.50.01 anorexia, with the former described without active weight loss measures and the latter with active weight loss measures (WHO et al., 2008). The atypical AN type is characterized by active weight loss mechanisms, which for example consist of engaging in excessive sports, but also vomiting, the misuse of digestive enhancers as well as the misuse of appetite suppressants (Tuschen-Caffier & Svaldi, 2014). In the typical variant of AN, these methods are not used, but an extremely restrictive eating behaviour is demonstrated (Tuschen-Caffier & Svaldi, 2014), therefore it is also called AN restrictive-type.

In a longitudinal study of Eddy et al. (2022), it was investigated whether the AN restrictive-type or the binge/purge AN type differed in the history of kleptomania, substance abuse, suicidality, or borderline personality disorder as well as the recovery rates, relapse, and the mortality. No difference could have been stated between the two groups in any of these aspects (Eddy et al., 2002). At the eight-year follow-up time point, it was found that 62% of the AN restrictive-type group had also exhibited binge/purge type behaviours and only 12% never adapted such behaviours on a regular basis. It is concluded that AN or atypical AN are likely to be demarcated phases in a disease rather than distinct subtypes (Eddy et al., 2002).

iii. Aetiology of AN

The aetiology of anorexia is not yet fully explained in many respects, but social as well as psychological and genetic influences seem to be at work. Genetic influences are thought to be mainly due to the fact that there is often an aggregation of people suffering from AN in one family (Berrettini, 2004; Trace et al., 2013). The likeliness of developing an AN throughout the lifetime of a person is up to 11 times higher when being a first-degree relative of an individual with AN than unaffected controls (Strober et al., 2000; Trace et al., 2013). Also, milder phenotypes of AN seem to cluster in families, but less severe. Affected subjects seem to be exclusively females (Strober et al., 2000). Risk factors for developing AN include female gender, having a sibling with AN, having family members with affective mood disorders, anxiety, substance-abuse, or personality disorders. Mothers of individuals suffering from AN, have a tendency six times higher to be also affected than mothers of healthy controls (Steinhausen et al., 2015)

Dysphoria, avoidance behaviours, disturbed appetite and compulsions might be related to an altered serotonin activity (G. K. Frank et al., 2001).The genome wide association studies (GWAS) have not yet identified genome-wide significant loci (Treasure et al., 2015). One system, that is a frequent target in research, is the serotonergic 5-HT receptor gene, but results are inconclusive (Berrettini, 2004; Gorwood et al., 2003; Trace et al., 2013). More specific, the 5-HT2A gene is significantly associated with a risk for developing AN and the receptor is altered in acutely affected patients (Gorwood et al., 2003) but is also reduced in the postsynaptic receptor activity in individuals who have been weight-restored, hence still altered after improvement (G. K. Frank et al., 2001). The 5-HT genes affect the serotonergic system and are involved in mood, weight regulation but also appetite (Kaye et al., 2009; Trace et al., 2013). Individuals prone to developing an eating disorder might similarly exhibit a predisposition to elevated extracellular serotonin (5-HT) concentrations and a consequent imbalance in postsynaptic 5-HT receptor activity (G. K. Frank et al., 2001). Gorwood et al. (2003) propose that the -1458A allele of the 5-HT gene is significantly associated but not linked with anorexia nervosa, from which is concluded that this vulnerabilizing allele has a complex effect on AN and could possibly alter the phenotype of the disease decisively.

Anorexia nervosa has not only a complex appearance and a complicated aetiology, but also affects the social, cognitive, and biological domains in a complicated and multifaceted way (Davis et al., 2005; Keating, 2010).

AN is a psychiatric diagnosis with one of the highest mortality rates (Micali et al., 2013; Skowron et al., 2020), which is not surprising, considering that severe health problems are entailed by underweight and reduced food intake. Possible side effects are cardiovascular disorders, osteoporosis, damage to the enamel, organ damage, but also many endocrinological clinical diseases (Herpertz-Dahlmann et al., 2005; Micali et al., 2013). In a Canadian population studied by Birmingham et al. (2005) the most common cause for the death of patients diagnosed with AN (N=326) was suicide.

Apart from genetic influences, regarding the social and psychological risk factors, it must be stated that marital problems of the parents, anxious and overprotecting behaviour of the parents as well as criticism concerning the weight and body of the child and family dieting correlate positively with the development of AN (Fairburn & Harrison, 2003). Furthermore, sexual abuse is considered a crucial risk factor, but applies non-specifically to many mental health disorders (Fairburn & Harrison, 2003; Herpertz-Dahlmann et al., 2005)

The most common comorbid disorder is depression (Tchanturia et al., 2012), since 59% of all eating disorder patients experience at least one episode of major depression (Mischoulon et al., 2011). Furthermore, anxiety disorders (Kaye et al., 2013), especially separation anxiety (Fairburn & Harrison, 2003) and social phobia (Fairburn & Harrison, 2003; Raney et al., 2008) are commonly enumerated. Moreover, women, who were overanxious in their childhood, exhibit more severe eating disorder phenotypes (Raney et al., 2008). Anxiety disorders are considered as an overactive and hyper-responsive fear response to specific objects or situations (Shin & Liberzon, 2010). In patients suffering from AN especially food cues trigger arousal and fear, but also avoidance behaviours (Giel et al., 2011). The fear network in AN seems to be specific to food cues due to the fact that the response to general aversive emotional stimuli and fearful emotional faces does not differ to healthy controls (Zhu et al., 2012).

iv. Incidence, prevalence, mortality & recovery rates

Most studies present higher incidence rates in girls and women than in boys and men, with rates ranging from 10:1 to 15:1. In the study of Hudson et al. (2007) the median of onset was 18.0 years, which in comparison with other eating disorders like bulimia nervosa (BN), Binge Eating Disorder and other forms of Eating Disorders, was the earliest median of onset. Many publications support the assumption that the first AN diagnosis is most frequently given in the age group of 15 - 20 years both in girls and boys (American Psychiatric Association, 2022; (Fichter et al., 2006); Keski-Rahkonen et al., 2007). The lifetime prevalence estimates of AN (diagnosed with DSM-IV) is 0.9% among women and 0.3% among men. There was also a significantly high comorbidity stated with other DSM-IV disorders. It is also interesting that in this large-scale study (N=9282) a correlation of lifetime AN and low current weight was found. 15.6% of the individuals with a lifetime diagnosis of AN still had a current body mass index (BMI of less than 18.5 at the time of interview) (Hudson et al., 2007). Keski-Rahkonen et al. (2007) researched female Finnish twin pairs and showed a lifetime prevalence of 2.2 with a 95% confidence interval of 1.6-2.7 for anorexia nervosa according to DSM-5 and a lifetime prevalence of 4.2 (95% confidence interval 3.4-5.0) for broad anorexia, which in addition to typical anorexia also includes cases of atypical anorexia nervosa.

Dobrescu and colleagues (2020) studied 51 people with anorexia and 51 healthy controls matched by grade and gender in 1985 in Gothenburg and conducted a follow-up 30 years later. , 19% (N=9) of the patients of the anorexia group suffered currently from an eating disorder, 3 of these 9 suffering from AN. 64% i.e., N=30 were in complete remission and no significant difference in BMI between the patients and the control group at the follow-up was found (Dobrescu et al., 2020).

Fichter and colleagues (2006) examined 635 inpatients in a Bavarian clinic with eating disorders (592 females and 43 men) whereas N=103 women fulfilled the characteristics for a diagnosis of AN. The mean age of onset of AN was 18.5 years and the average age at admission was 24.9 ± 6.7 years (Fichter et al., 2006). The participants were reassessed after 2, 6 and again after 12 years since leaving the clinic. Regarding mortality, all causes of death were due to anorexia and amounted to 4.9% at 2-year follow-up, 5.8% at 6-year follow-up, and 6.8% of subjects have died after 12 years (Fichter et al., 1998). The Structured Inventory for Anorexic and Bulimic Syndromes (SIAB-EX) (Fichter et al., 1998) was used to assess participants symptoms at every testing time point. AN patients showed a significant symptom reduction in relation to healthy controls, yet the SIAB-EX scores were still significantly elevated. The severity of comorbid depression was assessed with the BDI and decreased from baseline (24.0 +-10.9) to the end of treatment, so upon discharge from the Bavarian clinic, (12.3 +- 10.8), increasing significantly again at 6- and 12-year follow-up, respectively (Fichter et al., 1998).

Regarding the mortality of AN, it can be stated that both suicide as a consequence of the eating disorder and severe physical damage due to malnutrition can lead to death in AN patients (Fichter et al., 2017; Löwe et al., 2001). The rates are reported in different publications between of 3,4 and 16% (Keel et al., 2003; Lee et al., 2003; Löwe et al., 2001; Steinhausen, 2009).

v. Predominant personality factors in individuals with AN

For AN it is significant that the backgrounds of the disease are often very different, from the motivation to live healthy, to traumatization as well as a lifelong disturbed body image are all these possibilities facets of the disease (G. K. W. Frank et al., 2019).

Although there are many theories and possibilities about the origin but also about the personal history of suffering, the presentation of symptoms is usually less broad and many sufferers are affected by the same manifestations, such as behaviours aimed to reduce one’s weight (Keating et al., 2012), repetitive behaviours, but also mood lability (Crucianelli et al., 2016). One of the first symptoms to present is excessive exercise, approximately 80% of AN patients are hyperactive at least one time in their medical history (Davis et al., 2005). The theory was investigated that decreased serotonin neurotransmission triggered by malnutrition can explain hyperactivity, strong impulsivity in behaviour but also depressive symptoms (Haleem, 2011). Another example of an explanation of the origin of the symptoms that follow the disease was presented by Södersten et al. (2008). They hypothesize that the obsessive movement of AN patients is an evolutionary repressed food-seeking behaviour that comes from times of food shortage (Södersten et al., 2008).

Considering psychological factors of patients with AN an anxious-avoidant, perfectionist (Fairburn & Harrison, 2003; Kaye et al., 2013; Strober, 2003) and obsessive-compulsive temperament as well as low self-esteem have been demonstrated in research (Fairburn & Harrison, 2003; Strober, 2003). Furthermore it is suggested that the self-starvation might be a dysfunctional behaviour to weaken the anxious temper in AN patients (Strober, 2003).

Frank et al. (2019) proposed a motivational model for the continuous and vicious cycle of energy restriction in AN. It consists of the drive for thinness, but also of the dissatisfaction with one's own body and the fear of gaining weight, which are factors that then result in weight loss. Since the body adapts to weight loss through changes in the reward system and more precisely the dopamine-based neuroendocrine system is altered, this again results in reduced food intake and subsequent weight loss (G. K. W. Frank et al., 2019).

These weight-induced changes, i.e., reactions to weight loss, showed in animal experiments, among other things, changes in digestive hormones, increases in cortisol levels in the brain, but also changes in postsynaptic dopamine receptor function (Beck & Luine, 1999; G. K. W. Frank et al., 2019; Oswald et al., 2005).

vi. Altered neurobiology in individuals with Anorexia Nervosa

Anorexia nervosa is classified as a psychosomatic disorder and is therefore characterized by interactions between neurobiology and behaviour. Starvation for example alters the neurotransmitter metabolism in the brain (Pirke & Platte, 1995) What results of being underweight are often low gonadal hormone levels as well as low levels of appetite regulating hormones such as leptin. Those abnormalities in endocrine alterations are commonly reduced when weight restoration is achieved (Treasure et al., 2015).

Damage to the lateral hypothalamus results in decreased appetite and subsequently anorexia and is referred to as lateral hypothalamic syndrome (Bear et al., 2016).

Reduced grey matter in patients with AN seems to normalize after recovery. It was shown by King et al. (2015) that 85% of the cortical surface of patients with acute AN was significantly thinner than in healthy control subjects. Cortical thickness seems to normalize after long-term weight restoration (King et al., 2015).

Many publications have already discussed the vicious circle that follows from malnutrition and weight loss and the subsequent further restriction and reduction of food intake (Haleem, 2011; Kaye et al., 2009). The above-mentioned alteration of 5-HT receptors could be related to increased satiety and an anxious and a harm-avoidant temperament (G. K. Frank et al., 2001; Kaye et al., 2009). Also, it could lead to fearful avoidance behaviour concerning food. Kaye and colleagues (2009) have inferred from the frequent anhedonia and ascetic lifestyle of individuals with anorexia nervosa and the appearance of these characteristics even after recovery, that these qualities might be trait rather than state related. They also examined the effects of changes in the dopamine (DA) system on reward behaviour (Kaye et al., 2009). It was proposed that an alteration in striatal circuitry could lead to altered reward processing, as well as altered executive functions but also altered affect. In a functional magnetic resonance imaging fMRI study, recovered anorexia patients were compared to healthy control subjects while performing a Simple Choice and Feedback Task. The Blood-Oxygenation-Level Dependent signal (BOLD) was examined and similar activity was found during positive and negative feedback in the subgenual anterior cingulate cortex (ACC) and the ventral striatum, suggesting that there may be discrimination difficulties between positive and negative feedback in former AN patients (Wagner et al., 2007).

Another model that has been proposed to better understand anorexia nervosa is by Coniglio and colleagues (2019). It describes that dysregulated positive affect maintains restrictive eating behaviours, contributing to the downward spiral of weight loss. It is reasoned that when people with AN experience restrictive eating behaviour, like e.g. excessive exercise, weight loss, etc., they experience positive affect hence a perceived reward, but when they experience typical rewarding stimuli, this does not occur (Coniglio et al., 2019).

Keating et al. (2012) note, however, that despite much evidence of altered reward processing in patients with AN, no definitive conclusions can yet be drawn about reward abnormalities and disease behaviour yet.

vii. Anorexia nervosa in times of the COVID-19 pandemic

The COVID-19 pandemic can probably be seen as the most important game-changing aspect of the current era for humanity's mental health. The effects of lockdowns and social distancing have already been presented in several publications. A risen rate of depression in children and adolescents can be stated as well as high anxiety rates concerning personal isolation in that population (Loades et al., 2020). One important point about why the pandemic has such a profound effect on people's psyches is that lockdowns and social isolation interfere with the originally human pursuit of a social environment and human connection (Hagerty & Williams, 2020).

Thus, it is only natural that the pandemic is expected to have an impact on the part of the population that was already struggling with severe mental disorders before the pandemic. Schlegl and colleagues (2020) investigated the effects of said pandemic on ED symptoms in May 2020 of 159 former patients suffering from anorexia nervosa who were discharged from inpatient treatment in 2019. In an anonymous online survey among other things the impact of the COVID-19 pandemic on ED symptoms, the incidence of possible new symptoms as well as their perceived quality of life and the impact on therapy was investigated. 41.5% reported that their ED related symptoms worsened during lockdown, whereas only 20% said that they experienced new symptoms. 70% of participants explained that ED cognitions worsened which were e.g., eating concerns, weight gaining concerns or drive for physical activity. 70% of the sample explained that the symptoms loneliness, sadness, and inner restlessness worsened over time. 73% of the asked population reported to have maintained their weight throughout the first COVID-19 related lockdown (Schlegl et al., 2020)

Clark Bryan and colleagues (2020) stated that for AN patients in the United Kingdom it was on the one hand the reduced access to ED care but on the other hand the loss of their normal routine which resulted in amplified eating disorder symptoms and intensified anxiety (Clark Bryan et al., 2020). Data also indicates that individuals who were first diagnosed during the covid pandemic had lower weights and exhibited more compulsive exercise behaviours (Datta et al., 2022).

viii. Anhedonia in individuals with Anorexia Nervosa

Anhedonia in patients with eating disorders has been widely studied. Anhedonia, i.e. the reduced ability to feel pleasure (Dolan, Khindri, et al., 2022; Keating, 2010) or to perceive a reward, or even the loss of interest in activities (Craske et al., 2016; Tchanturia et al., 2012). Anhedonia can result from the collapse of the hedonic system (Berridge & Kringelbach, 2015). By Dolan and colleagues (2021), the altered nature of reward perception was investigated in a large-scale meta-analysis. The goal was to gain insight into the role of rewards in eating disorders. They found that anhedonia is elevated in individuals suffering from eating disorders, and thus this fact could offer itself as an important target for the treatment of these mental disorders. A suggestion for further research would be to match the relationship of self-reported anhedonia with reward processing in order to subsequently develop more targeted interventions (Dolan et al., 2021).

The significant reduced hedonic response to sucrose of individuals with eating disorders (bulimia nervosa, anorexia nervosa and various subtypes) was further investigated by Eiber et al. (2002), who hypothesized that this response could be rather linked to fear of weight gain, than to a decreased liking, so an impaired hedonic response (Eiber et al., 2002). The importance of liking in the context of reward processing will be explained in detail later.

The hypothesis was proposed that the decreased hedonic response does not refer to a decreased ability to feel pleasant stimuli, which would be rather a consummatory not a motivational deficit, therefore whether swallowing the sucrose solution produced a significant difference in the “liking”. The individuals with eating disorders liked the sucrose solutions significantly less in the "swallow" than in the "spit" condition. However, the effect disappeared, when the answer to the question “Are you afraid to swallow sucrose solutions?” was included. This fear of swallowing may therefore serve as a moderator and influence the pleasantness ratings of sucrose solutions in individuals with EDs (Eiber et al., 2002).

Another finding was that social anhedonia was correlated significantly positively to depression, as well as the drive for thinness, which is a subscale in the Eating Disorder Inventory (EDI; Garner, et al. 1983). Also, fear and less pleasure was related positively to social anhedonia, when they were swallowing the solution instead of spitting it out (Dolan, Khindri, et al., 2022; Eiber et al., 2002).

Boehm and colleagues (2018) studied anhedonia and symptoms of depression in female patients with anorexia nervosa. The subjects were in different groups such as, acutely ill (N=35), recovered over a longer period (N=33) and 62 healthy control subjects. A part of the group of acutely ill subjects (N=24) at the first time of the survey were re-examined after they achieved at least 15% weight gain. After weight was restored, depressive symptoms decreased significantly, but no change was seen in anhedonia. They therefore conclude, among other things, that anhedonia is a trait characteristic in patients with AN (Boehm et al., 2018).

Concerning anhedonia in patients with AN it can be stated that anhedonia is associated with a greater degree of severity compared to other eating disorders. The AN group (N=78) showed significantly higher anhedonia scores than the control groups, which were Binge Eating Disorder patients (N=76) and weight-restored AN-Patients (N=32) (Davis & Woodside, 2002). Nevertheless, it must be statedthat the meta-analysis by Dolan et al. (2022) also found increased anhedonia in other eating disorders, such as bulimia nervosa and binge-eating disorder. In summary, there is evidence that anhedonia may be related to longer duration of illness (Harrison et al., 2014), but also to increased severity of an eating disorder (Boehm et al., 2018).

To determine the extent to which anhedonia changes during eating disorder treatment, the Eating Disorders Examination Questionnaire (EDE-Q) and the Beck Depression Inventory (BDI) subscale surveys of anhedonia were reviewed at two survey time points. The two time points of researching were at inpatient admission and at hospital discharge, of participants (N=499), with a mean age of 21.46 years. At t1, anhedonia scores (with M=5.04 ± 2.98) were found to be 2-3 standard deviations (Dolan, Brown, et al., 2022) above the mean (M=1.2 ± 1.3) of healthy students (Treadway et al., 2009). Fitting with previous findings by Harrison et al. (2014), which found that acutely ill AN patients scored significantly higher in social anhedonia scales The Revised Social Anhedonia Scale (RSAS; Eckblad et al., 1982) than recovered AN patients (Harrison et al., 2014), Dolan et al.'s (2022) scores also showed a reduction. In conclusion, it can be stated that these results suggest, that anhedonia may decrease during ED treatment.

Reward Processing

In the following paragraph, the phenomenon of reward processing in humans is comprehensively explained. Reward processing is discussed in this context because the present thesis relates to reward processing in individuals with anorexia. This first introduction refers to the basics of reward processing and describes the phenomena of wanting and liking, since these aspects will play a relevant role for the formulated hypotheses.

Reward objects for animals are mostly vegetative in nature, so primary awards like food and sex and therefore derive from the necessity to survive, hence primary rewards. In humans, on the other hand, many other possible rewards are added to this, such as money, power, and security (Schultz et al., 1997). These are the so called higher-order rewards or non-primary rewards (Berridge & Kringelbach, 2015). Rewards have been researched and broken down into its components for many years in a variety of areas (e.g., neurophysiology, behavioural aspects, learning theories, etc.) In this paper, we look in more detail at the distinction between the wanting and liking components of rewards.

The concept of incentive salience (Berridge & Robinson, 2003) is often linked to reward processing and has been formulated on the basis of an animal model (Berridge & Robinson, 2003).

Connected to reward processing and especially involved in identifying rewarding and emotionally salient stimuli is the ventral limbic neural circuit (Kaye et al., 2013). There is some data that supports the hypothesis, that these circuits are altered in AN patients (Kaye et al., 2009). The proposed idea here is that the restricted eating behaviour is due to altered reward processing and, further, altered awareness of homeostatic necessities (Kaye et al., 2013).

Reward processing is classically divided into phases of appetite, consumption, and satiety. Furthermore, brain systems that distinguish between "liking" and "wanting" are studied (Craske et al., 2016). Wanting is a phenomenon, that is differentiable from the phenomenon “liking” - nevertheless, both often occur together (Berridge, 2009). The pleasurable reaction of, for example, eating a piece of chocolate cake can be described as “liking”, whereas the attention seeking salience, that serves as a motivational target, can be characterized as the "wanting" reaction

(Berridge, 2009). The hedonic component of “liking” refers more to the consummatory phase, whilst the anticipatory component is indicated in the “wanting” (Craske et al., 2016), wanting is described as an inherent property of conscious goals (Anselme & Robinson, 2016). In special cases like drug addiction, the phenomena “wanting” and “liking” are known to be dramatically detached when speaking of the same rewards (Morales & Berridge, 2020).

Wanting rewards are often given meaning by their linkage through classical conditioning. Wanting, then, has an underlying but unconscious and objective motivational component (Berridge & Robinson, 2003). For a reward, however, both phenomena are necessary parts. Stimuli that are attributed with this incentive salience, are sought, and elicit appetite (Berridge & Robinson, 2003). The “incentive”, so the reward-associated cue, must be presented before the reward is being handed out. It must therefore also be measured before reward consumption and not during or afterwards (Pool et al., 2016). The hedonistic part of “liking” would not trigger classical reward behaviour without the motivational parts of wanting (Berridge, 2009). “Liking” on the other hand, since it is the sensual reaction to a reward, must be measured during or closely after the consumption of said reward (Pool et al., 2016). Mechanisms that enhance “liking” on a neurobiological basis include hedonic hotspots in the brain, hence specialized subregions like the nucleus accumbens, the orbitofrontal cortex, insula cortex and the brainstem (Morales & Berridge, 2020).

Getting a little deeper into the measurement and operationalisation of wanting and liking: They are commonly investigated as separate and contradictory concepts (Pool et al., 2016), as well as in implicit and explicit measures (Anselme & Robinson, 2016; Berridge & Robinson, 2003). The explicit and implicit measures concerning this thesis will be described thoroughly in the paragraph “procedure”. The incentive salience hypothesis suggest three key elements when measuring the concepts of wanting and liking (Pool et al., 2016). The unconditioned stimulus or generally the rewarding outcome is preceded by the conditioned stimulus, i.e., the cue associated with the reward. But what also plays an important role, is the physiological state of the person in question. Since wanting is produced through a synergy between this current physiological state of a human being and the encounter of the cue that predicts an anticipated reward, neither one can be used alone to measure wanting. Both components must be present in the situation to ensure that the operationalized concept of wanting truly prevails (Balleine, 2005; Pool et al., 2016). To measure the incentive salience and therefore the implicit wanting, it must be an unconscious mechanism, that is tried to be made visible. At the same time the explicit wanting is an aware, cognitive desire that often involves active feeling of being attracted to something. These conscious mechanisms are primarily driven by prior hedonic liking experiences (Pool et al., 2016). Hence, the two mechanism cannot be completely independent from each other but rather coherent in a way that the implicit wanting is potentially independent from the hedonic aspect of the reward (Berridge & Aldridge, 2008).

To objectively measure a liking reaction, a behavioural or neural unconscious liking reaction must accompany the corresponding conscious liking. These reactions can be measured independently, and the subjective rating is not always more accurate than the objective hedonic reaction (Berridge & Kringelbach, 2015).

Basic affective reactions do not only influence the immediate judgement and the approach-avoidance behaviour of individuals (Neumann et al., 2003), but also more sophisticated behaviours such as the consumption of unknown beverages (Winkielman et al., 2005). From the study by Winkielman and colleagues (2005), it can be concluded that subliminal affect and motivation interact. Implicit affective reactions can therefore influence active behaviour without being perceived consciously. This approach is particularly interesting with respect to the present research because liking the given rewards (here: Chocolate milk, sweetened milk, and a mixture of sweetened milk and chocolate milk) can influence the behaviour in subsequent trials.

A current definition of the relationship between motivation and affect states that hedonic behaviour is strongly triggered by incentive value, i.e., that a stimulus triggers either positive or negative affect, resulting in either approach or avoidance (Toates & Gray, 1987; Winkielman et al., 2005).

Another line of research has focused on social and non-social rewards, as well as their perception. Social rewards can be rather heterogeneous, the types range from smiling, caressing, praise, compliments, or many more. Research often included contrasting the differences and stating the similarities of social and non-social rewards (Matyjek et al., 2020).

i. Social touch as a reward

Humans among most other mammals share the need of social proximity and social bonds. Social rewards are sometimes even preferred over food rewards (Mason et al., 1963). Chimpanzees preferred to play with an experimenter over receiving their favourite food even when they were hungry. As a summary of a large body of literature, both neuronal and hormonal responses to anxiety-provoking cues are reduced when social support is available (Von Mohr et al., 2017). Touch plays a very important part in social interaction and has the power to evoke strong emotional reactions (Wilhelm et al., 2001). Regarding its effects, social touch is being investigated whether it has a positive influence on the immune system, the blood pressure, the heart rate and it appears to promote non-aggressive behaviour (Barnett, 2005). Social support seems to reduce activity in brain regions which are commonly connected with emotions and affect (i.e., anterior cingulate cortex, the prefrontal cortex, as well as the dorsolateral and ventrolateral cortex) (Coan et al., 2006; Eisenberger et al., 2007).

Regarding social touch, a distinction is often made between different velocities of stroking in research. Slow speeds are mostly conducted with 1-10 cm/s and is associated with the slow-conducting unmyelinated C tactile afferents, which specific mechanoreceptors in non-glabrous, so hairy skin in mammals (Crucianelli et al., 2016; Korb et al., 2020) This speed is therefore also referred to, as ‘CT-optimal’. The CT fibres seem to code pleasant tactile sensations and the gently and slow touch at this speed, activates those fibres (Von Mohr et al., 2017). Faster, but otherwise identical caresses are known to not activate the CT system optimally and these caresses are therefore perceived as rather neutral (Von Mohr et al., 2017). In research they are often administered at a speed of about 18 cm/s (Crucianelli et al., 2016). Strokes with a higher speed (e.g. 30 cm/s) are mostly rated less pleasant than strokes with a CT-optimal speed (Taneja et al., 2019).

Von Mohr et al. (2017) stated that an increased distress after social exclusion can be modulated by social touch. In their experiment the participants were playing the cyberball-exclusion game for two-three minutes, which is an online-ball-tossing game. In the cyberball exclusion condition, the participants are actively excluded from two computer-generated teammates (whereas the participant thinks these are other participants) and the person received only two ball tosses in the entire game.

Therefore the game can simulate social exclusion (Meneguzzo et al., 2020; Von Mohr et al., 2017). It was also reported from their participants that they felt distress after playing the game. After this round, they were stroked on the forearm, whereas one group was stroked with a soft brush on the forearm in CT-optimal speed (3 cm/s) or with a CT-non-optimal velocity of 18 cm/s. Then the participants were then asked about their positive and negative affect and the pleasantness of the stroking. It was found that the touching was not enough to completely prevent the distress after the exclusion phase, but what can be stated is that the distress in the groups after the exclusion differed. The group which was touched in CT-optimal speed was lower than the distress of those, who were touched in the neutral, CT-non-optimal speed (Von Mohr et al., 2017).

Wilhelm et al. (2001) were considering the above-mentioned effects of social touch to attenuate anxiety and compared a group of high-socially anxious women with low-anxious individuals regarding their attitudes concerning social touch, their affective and their physiological response to social touch. They were caressed on the wrist by a male experimenter. All in all, the individuals in the group who reported more anxiety regarding touch in social situations beforehand, also showed increased self-report anxiety, stronger embarrassment, and were more self-conscious during testing. Regarding physiological parameters such as sympathetic-parasympathetic activation, heart rate changes, skin conductance, but also blood pressure and respiratory rate, among others, no significant differences were found between the two groups (Wilhelm et al., 2001).

ii. Food reward processing

The perception of food rewards, as well as the perception of cocaine, sex, or even monetary rewards, among others, leads to activation of the ventral pallidum. In rats the ventral pallidum is known to perceive hedonic input and it has been shown to be activated stronger when sweet sucrose solutions are presented than when salty, unpleasant solutions are offered (Berridge et al., 2009).

Food rewards and related cues like taste and smells are powerful motivators (Higgs, 2016; Rolls, 2015). It is argued that the response to food cues is influenced by the working memory as well as the episodic memory and it affects how much attention is paid to food cues. There is also a theory that food cues are more attractive to people who are hungry (Higgs, 2016).

The association between altered hedonic responses and obesity has been researched with the response that no empirical support could have been found for the idea that altered sweet taste perception contributes to obesity (De Araujo et al., 2020).

Reward processing in AN

Subsequently, the peculiarities of reward processing in people with eating disorders and then especially the peculiarities of reward processing in people with anorexia nervosa will be discussed. In doing so, the state of scientific research is presented first on touch rewards and then on food rewards.

Because there is also the general concept that individuals with AN exert strong self-control to suppress primary drives, Ehrlich and colleagues (2015) conducted a fMRI study in 30 female recovered AN patients and 30 female healthy controls. The brain reward system was examined during the monetary incentive delay paradigm (Knutson et al., 2001) and during reward-related feedback (Ehrlich et al., 2015). They found no altered response in ventral limbic reward networks, but increased connectivity in lateral-frontal brain circuits in recovered patients. The altered response in the reward expectancy phase occurred therefore in brain regions associated with cognitive control. This may suggest that former patients respond to rewards with increased self-regulatory processes. No difference was found in the behavioural responses of the groups (Ehrlich et al., 2015). This raises the question for the present research of whether there is a detectable difference in behavioural response to rewards when these include food rewards.

Regarding taste sensitivity, one study showed that women suffering from AN showed decreased sensitivity to salty tastes, perceived umami tastes more strongly, and showed more frequent misclassification of sucrose solutions in different strengths than control subjects. What did not differ from controls, however, was hedonic assessment. It was therefore concluded that the altered taste perception was not related to negative attitudes toward food intake (Hartman-Petrycka et al., 2022).

Nozoe and colleagues (1996) examined patients with AN and healthy controls regarding their taste responsiveness development during a behavioural therapy. At admission the taste responsiveness of AN patients was lower compared to controls, but it significantly improved over the course of treatment. There could not have been seen a significant correlation between weight gain and improvement of taste responsiveness, but it improved sooner than patients gained weight. More specifically, taste sensitivity improved significantly at the time 1600 kcal per day were consumed (Nozoe et al., 1996).

Via and colleagues (2015) stated that social behaviour is modulated by reward-based processes, and that dysfunctional brain systems on a reward level have been involved in neurobiological AN theories and models even though there is no evidence whether these neural alterations would be equally present in social contexts. In a fMRI study they assessed the brain activity during acceptance and rejection in a few different tasks and correlated with severity measures of the eating disorders. Patients showed hypoactivation of the dorsomedial prefrontal cortex (DMPFC) during social acceptance and hyperactivation of visual areas during social rejection. Ventral striatum activation during rejection was positively correlated in patients with clinical severity scores. The specific association of reward related regions with clinical measures suggests the involvement of reward structures in the maintenance of pathological behaviours in AN (Via et al., 2015).

Individuals with AN often describe primary rewards, such as sex, food, or pleasant touch, as unpleasant and that they avoid them (Davis & Woodside, 2002; Giel et al., 2011; Klein et al., 2010). Klein and colleagues (2010) examined the behaviour of 24 AN patients and 10 healthy controls and presented them randomly with a variety of concentrated sweet solutions (0; 0.01; 0.03; 0.08 and 0.28% of aspartame). They were instructed to sip as much as they wanted and spit the rest out in a bucket. Furthermore, the self-reported wanting and liking was assessed with a visual analogue scale (VAS). They demonstrated that AN patients sipped significantly less solution (approximately 33%) than healthy controls and there was a tendency towards less intake at the highest aspartame concentrations with a p-value of 0.06 (Klein et al., 2010). It is concluded that no abnormal negative feedback from the visceral system in AN patients causes less food to be ingested. Also, it has been shown that the experimental group consumed significantly more quantity in the first of 3 trials than in trials 2 and 3. This difference could not be found in the control group. Regarding wanting and liking the groups did not differ in the self-report measures which is contradictory to other research which suggests that patients with AN show decreased hedonic responses to sweet (Lacey et al., 1977), high fat solutions (Y.

Simon et al., 1993) or high calorie solutions (Cowdrey et al., 2013), but in line with the research of Y. Simon et al. (1993), were no significant difference in the perception and preference for sweet food could have been detected as well.

Cowdry and colleagues (2013) investigated whether liking and wanting of food in variable densities differed between patients at different stages of AN (N= 64) and healthy controls (N=41). The patient group was divided in 3 subcategories, recovered, weight-restored and current AN patients. To obtain the explicit ratings 16 trials were performed, showing one stimulus at a time and a question aiming at either wanting ("How much do you want some of this food now?") or liking ("How pleasant would it be to experience some of this food now?" and asking to rate on a scale from "not at all" to "extremely". Whereas the implicit ratings for wanting were derived from reaction times, because each of the food stimuli was paired with another from a different food category. The participants were asked to indicate by pressing a button, which food they would like "to eat the most now". The categories comprised high-calorie savoury, high-calorie sweet, low-calorie savoury and low-calorie sweet foods (Cowdrey et al., 2013). In explicit rating the currently ill restrictive-type AN participants liked high-calorie foods significantly less than healthy controls. Currently ill AN participants and weight-restored AN participants wanted high-calorie foods less in explicit ratings than the healthy controls did. Moreover, regarding the implicit wanting ratings is can be stated that the currently ill AN group as well as the weight-restored AN group wanted high-calorie foods less than the healthy controls did. It can also be noted that the currently ill AN group wanted the high-calorie foods significantly less than the recovered AN participants. Significantly greater implicit wanting could have been shown for the currently ill and the weight restored AN groups. One possible explanation for these results can be that starvation regulates and affects the appetite. These findings do support the hypothesis that liking and wanting are two distinct psychological processes and even if the motivational drive is impaired (wanting), the hedonic properties (liking) of food might not be reduced (Cowdrey et al., 2013).

i. Food reward processing in EDs

Regarding the processing of food reward stimuli, it is assumed that patients with AN like hedonic stimuli and are also able to identify hedonic stimuli but it is considered that they are less motivated to receive them, i.e., wanting is less pronounced. It is also concluded from neuroscience studies that altered activity of affected areas (including cingulate cortex and striatum) may explain the strong pursuit of pathological behaviours such as self-starvation. These appear aversive to people who do not suffer from eating disorders and appear to be rewarding in patients with AN (Keating et al., 2012). It is suspected that even in recovered individuals with AN, the ability to process positive or negative feedback in a guessing game is altered and it is figured that recovered AN patients might have an impaired ability to identify emotional significance of certain stimuli. This might explain, why the motivation to engage in treatment is often very low (Wagner et al., 2007).

Food reward processing, so non-social reward processing in patients suffering from bulimic-type disorders was investigated by J.J. Simon et al. (2016), whereas 27 patients had a binge-eating disorder, and 29 patients were diagnosed with bulimia nervosa. 55 matched healthy controls underwent the same event-related fMRI procedure, doing food and monetary incentive delay tasks. It was found that in the experimental group in the food condition, bulimic-type-eating (BTE) patients showed differences in the following regions: decreased brain activation in the posterior cingulate cortex during anticipation of food and increased activity in the medial orbitofrontal cortex, anterior medial anterior prefrontal cortex, and posterior cingulate cortex during receipt of food reward. Their results suggest that regions serving self-control show lower involvement while expecting a non-social reward (here: food) (J. J. Simon et al., 2016).

Giel and colleagues (2011) studied the attentional processing of food pictures in AN patients and healthy controls. AN patients showed more attentional disengagement to food pictures, but they did not show attentional bias toward pictures of food. Healthy control subjects who fasted in the 8-hour period before being tested, showed significantly longer fixation of food pictures than on control pictures. Attentional commitment to food pictures was stronger in healthy controls than in anorectic patients. It was concluded that starvation may increase the intensity of the processing of food related pictures in healthy individuals (Giel et al., 2011).

ii. Altered social reward processing in AN

Regarding the perception of and response to social touch in patients with AN, Crucianelli and colleagues (2016) examined the perceived pleasantness of light stroking (in CT afferents-optimal and non-optimal velocities) on the forearm, applied to individuals with AN and healthy controls while being shown images of faces with neutral, accepting and rejecting expressions. CT-optimal stroking yielded in significantly lower pleasantness rates in AN patients compared with healthy controls, which results in the consideration that the CT-based affective touch system might be impaired in patients suffering from AN. Socially accepting faces increased the perceived pleasantness in both groups to a greater extent than neutral and rejecting faces. It is concluded that this detected altered CT-based touch system may be associated with decreased interoceptive perception and altered body awareness. (Crucianelli et al., 2016).

Regarding the pleasantness of stroking another research group showed that AN patients perceived the stroking of the skin significantly less pleasant than healthy controls. They figured that it was associated with an altered functioning of the dorsal striatum which could affect this altered perception of the tactile stimuli and also drew the conclusion that this might be associated with the distorted body image that is often present in patients suffering from AN (Davidovic et al., 2018)

Crucianelli and colleagues (2021) showed that both acutely ill AN patients as well as recovered AN patients rated slow, low-pressure tactile stimuli on the forearm less pleasant than healthy controls did. It was concluded that tactile anhedonia seems to persist in AN patients even after their recovery (Crucianelli et al., 2021).

iii. Facial muscles as an indicator of implicit liking or disliking

The validity of implicit measurement of wanting and liking was dissected by Tibboel and colleagues (2015). They noted that an implicit test of wanting the individuals desire or need to do something and the (preconscious) process before getting the announced reward. Whereas a valid implicit measure of liking should capture the (preconscious) experience of pleasure (Tibboel et al., 2015).

Human faces are known to express emotions in order to inform those around you about the emotional states you are in (Kulke et al., 2020). Identification of those states is not only a helpful skill for everyone, but it is also crucial in research. The above-mentioned objective and implicit measurement of hedonic aspects of reward perception is often executed via the usage of a facial electromyography (facial EMG) (Berridge, 2000; Korb et al., 2020), because the hedonic response to rewards consists in facial reactions (Korb et al., 2020). The facial EMG records muscle activity through electrodes placed on the subject's skin (Kulke et al., 2020) and allows to detect small or even invisible changes in activation (Korb et al., 2020; Pool et al., 2016). What makes this method so helpful for us is that emotions can be recognized and distinguished by the distinct activity of the muscles involved (Kulke et al., 2020). To differentiate between positive and negative emotions, mostly the Zygomaticus Mayor (ZM) and the Corrugator Supercilii (CS) are used in research. The zygomaticus muscles are responsible for smiling. The second muscle group is responsible for frowning so therefore contracting the eyebrows (Korb et al., 2020; Zeinstra et al., 2009).

In juvenile monkeys as well as human babies' food rewards are known to evoke powerful facial expressions, like middle-face relaxation, lip smacking and tongue protrusion (Berridge, 2000). In adults, reactions to food rewards are also observed, but they are more subtle and often consist of facial muscle relaxation rather than activation (Zeinstra et al., 2009). After consuming rewarding odours or food, the CS spontaneously relaxes and the ZM is known to be activated (Korb et al., 2020; Zeinstra et al., 2009).

We know less about the reaction of the facial muscles during the phase of anticipation of a reward. Korb et al. (2020) studied how the CS and the ZM behave during the anticipation and the consumption of social (affective touch) and non-social (food) rewards. They figured that the CS muscle was activated less intense in trials with higher wanting and greater effort during the anticipation phase. The assumption that the CS is a sensitive measurement for reward processing could have thus been demonstrated (Korb et al., 2020). They did not find any significant modulations of the ZM, what also serves as a research question in this current thesis.

Regarding the impact of social rewards on facial expressions, it was found that the ZM was activated significantly when individuals received CT-optimal strokes with a velocity of 3 cm/s on the forearm. The ZM was not activated when people were caressed with a CT-non optimal speed of 30 cm/s, neither when they were stroked on the palm of their hands (Pawling et al., 2017). However, it was found that the CS muscle activates more strongly when being stroked at a speed of 30 cm/s. This activation happens when the eyebrow muscles are contracted, and it relaxes during smiling. Apart from this, it has been shown that the CS relaxes while stroking at a speed of 3 cm/s, thus it provokes a positive facial expression. From these results, it can be concluded that being touched in the CT-optimal manner can produce positive affective facial expressions, whereas nonoptimal stroking can produce negative facial expressions and thus negative affective responses (Mayo et al., 2018).

iv. Measurement of implicit wanting

Since it has already been stated that wanting and liking should be seen as to separable components they should therefore be measured accordingly. Many studies focused on the connection with drug addiction and therefore manipulated animals administering drugs and hence induce brain changes inherent in studies of drug addiction (Waugh & Gotlib, 2008).

Apart from pharmacological manipulation studies, effort in the anticipation phase of reward processing was proposed as a useable measurement. It was demonstrated that rats choose the less-preferred reward, when it has an easy access to it vs. a preferred reward with a more effortful access (Salamone et al., 2007). To determine the implicit level of wanting in human participants Waugh and colleagues (2008) gave the subjects the opportunity to choose between differently labelled cartoons. They presented them with choice of varying amount of effort to obtain either rewarding or less preferred non-rewarding outcomes. The cartoons were labelled as on average being rated “funny” vs. “not funny”. To measure effort, they used the so-called “click-count”, hence how often the participant would click on a moving square until he or she could see the cartoon. The 2x2 inch black square appeared in a new location several times and the mouse appeared each time in the centre of the screen. It could have been shown, that with higher effort they needed to show, the number of people choosing this cartoon decreased. It was concluded that under high effort it is possible to distinguish well between liking and wanting in people (Waugh & Gotlib, 2008).

Research Questions & Hypotheses

i. Clinical and social significance

The relevance of the specific topic reward processing has been addressed in many publications. The differentiation between wanting and liking has not yet been fully researched and clarified. Even if the neurophysiological correlates have already been presented in several publications (Ehrlich, Geisler, Ritschel, King, Seidel, et al., 2015; Knutson et al., 2001; Via et al., 2015).

The relevance of studying and researching social rewards has only increased since the COVID-19 pandemic. The impact on population's mental health due to social isolation became highly visible (Datta et al., 2022; Hagerty & Williams, 2020; Loades et al., 2020; Schlegl et al., 2020). And thus, a better understanding of the extent to which social rewards are perceived as such and how this also plays out in a clinical sample is needed.

The result is intended to fit into a series of collected information on AN and contribute to a better understanding of this complex phenomenon. A comprehensive understanding of the mechanisms in AN reward processing should contribute to new AN treatments. The altered processing of first and foremost food rewards can make an important contribution here.

Since wanting plays an important role in motivational theories, to better understand the altered processing of wanting in AN patients can also be crucial for developing new treatment strategies. Wagner et al. (2007) figured the ability to recognize the emotional salience in AN patients can be among the reasons why the enhancement of motivation for treatment is very hard. If there was a better understanding of the processes, these insights could be implemented and incorporated in the specific treatments.

ii. Research gap

Viewed comprehensively, it can be stated that the behavioural and hedonistic correlates of reward processing have hardly been clarified yet.

In the existing research, wanting and liking are usually measured only through self-reports and thus cannot be captured in their explicit and implicit dimensions (Pool et al., 2016).

A high percentage of studies generally do not distinguish between wanting and liking, which is considered a very important distinguishing component and can be mentioned as a bias in the data (Pool et al., 2016).

Another point is that in many experiments no “physical” rewards were presented to the participants, but the offering of rewards was only imagined by the subjects. It also happened that rewards were only given at the end of an experimental session and not during the entire experiment (Pool et al., 2016).

Also, the comparison between the reward processing of a healthy population and a population affected by AN has not yet been performed in this form. The result findings may contribute to further understanding of this disorder.

To be able to understand the processing of social rewards in AN patients better, the comparison should be made between healthy controls and individuals with AN regarding the hedonic aspect liking.

Furthermore, it is unclear whether the fear of weight gain or the reduced ability to perceive food as a hedonic reward plays the most important role in this topic. The fear of weight gain (DSM-V, 2020) in general, as well as the fact that food cues are known to trigger arousal and fear in AN patients (Giel et al., 2011). These might be some of the reasons why AN patients are expected to show a poor hedonic response in the food reward trials.

Regarding the processing of touch rewards the derived hypotheses refer to the fact that CT-optimal stroking is assumed to carry a positive affective feeling in the person being touched due to the mediation of the special and separate C-specific tactile neurobiological system (Pawling et al., 2017; Von Mohr et al., 2017). It is therefore assumed that people will show a high hedonic response to touch rewards that are delivered in the speed of 6 cm/s.

These results could also postulate further explanations in what way the reward processing in teenage and adolescent women is altered compared to healthy controls. These population is highly affected of this mental illness and therefore an especially important study target.

This master’s thesis represents a small part of a large-scale fMRI study which focuses on the functional magnetic resonance correlates of this experimental test set-up. The focus of this thesis, as already described, is on the group difference in the explicit and implicit data on wanting and liking of the subjects. The research questions and hypotheses of this master’s thesis emerged from the literature presented. The conditions described in the methods section follow the circumstances arising from the fact that the large-scale study is conducted as an fMRI study. It intends to fill in the knowledge gap in literature described above in the theoretical background and to furthermore make a small contribution to a better understanding of reward processing in general.

What has been established in numerous studies is that anhedonia is elevated in individuals with eating disorders and that greater anhedonia scores are also associated with elevated ED symptoms (Dolan, Brown, et al., 2022; Dolan, Khindri, et al., 2022). Social anhedonia seems to be remarkably high in patients with anorexia nervosa and this seems to be the case in recovered patients also (Harrison et al., 2014). What has also been noted repeatedly in various studies is the decreased subjective perception of pleasure (Crucianelli et al., 2021; Kaye et al., 2013). Also, many primary rewards are not perceived as rewarding but rather unpleasant by eating disorder patients (Davis & Woodside, 2002). Thus, it can be concluded that a reduced hedonic response can be expected from AN patients.

The components wanting and liking will be presented in implicit as well as explicit measurements in comparison between healthy subjects and patients suffering from AN. A conceptual advantage of the study described in this thesis is the sequence and order of measurements since this is adapted to the respective phase in reward processing. The explicit and implicit measurements of wanting are placed before being given the award, hence in the anticipation phase, the explicit and implicit liking is measured during and directly after the reception of the reward.

In more detail: explicit (self-report on a VAS) and implicit wanting (pressing the hand dynamometer, facial muscle activation and relaxation in the anticipation phase) are measured in the phase of expectation of the reward, after it has been announced which reward will be administered. Implicit liking (facial muscle demeanour) is tested during the administration and after the consumption of the reward, whereas explicit liking is tested after the administration.

iii. Research question

Hence, two research questions are derived from literature.

Is the hedonistic perception (liking) of food and touch rewards in individuals with anorexia nervosa altered compared to healthy control subjects?

Is the motivational aspect (wanting) of reward processing of food and touch rewards altered in AN affected patients compared to healthy control subjects.

iv. Hypotheses

The following hypotheses regarding the first research question are derived from literature.

H1a: reduced scores in the explicit rating of food rewards in anorexia nervosa.

H1b: increased tension of the corrugator supercilii in AN patients in food reward trials in the consumption and relaxation phase

H1c: decreased activation of the zygomaticus major in participants with AN in food reward trials in the relaxation phase

H1d: lower values in the explicit liking of the touch rewards in AN patients

H1e: increased tension of the corrugator supercilii in AN patients in touch reward trials in the consumption and the relaxation phase

H1f: decreased activation of the zygomaticus major in participants with AN in touch reward trials in the consumption and relaxation phase

The following hypotheses do not include a group comparison, but pertain only the groups separately:

H1g: lower liking score means in food rewards than in touch rewards in AN patients

H1h: no differences concerning the liking scores in food vs. touch rewards in the control group

Wanting in reward processing in AN patients is less clear in the literature. All hypotheses below refer to AN patients compared to healthy controls. The following hypotheses could be drawn less clearly from the literature and therefore follow the related concept of liking, as no contrary assumptions emerged from the literature.

H2a: decreased explicit scores in wanting in food trials in AN patients

H2b: reduced values of effort, so lower scores in the hand-dynamometer in food trials in AN patients

H2c: increased values of wanting in touch trials in AN patients

H2d: increased values of effort in the hand-dynamometer in touch trials

H2e: increased tension in the CS in AN patients during the anticipation phase in food trials

H2f: increased tension in the CS in AN patients during the anticipation phase in touch trials

H2g: reduced tension in the ZM in AN patients during the anticipation phase in food trials

H2h: reduced tension in the ZM in AN patients during the anticipation phase in touch trials

Methods

Participants

The participants were recruited over flyers, Facebook, personal requests to acquaintances of the experimenters. Women with AN were re-recruited as they have been subjects in previous studies. It was mandatory to do an eligibility pre-screening beforehand. After giving informed consent they were invited to the Vienna General Hospital. Consent was also obtained from the legal guardians if the subjects were under 18 years of age.

The participant sample consisted of 31 female volunteers whereas the sample was divided in AN patients and healthy controls. The 19 participants of the AN group were 15-22 years old (M = 18.11; SD = 2.26) and had a mean BMI of 17.77 (SD = 2.53), whereas the group of the healthy controls consisted of 12 female participants aged 16 – 22 years old (M = 19.42; SD = 2.5) and had a mean BMI of 21.37 (SD = 2.07). The BMI range of the AN group was 13.2 - 22.4. The BMI range in the control group was 18.8 - 25.7. Regarding the weight, the AN group showed a mean weight of 48.9 kg (SD = 7.66) and the control group showed a mean weight of 58.1 kg (SD = 7.0).

Stimuli

i. Social rewards

The social reward was operationalized as gentle caresses on the forearm of the participants. The caresses were delivered by person from the same sex as the participant if the subject was heterosexual. If there had been homosexual participant, the opposite sex would have delivered it, but none of the participants self-reported as being homosexual. The touch was delivered in a 9 cm range which was marked on the forearm of the participant. As derived from the literature a velocity of 3-10 cm/s activate CT-fibres is generally perceived as more pleasurable (Mayo et al., 2018; Pawling et al., 2017). Three different touching speeds were applied: 6 cm/s and therefore correspondingly the highest reward, a low reward with a touching speed of 21 cm/s and also derived from literature the CT-non-optimal touching speed of 27 cm/s (Pawling et al., 2017), which is the very low reward.

ii. Non-social rewards

The non-social rewards were operationalized as food rewards and also consisted of three conditions. All of the three options have the same fat and sugar content (1.5 g fat and 10 g of sugar per 100 g) and comprise of sugared milk, a 4:1 mix of chocolate milk and sweetened milk and chocolate milk, whereas the latter was considered the highest reward. The mix of chocolate milk and sugared milk was considered the low reward and the sweetened milk the very low reward, correspondingly.

Procedure

The study was conducted as a collaboration project of the Medical University of Vienna and the University of Vienna and it took place at the Vienna General Hospital. The procedure is unusual because the large-scale study is an fMRI study, which means that both the behavioural measurements with VAS and the measurements with the hand dynamometer are performed lying down in the MRI tube. The facial EMG is attached before entering the fMRI room and all measurements are taken while the scanner is on. More precisely at 4 distinct time points in each trail. These time points are the first anticipation phase, before the reward is announced, the second anticipation phase after the reward is announced, the consumption phase and the relaxation phase after having consumed the reward.

The participants are examined in a first testing phase by clinical psychologists with a series of psychological questionnaires (among others: Eating Disorder Inventory 2, Diagnostic Interview for Mental Disorders, Junior Temperament und Charakter Inventar, etc..). Afterwards they are taken to the fMRI area and are prepared for the scan there. The facial EMG is also applied in this step. The application of the EMG is done by the same experimenter that accompanies the participant throughout the whole second part of the experiment. After cleaning the respective areas on the face with water and an abrasive paste, electrodes are placed on the left corrugator supercilii and the left zygomaticus major muscles.

After that, the subjects are placed in the scanner which is still switched off for the first phase and the measurement of the maximum voluntary contraction (MVC). Also, their respective reward preferences are ranked after the complete set of three stimuli each is administered. The individual ranking is performed by choosing the most liked and the second most liked of both reward types. After the explanation of the experiment and the four practice trials (each reward type two practice trials) is completed, the real testing takes place with 4 blocks of 16 trials each.

Each block lasts about 10 minutes whereas food blocks are slightly longer (~13 min) than touch blocks (~10 minutes), hence the duration of the whole experiment is about 50 minutes. The order of administration is randomized between the subjects. The participant is instructed that she has ~4 seconds to answer, both for using the hand-dynamometer as well as the explicit answers using the button-box.

The MVC is measured again at the end of the experiment to allow the comparison and to be able to detect fatigue effects.

i. Explicit measures

To allow for explicit self-reporting by the subjects, a VAS is used, as this tool is common in literature. Since the participant is lying down in the scanner, there is a button-box placed in their left hand. The button-box is used to indicate the explicit wanting and the explicit liking. The scale is centred in the middle at the time of the presentation, i.e., neutral, and is adapted by the subject to match how the subject feels, i.e., the indicator bar is moved either to the left (lower wanting or less liking) or to the right (higher wanting or higher liking).

The respective point of measurement results from the operationalization of the two constructs. Wanting is measured after the announcement of the respective reward, since this is the phase of expected reward (Korb et al., 2020).

Liking is again measured after the presentation of the reward, since the consumption of the reward must have already taken place in order to elicit a hedonistic response (Berridge, 2009).

ii. Implicit measures

For the implicit measurement of wanting, the value of the pressure that the person exerts on the hand-dynamometer in the phase of anticipation of reward is measured. The pressure is presented as a percentage change from the personal MVC, measured before the start of the experiment. Participants are asked to press the hand-dynamometer as hard as much they would like to obtain the reward. The instruction indicates that they will definitely obtain the announced reward if they fill up the bar to the top. If they fill it up halfway, the chance is 50:50 if they will receive the highest reward or the low or very low reward. It also applies here that people have 4s time for pressing the dynamometer. Implicit wanting is also measured via facial EMG during the phase of anticipating the announced reward. Facial expressions are determined by using the facial EMG and here more precisely the muscle group responsible for smiling, the Zygomaticus Mayor (ZM) as well as the muscle group for frowning, the Corrugator Supercilii (CS). The anticipated results are as follows: With higher liking and higher wanting, activation of the ZM and relaxation of the CS are expected.

In total, the facial EMG data was recorded in four periods of interest, with three phases being evaluated below. The phases are divided into the anticipation phase, the preparation phase, the delivery phase and the relaxation phase. The anticipation and relaxation phases are evaluated for both muscle groups and both reward types, and the delivery phase is evaluated for both muscle groups in the touch reward type, but only for the CS in the food reward type. This decision is based on the assumption that the data of the zygomaticus mayor is affected by the swallowing of the food-type rewards.

Data Analysis

Statistical analysis

For the statistical analysis the program IBM SPSS Statistics (Statistical Package for Social Sciences) Version 28.0 for Windows was used. To indicate the effect size, the partial η^2 is used. It estimates the explained variance of a given variable after controlling for the influences of all other factors in the overall variability (Okada, 2013).

For inferential statistical analysis, several mixed ANOVAS were performed since between-subject factors and within-subject factors are being examined.

The group factor serves as the intermediate subject factor in each case. The respective inner-subject factors are listed in the description of the relevant subitem. On the one hand, these are the Food vs. Touch reward types, but on the other hand there are also the reward levels, which are different in number.

The conditions relevant for the ANOVA were fulfilled: The dependent variables were at least interval-scaled, and the between-subjects factor group was independent and nominally scaled. Since it is concluded from previous research that the mixed ANOVA is robust to violations of the normal distribution, it was tested but no further action was taken. Levene's test for variance homogeneity, Mauchly's test for sphericity were performed for each ANOVA. If sphericity could not be assumed, the Huynh-Feldt correction is applied (Girden, 1992). The Box-test is tested according to recommendations in the literature with a significance level of 0.01 (Mertler, 2004).

When significant interactions or main effects were found in ANOVA, they were further explored in post-hoc analyses.

Results

Explicit measures of liking (VAS):

In order to find out whether the groups differed in the likening of the two reward types social and non-social in terms of reward levels (high, low, and very low), group membership was set as a between-subjects factor and reward types as well as reward levels as within-subjects factors.

Table 1

Descriptive statistics of the mean values of explicit liking

group	Reward Type	Reward Level	Mean value	95% CI
control	touch	high	33.33	[13.132; 53.535]
		Low	25.433	[6.365; 44.502]
		Very low	-0.142	[-21.075; 20.792]
	food	High	40.083	[14.094; 66.073]
		Low	8.675	[-14.888; 32.238]
		Very low	-34.408	[-60.191; -8.626]
AN	touch	High	53.089	[36.594; 69.583]
		Low	25.206	[9.636; 40.775]
		Very low	-20.689	[-37.781; -3.597]
	food	High	18.339	[-2.881; 39.559]
		Low	5.983	[-13.256; 25.222]
		Very low	-13.644	[-34.696; 7.407]

Across both groups, the mean scores of the explicit liking in both groups decreased from high to very low reward in an expected manner. The same picture emerges when the mean values of the groups are considered separately for both groups as can be seen in Table 1.

Since none of the groups became significant in the Levene's test, it can be assumed that the error variance of the dependent variable is the same across groups. Since sphericity was not confirmed by the Mauchly test, the Huynh-Feldt correction is applied, as this correction is recommended, when epsilon >0.75.

The interaction of group * reward type was not significant under the correction of Huynh-Feldt, $F(1.000, 28.000) = 0.006$, $p = .937$, partial $\eta^2 = .000$. Neither was the interaction of group * reward level significant under the Huynh-Feldt correction, $F(1.932, 54.097) = 0.006$, $p = .993$, partial $\eta^2 = .000$, nor was the reward level * reward type interaction significant under the Huynh-Feldt correction, $F(1.500, 42.002) = 0.060$, $p = .896$, partial $\eta^2 = .002$.

There was a statistically significant interaction between group * reward type * reward level, under the correction of Huynh-Feldt with $F(1.500, 42.002) = 4.396$, $p = .028$, partial $\eta^2 = .136$. This interaction means that there is a two-way interaction that varies across the levels of a third variable.

Table 2

Tests of the within-subject effects of explicit liking

Interaction	F	sig	Partial η^2
Reward type * group	0.006	.937	.000
Reward level * group	0.006	.993	.000
Reward type * reward level	0.060	.896	.002
Reward type * reward level * group	4.396	.028	.136

Since a significant interaction of reward type * reward level * group was shown, the post-hoc analyses performed are now described. The post hoc comparison of the following groups results from the formulated hypotheses: t-test of the anorexia and control groups for liking the high food rewards and another t-test for liking the high touch rewards, to test the hypotheses *H1a* and *H1d*. Since several t-tests are calculated in the following section using the same sample, the Bonferroni-correction is used to compensate for the alpha-error accumulation and the Bonferroni correction is applied here with a p-value of .0125, since 4 t-tests are conducted as post-hoc analyses.

The difference in mean liking of high food rewards between AN patients ($M = 18.3$; $SD = 47.5$) and controls ($M = 40.1$; $SD = 37.8$) was not significant ($t(28) = 1.328$, $p = .098$).

Another t-test for mean liking of high touch rewards was calculated. AN patients (M = 54.9; SD = 36.34) and controls (M = 33.33; SD = 30.12) differed in their rating, (t (28) = -1.716, p = .048). Because the Bonferroni correction requires the p-value to be less than .0125, this interaction is not significant.

Neither significant was the group comparison of low food rewards between AN patients (M = 5.983; SD = 46.44) and controls (M = 8.675; SD = 26.62) with a p-value of .429 and the group comparison of low touch rewards between AN patients (M = 24.25; SD = 34.38) and controls (M = 25.43; SD = 27.21) with a p-value of .458.

To test the hypothesis *H1g* whether the group means in AN patients in the explicit liking of the food condition are lower than the group mean of the touch condition, a paired-samples t-test was calculated. In the AN group, the difference was significant with t (17) = 2.451, p = 0.013, which is still significant even with the Bonferroni-correction applied.

The control group did not differ in their mean liking rates of food vs. touch, so the t-test was not significant, t (11) = -0.546, a p-value of .298, which is heavily above the Bonferroni-corrected cut-off of .025.

Due to the significant interaction, the main effects cannot be interpreted without restrictions.

Table 3

Post-hoc analyses of the main effect in explicit liking

Pairs	T	df	Two-sided p-value
Reward level (high) – reward level (low)	-1.064	59	.292
Reward level (high) – reward level (very low)	0.024	.396	.005
Reward level (low) – reward level (very low)	.734	.470	.165

Explicit measures of wanting (VAS):

To find out whether the groups differed in their explicit rating of wanting, a mixed ANOVA (2x2x3) was calculated with the between-subject factor group and the two within-subject factors reward type and reward level.

Across both groups, the mean scores of explicit wanting in both groups decreased from high to very low reward in an expected manner. The same picture emerges when the mean values of the groups are considered separately for both groups as can be seen in Figure 2.

Table 4

Descriptive statistics of the mean values of explicit wanting

group	Reward Type	Reward Level	Mean value	95% CI
control	touch	high	37.500	[8.273; 66.727]
		Low	-1.917	[-27.361; 23.528]
	food	High	35.925	[16.394; 55.456]
		Low	20.392	[4.112; 36.671]
AN	touch	High	16.522	[-7.341; 40.386]
		Low	2.072	[-18.703; 22.847]
	food	High	52.700	[36.753; 68.647]
		Low	21.950	[8,658; 35.242]

Wanting was normally distributed for all groups, as assessed by the Shapiro-Wilk test ($p > .05$). In the control group there was one slight outlier for "wanting_touch_low", as well as 3 slight and one severe outlier for "wanting_touch_high". Since none of the groups became significant in the Levene's test, it can be assumed that the error variance of the dependent variable is the same across groups. Neither was the box-test significant, which tests for the equality of covariance matrices, which hence can be assumed.

There was no significant interaction between group * reward type, $F(1,28) = 1.265$, $p = .270$, partial $\eta^2 = .043$. There was neither a significant interaction between group * reward level, $F(1,28) = 0.122$, $p = .729$, partial $\eta^2 = .004$. The interaction of group * reward type * reward level was also not significant, $F(1, 28) = 3.270$, $p = .081$, partial $\eta^2 = .105$.

Since we cannot report any significant interactions in the model as visible in table 5, the main effects are now interpreted.

The main effect reward type is significant F (1,28) = 5.980, p-value of .021, partial η² = .176, meaning that the values in the food and touch reward types are significantly different from each other and the reward type touch was significantly wanted more than the food rewards.

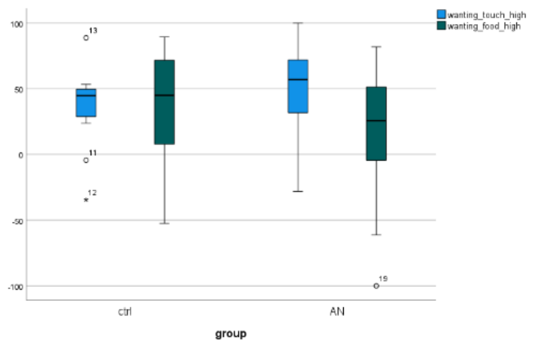
Table 5

Tests of the within-subject effects of explicit wanting

Interaction	F	sig	Partial η²
Reward type * group	1.265	.270	.043
Reward level * group	0.122	.729	.004
Reward type * reward level	0.116	.735	.004
Reward type * reward level * group	3.270	.081	.105

Figure 1

Boxplots showing the comparison of explicit wanting rates of high food rewards and high touch rewards



Boxplots showing the comparison of explicit wanting rates of low food rewards and low touch rewards

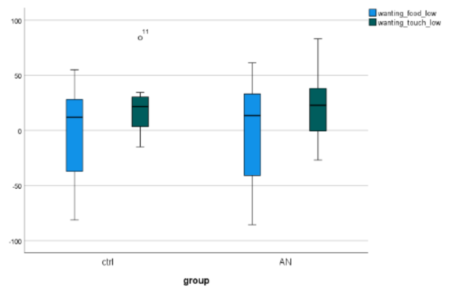


Figure 2

The main effect reward level was also significant with an F (1,28) = 12.872, p value of .001 and a partial η² = .315. This means that the values in the high and low levels in the wanting condition are significantly different from each other. High rewards were wanted more than low rewards.

Figure 3

Boxplots showing the comparison of high and low food rewards between the groups AN and control subjects

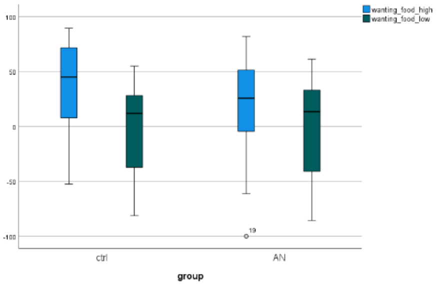
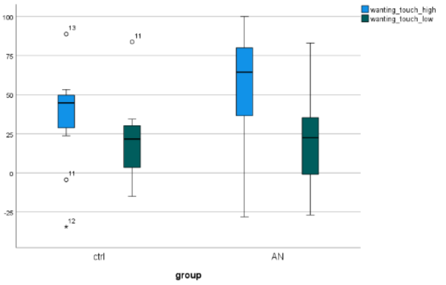


Figure 4

Boxplots showing the comparison of high and low touch rewards between the groups AN and control subjects



The main effect of the between-subjects factor group was not significant with the following values: $F(1,28) = 0.002$, $p = .969$, partial $\eta^2 = .000$. Therefore, there is no dependence of the data on the particular group.

Figure 5

Boxplots showing the comparison of explicit wanting rates in reward types food and touch on the reward levels high and low

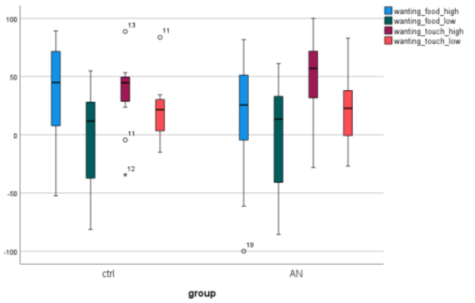


Table 6

Tests of the main effects of explicit wanting

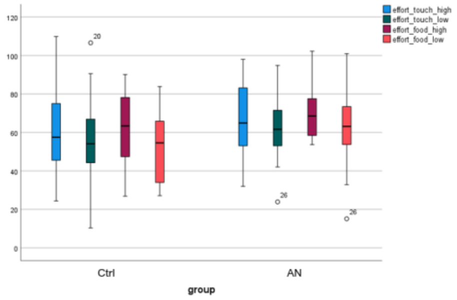
Interaction	F	sig	Partial η²
Reward type	5.980	.021	.176
Reward level	12.872	.001	.315
Group	.002	.969	.000

Implicit measures of wanting (effort):

Wanting was assessed implicitly with the measurement of effort exhibited by the participants. Effort was normally distributed for all groups, as assessed by the Shapiro-Wilk test ($p > .05$). There were three slight outliers, one in the control group for touch_low, one in the anorexia-group for touch_low and one in food_low, as visible in figure 6.

Figure 6

Boxplots showing the comparison of effort exerted in reward types food and touch on the reward levels high and low



None of the groups became significant in the Levene's test, therefore it can be assumed that the error variance of the dependent variable is the same across groups. Neither was the box-test significant, which tests for the equality of covariance matrices.

There was no significant interaction between group * reward type, $F(1,28) = 0.246$, $p = .624$, partial $\eta^2 = .009$. There was neither a significant interaction between group * reward level, $F(1,28) = 0.031$, $p = .862$, partial $\eta^2 = .001$. The interaction of group * reward type * reward level was also not significant, $F(1,28) = 0.012$, $p = .913$, partial $\eta^2 = .000$.

Table 7

Tests of the within-subject effects of implicit wanting

Interaction	F	sig	Partial η^2
Reward type * group	0.246	.624	.009
Reward level * group	0.031	.862	.001

Reward type * reward level	0.875	.358	.030
Reward type * reward level * group	0.012	.913	.000

Since there are no significant interactions, the main effects will be looked at. The main effect reward type was not significant, $F(1,28) = 0.003$, $p = .958$, partial $\eta^2 = .000$. The main effect reward level was significant $F(1,28) = 7.426$, $p = .011$, partial $\eta^2 = .210$. Since the main effect reward level has only two factor levels, the ANOVA can be interpreted as a t-test. The main effect group was also not significant $F(1,28) = 2.102$, $p = .158$, partial $\eta^2 = .070$.

Table 8

Main effects of implicit wanting

Interaction	F	sig	Partial η²
Reward type	0.003	.958	.000
Reward level	7.426	.011	.210
Group	2.102	.158	.070

Implicit measures of wanting and liking (facial EMG):

Implicit measurement of wanting and liking was made possible via application of a facial EMG. The anticipation phase was selected for measuring wanting as an implicit measurement. To determine the liking of the rewards, 2 phases were selected in which the facial EMG data were examined. These were the phase in which the reward was delivered and the relaxation phase after the reward was given. In the delivery phase the touch condition was evaluated completely, in the food condition the ZM was not examined due to the expected unreliable outcomes caused by the natural tension of the mouth area when swallowing liquids.

For the following analysis, some subjects had to be excluded due to technical problems, therefore it will be a N=27 subsequent calculations. The normal distribution was violated in three cases here (food_CS_ar_1; food_ZM_ar_1; touch_CS_ar_2), but as in the previous analyses, the mixed ANOVA is assumed to be robust to normal distribution violations.

The phases are displayed one at a time in the following section:

Anticipation phase

Corrugator Supercilii

A mixed ANOVA with the between-subjects factor group and the within-subjects factors reward type (food or touch), reward level (high or low) was calculated for the corrugator supercilii. Sphericity could be assumed, and the variance homogeneity tested by Levene’s test was not significant in any case.

The interaction reward type * group was not significant, $F(1, 25) = 0.013$, $p = .912$, partial $\eta^2 = .001$. The interaction reward level * group was not significant, $F(1, 25) = 0.028$, $p = .869$, partial $\eta^2 = .001$. The interaction reward type * reward level * group was not significant, $F(1, 25) = 0.029$, $p = .866$, partial $\eta^2 = .001$.

The interaction reward type * reward level was significant, $F(1,25) = 9.132$, $p = .006$, partial $\eta^2 = .268$.

Table 9

Tests of the within-subject effects (CS) in the anticipation phase

Interaction	F	sig	Partial η²
Reward type * group	0.012	.912	.001
Reward level * group	0.028	.869	.001
Reward type * reward level	9.132	.006	.268
Reward type * reward level * group	0.029	.866	.001

The interaction reward type * reward level is shown in Figure 7 and 8 below and as can be seen there the activation of the CS differs for high and low rewards depending on whether they are food or touch rewards. Reward type food shows a mean activation of 0.9996 (SD = 0.065) for high rewards and a mean of 1.0382 (SD = 0.06719) for low rewards. For touch rewards a mean of 1.0226 (SD = 0.04503) for high rewards and a mean of 1.0141 (SD = 0.05017) could have been observed. The values broken down by group are shown in Table 10.

Figure 7

*Comparison of CS activation for reward type * reward level in AN patients*
Reward type 1 = food; Reward type 2 = touch

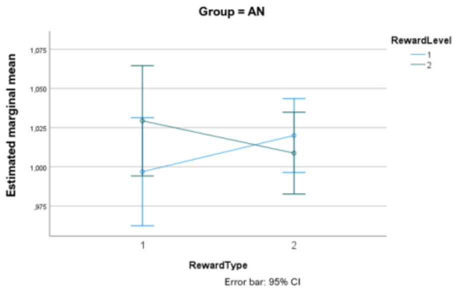


Figure 8

*Comparison of CS activation for reward type * reward level in control patients*
Reward type 1 = food; Reward type 2 = touch

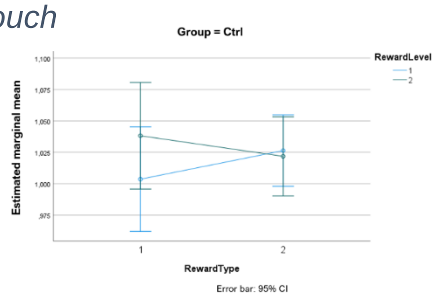


Table 10

Descriptive statistics of the activity of the CS in the anticipation phase

Group	*Reward type*	*Reward level*	*Mean Activation*	*Standard Deviation*
AN	*food*	*high*	*0.9969*	*0.07516*
		low	*1.0294*	*0.07819*
	touch	*high*	*1.0200*	*0.05007*
		low	*1.0088*	*0.05149*
Ctrl	*food*	*high*	*1.0036*	*0.05278*
		low	*1.0382*	*0.05016*
	touch	*high*	*1.0264*	*0.03854*
		low	*1.0218*	*0.04956*

Zygomaticus Mayor

A mixed ANOVA with the between-subjects factor group and the within-subjects factors reward type (food or touch), reward level (high or low) was calculated for the muscle group zygomaticus mayor. Sphericity could be assumed, and the variance homogeneity tested by Levene's test was not significant in any case. None of the interactions concerning the zygomaticus mayor were significant, the exact values can be taken from the table below.

Table 11

Tests of the within-subjects effects (ZM) in the anticipation phase

Interaction	F	sig	Partial η²
Reward Type * group	0.172	.682	.007

Reward level * group	2.775	.108	.100
Reward type * reward level	0.010	.921	.000
Reward type * reward level * group	0.006	.940	.000

Likewise, none of the main effects became significant. The main effect reward type was not significant at $F(1, 25) = 0.218$, $p = .645$, partial $\eta^2 = .009$, nor was the second within-subject factor reward level, $F(1, 25) = 0.389$, $p = .538$, partial $\eta^2 = .015$.

The between-subject factor group was barely not significant at $F(1,25) = 3.738$, $p = .065$, partial $\eta^2 = .130$.

Table 12

Tests of the main effects (ZM) in the anticipation phase

Interaction	F	sig	Partial η^2
Reward type	0.218	.645	.009
Reward level	0.389	.538	.015
Group	3.738	.065	.130

Consumption phase

Corrugator Supercilii

Here we find some missing values, as the data was only recorded when the person received the corresponding reward. So, if there was consistently too little effort to get the high reward, it was never received and therefore no EMG data could be recorded for it.

Due to the significance of the Mauchly test for reward type * reward level ($p = .033$), the Huynh-Feldt correction was applied.

The results of the mixed ANOVA with the between-subjects factor group and the within-subjects factors reward type and reward level are displayed in the table below.

Table 13

Tests of the within-subject effects (CS) in the consumption phase

Interaction	F	sig	Partial η²
Reward Type * group	0.160	.692	.006
Reward level * group	0.943	.396	.034
Reward type * reward level	0.734	.470	.026
Reward type * reward level * group	1.137	.324	.040

In the table is visible that none of the interactions are significant, therefore the main effects can be interpreted.

The main effect reward type was not significant with F (1.000, 27.000) = 0.777 with p = .386 and a partial η^2 = .006. The main effect reward level was significant, F (2.000, 54.000) = 4.167, p = .021, partial η^2 = .134. The main effect group was not significant, F (1,27) = 2.928, p = .099, partial η^2 = .098.

Table 14

Tests of the main effects (CS) in the consumption phase

Interaction	F	sig	Partial η²
Reward Type	0.777	.386	.028
Reward level	4.167	.021	.134
Group	2.928	.099	.098

To further investigate the main effect of reward level post hoc, the reward types were disregarded, and thus new variables were created that include all values of the respective reward level. The reward levels were then all compared using a t-test for paired samples, resulting in an applied significance level of .016 using the Bonferroni correction.

Table 15

Post-hoc analyses of the main effect reward level (CS) in the consumption phase

Pairs	T	df	Two-sided p-value
Reward level (high) – reward level (low)	-1.064	59	.292
Reward level (high) – reward level (very low)	0.024	.396	.005
Reward level (low) – reward level (very low)	.734	.470	.165

Therefore, no significant comparisons using the Bonferroni correction could have been shown.

Zygomaticus Mayor

In the further explanations of the ZM in the consumption phase, only the reward type touch was evaluated, since it is assumed that the evaluation of the muscle group near the mouth is impaired by the swallowing of the liquids in the eating condition and the activation or relaxation cannot be assigned to the liking without interference.

For the following explanations, the between-subjects factor group was used as before and the within-subjects factor reward level. Only the results in the touch trials were used. Since the Mauchly test showed significant results ($p = 0.04$), the Huynh-Feldt correction was applied.

No significant interactions, reward level * group, $F (1.707, 48.507) = 0.179$, $p = .814$, partial $\eta^2 = .007$, nor significant main effects could have been shown. Main effect reward level: $F (1.797, 48.507) = 2.227$, $p = .124$, partial $\eta^2 = .076$. Main effect group: $F (1, 27) = 0.272$, $p = .606$, partial $\eta^2 = .010$.

Table 16

Tests of the within-subject effects (ZM) in the consumption phase + main effects

Interaction	F	sig	Partial η^2

Reward level * group	0.179	.814	.007
Reward level	2.227	.124	.076
Group	0.272	.606	.010

Relaxation phase

Corrugator Supercilii

The relaxation phase was calculated in the same way as described above. The Levene's test for equality of error variances was not significant in any case.

None of the interactions became significant, the exact values can be found in the table below. All values below were adjusted with the Huynh-Feldt correction because the Mauchly test for sphericity was significant, with a p-value of .027 for the reward Level and a p-value of .033 for reward type * reward Level, and the epsilon >0.75.

Table 17

Tests of the within-subject effects (CS) in the relaxation phase

Interaction	F	sig	Partial η^2
Reward Type * group	1.147	.295	.046
Reward level * group	2.068	.149	.152
Reward type * reward level	0.370	.695	.031
Reward type * reward level * group	0.984	.389	.079

Reward type as a main effect is not significant, $F(1, 24) = 0.301$, $p = .588$, partial $\eta^2 = .012$. The main effect reward level is significant under the Huynh-Feldt correction with $F(1, 23.000) = 4.137$, p-value of .029, partial $\eta^2 = .265$. The main effect group is not significant with $F(1, 24) = 1.595$, p-value = .012, partial $\eta^2 = .062$.

For the post hoc analysis, a series of t-tests were conducted to look at the comparisons between the groups in each reward level and in both reward types. The Bonferroni correction is applied.

After applying the Bonferroni correction, hence the p-value would need to be lower than .00833, no significant group comparisons could have been found.

Table 18

Post-hoc analysis: t-tests for equality of means with regard to the groups AN and controls of the CS in the relaxation phase

t-test	T	df	Sig
Food_relaxation_1	2.389	24	.013
Food_relaxation_2	1.018	24	.159
Food_relaxation_3	0.259	25	.798
Touch_relaxation_1	0.818	25	.421
Touch_relaxation_2	- 0.944	25	.354
Touch_relaxation_3	1.041	25	.308

Zygomaticus mayor

The examination of the second muscle group was also performed in the relaxation phase in the same way as described above for the anticipation phase. The Mauchly test for sphericity was not significant in this case, so no correction is applied to the values.

The non-significant interactions are shown with exact values in the table below. The interaction reward level * group was significant, under the Huynh-Feldt correction $F(2, 48) = 3.244$, p-value .048, partial $\eta^2 = .119$.

Table 19

Tests of the within-subject effects (ZM) in the relaxation phase

Interaction	F	sig	Partial η^2
Reward Type * group	0.326	.574	.013
Reward type * reward level	1.746	.185	.068
Reward type * reward level * group	0.317	.730	.013

Due to the significant interaction between group and reward level, post hoc analyses were subsequently conducted to determine in which levels the groups differed significantly. The Bonferroni correction is applied to counteract the alpha error cumulation and therefore the results of the t-test would only be significant below a p-value of <.0083.

For the highest food rewards, the groups did neither significantly differ in food rewards (t (24) = - 0.311, p-value = .379) nor for touch rewards (t (25) = 0.100, p = .461). The groups did not differ in the low food rewards (t (24) = 1.417, p = .085), neither in very low food rewards (t (25) = 2.465, p = .202) nor the very low touch rewards (t (25) = 0.849, p = .171). There was a t (25) = 0.970, p = .010 for the group difference in low touch rewards with, which would mean means that the individuals in the AN group showed a stronger activation of the Zygomaticus Mayor muscle in the relaxation phase. But after the Bonferroni correction is applied, that group difference is not significant either.

Discussion

This master's thesis aimed to provide a comprehensive account of the current state of research on the topic of reward processing at the behavioural level in people affected by anorexia. The limited number of studies on the behavioural aspects of reward processing in anorectic patients can be marked as a research gap. Especially research regarding the distinct investigation of the two components wanting and liking is lacking. The attempt was to present these components in depth and to make them measurable. This was the reason to compare them not only by explicit rating of the subjects on a scale, but also implicitly. As implicit methods, it was chosen that for liking, the activation of two muscle group, e.g., Zygomaticus Mayor and Corrugator Supercilii, was measured via a facial EMG in distinct phases of the experiment. Two methods were used to measure wanting. First, also the activation of these two muscles in the phase of the anticipation of the reward and second, the force applied on a hand dynamometer.

To test these considerations, a sample of 19 female subjects with anorexia and 12 healthy comparison subjects were recruited and presented with social and non-social rewards.

Regarding the explicit ratings of liking there was a significant interaction between group * reward type * reward level. To understand this interaction, a series of post-hoc t-tests was performed.

No significant group differences were found under the Bonferroni correction, meaning that the groups did not differ significantly in their liking of reward levels and reward types. Therefore, the hypothesis *H1a* could not be confirmed. In hypothesis *1a*, it was assumed that the explicit values of liking food rewards would be significantly lower than those of the healthy control subjects. The obtained results were not expected, since it was concluded from the assumed anhedonia of AN patients that hedonistic expression was reduced. Decreased hedonic responses in self-report measures in AN patients were found in different publications to sweet (Lacey et al., 1977), high fat solutions (Y. Simon et al., 1993) or high calorie solutions (Cowdrey et al., 2013). However, the results found here fit with the study by Klein and colleagues, as no differences were found in the statements regarding the self-report liking of the solutions in this case either (Klein et al., 2010). Less surprisingly, the comparison within the AN experimental group showed that AN patients liked the food rewards significantly less than the touch rewards. Whereas it should be noted that the control group does not differ significantly in the mean explicit ratings of liking between reward types.

Contrary to expectations, *H1d* could also not be confirmed which means that there was no significant difference between the explicit liking of touch rewards. It was hypothesized that AN patients would show significantly decreased liking rates for touch trials in comparison to healthy controls. Decreased hedonic responses for AN patients in a variety of categories would have been fitting with the theory that anhedonia is considered a characteristic trait in AN patients (Boehm et al., 2018), which could lead to this lower liking of rewards. Anhedonia is commonly diagnosed in AN patients and is described as a lack of hedonic feelings and not being able to feel pleasure (Dolan et al., 2021; Dolan, Khindri, et al., 2022). Eiber and colleagues (2002) discussed the theory that it is rather the fear of weight gain instead of anhedonia that produces low hedonic responses. The current data cannot support this idea, since there was neither a difference in explicit liking rates in food nor touch. The control group did not differ in their mean explicit liking concerning the two reward types, which meets the expectations beforehand and therefore the hypothesis *H1h* was confirmed.

Against the expectations, the groups did not differ significantly in their explicit rating of wanting the given rewards in both reward types. Here, none of the interactions could be reported as significant, ruling out group differences in terms of reward levels as well as reward types. The hypotheses *H2a* und *H2c* must therefore be rejected. What can be reported as significant here, are several main effects which will be explained hereafter. On the one hand, the main effect reward type was significant, which in this case means that both groups wanted the reward type touch more than the reward type food. On the other hand, the main effect reward level was significant, which means that there were differences in the mean of the explicit wanting of the factor levels based on all subjects. Here it can be seen that in relation to both groups, the high rewards achieved higher wanting scores than low rewards. The explicit motivation was therefore higher to gain the CT-optimal strokes. The motivational component of the effects of CT-optimal stroking could have been identified as a research gap, but Pawling et al. (2017) showed significant activation of the ZM when being caressed on the forearm with a CT-optimal velocity. A general positive affect could in consequence lead to higher motivation to gain that reward.

What was shown as expected in hypothesis *H1g* was a significant lower mean liking in AN patients of food rewards compared to touch rewards. This was expected due to a characteristic that lies within the mental illness anorexia nervosa, which is a negative affect towards food in general and especially high-density and sweet foods (Klein et al., 2010; Lacey et al., 1977). What could also play an important role in that case is reduced taste responsiveness in AN patients, as shown by Nozoe and colleagues (1996). Their results showed that people who have a daily intake over 1600 calories per day are able to detect sweet, salty, sour and bitter taste better than those who do not (Nozoe et al., 1996). The taste responsiveness could have an impact on the liking since the perception seems to be altered.

All values were also measured in another way, implicitly, to give further depth to the data and to see if the explicit response to rewards differs from the less conscious one. To operationalise implicit wanting, a pressure gauge was used, which the participants were asked to press as hard as they would like to have the previously announced reward. They were thus able to influence the reward given to them, as otherwise a reward was given that did not correspond to their personal favourite.

No significant interactions were shown, meaning that the groups did not differ in the amount of effort applied in terms of reward types and reward levels. Thus, in this sample, there were no group differences in implicit wanting in anorexia patients vs. healthy control subjects. This indicated that the hypotheses *H2b* and *H2d* were not confirmed. As no significant interactions were found, the main effects can be interpreted without restriction and here only the main effect reward level became significant, which means that in both groups more effort was shown for the high rewards than for the low ones. The main effects group and reward type were not significant, which means that no different behaviours were found that could be attributed to the group or the different reward category.

Regarding the facial EMG, it must be explained that two muscle groups were measured. The zygomaticus mayor is located on the cheek and is responsible for smiling whereas the corrugator supercilii on the forehead between the eyebrows is responsible for frowning (Korb et al., 2020; Zeinstra et al., 2009). The measurements are described and interpreted here for the anticipation phase, the consumption phase as well as for the relaxation phase. Due to this measurement in two different time slots the results must be interpreted independently. Since the first phase happens to be before receiving the reward, the activation of the facial muscles must be interpreted as showing implicit wanting (Korb et al., 2020; Massaccesi et al., 2021). The phases consumption and relaxation are interpreted as implicit liking.

The second phase that is being looked at here, is the consumption phase. Since it is assumed that the measurement of muscle activity of the ZM group is not unrestrictedly interpretable because the swallowing of liquids happens in this phase, only the CS is interpreted at this point in time for food-trials. The touch trials are outlined for both muscle groups as before for the anticipation phase. The relaxation phase was chosen because it shows the muscular activation just seconds after the consumption of the reward and therefore allows the ZM to also be interpreted as liking.

Across both groups in the anticipation phase, an interaction of reward type and reward level showed a stronger activation of the CS for low food rewards and the exact opposite picture for touch rewards, i.e., a stronger activation when being given high rewards. A stronger activation of the CS muscle therefore indicates stronger frowning and subsequently lower wanting. One could therefore conclude that in both groups the low food rewards were wanted less than the high food rewards in the implicit measurements and that in the touch rewards the low rewards were wanted less. One possible explanation could be that the frequency of the trials resulted in a saturation of the sweet cocoa milk. It could be discussed whether the slow touches, i.e. the high touch rewards, lead less quickly to a form of satiation than the food rewards.

For the ZM, no significant effects were visible in the anticipation phase, which is in line with the results of Korb and colleagues (2020), who also only found significant results for the CS in social and food conditions. Regarding this thesis, the hypotheses *H2f*, *H2g* and *H2h* must therefore be rejected, since no group differences can be stated as significantly different.

Moving on to implicit liking: For the consumption phase, no significant results can be stated regarding the CS and the ZM in the touch trials, nor the CS in the food trials. The main effect reward level was not significant in the post-hoc analysis under the Bonferroni correction. For the relaxation phase for the CS, no significant results can be reported for the ZM, as the post-hoc tests of the significant reward level * group interaction were no longer significant after applying the Bonferroni correction. It was hypothesised in advance, that AN patients would show greater activation of the CS muscle than control subjects in both reward types, which is not supported by the data shown. The hypotheses *H1b* and *H1e* are therefore not accepted. No significant group differences were visible. For the Zygomaticus Mayor muscle group, it was assumed in advance that there would be lower activation for control patients than for anorectic subjects in both reward types. This cannot be concluded from the available data either. The hypotheses *H1c* and *H1f* must therefore be rejected.

It is assumed that the non-significant results regarding facial EMG are partially due to a small number of participants and to technical problems which leads us to the section, where the limitations of this study are outlined. Further investigation of the research questions raised here and this experimental setup with a larger sample size would be desirable.

Limitations

All of these findings need to be interpreted with caution since there are a few important limitations which hinder the unrestricted interpretability.

A very important limitation concerns the sample and may be the main reason for the results not matching the hypotheses. The sample size was too small for the complex design with N=31. Furthermore, it needs to be mentioned that the groups were unequal in size: experimental group N=19, control group N=12. Due to technical problems regarding the scanner and the facial EMG, as well as individual problems, like the hesitation of one participant to consume the food rewards, the sample size varies throughout the measurements.

An improvement of the design would be to further divide the experimental group into patients who are acutely ill, patients who are in partial remission and patients who were previously ill with anorexia but are currently maintaining a healthy weight. The hypotheses should also be tested in this design.

Some very important limitations of the study relate to the external setting. The experiment was conducted in an fMRI scanner in a hospital. These measurements were carried out in the course of an fMRI study and therefore offered a less ecologically valid environment. This artificial environment entails many other problems, including the way the rewards are given. The non-social, i.e. food rewards were given via tubes into the subject's mouth, which is an unnatural drinking situation. The drinking situation was unnatural in another way since the person was laying down inside the scanner, which makes it harder to swallow. Furthermore, the social rewards as touching the forearm are a very strong simplification of this complex topic. This type of operationalisation presents social rewards as far too little complex and greatly reduces them. This type of setting can therefore not be described as externally valid. Therefore, it cannot be concluded from the available data that AN patients and the healthy population evaluate social and non-social rewards in the same way.

One aspect to consider regarding explicit liking of rewards is that of social desirability. The subjects may have indicated a higher liking to meet the researchers' expectations, as the study has the word reward in its name. The apparent background of the research is therefore clear to the subjects and this limitation needs to be considered in terms of explicit rating. Social desirability basically describes the phenomenon that people answer surveys in the way they think is socially appropriate or adequate (Pauls & Stemmler, 2003). This could have been also affected by a personality trait many individuals with AN display, which is perfectionism (Fairburn & Harrison, 2003; Kaye et al., 2009; Strober, 2003).

Another aspect that needs to be addressed are technical difficulties concerning the facial EMG. For many participants, the application of the facial EMG did not work perfectly. This can be caused by insufficient cleaning of the skin areas, but also by incorrect attachment of the electrodes or the loosening of the adhesive surfaces of the electrodes through movement e.g., when lying down in the scanner. The result was that the conductance was not sufficient to provide good results. Therefore the findings of those affected participants cannot be interpreted and also the other results must be interpreted with caution, since the EMG is very sensitive to adverse ascendancies.

Regarding the sample, another aspect must be stated. It was generally speaking very young and exclusively female. Therefore, it is recommended, that the research questions should be tested in other population strata such as older samples or to also include male test persons.

It would be of interest to observe how male and female subjects with anorexia differ, but also whether the young age of the subjects tested in this experimental setup has an influence on the results. It is not possible, or only possible to a very limited extent, to draw conclusions about the reward perception of older subject strata from this population, since the average age of the groups is very young. The mean age of the AN group was 18.11 years and 19.42 years respectively.

It would also be necessary to find out how the severity of anorexia affects reward behaviour. Thus, the severity would have to be included in a regression.

It would also be good to extend the paradigms to other eating disorders and find out if and what differences there are and how, for example, bulimia nervosa affects reward processing.

Current relevance of this research

Two important aspects of reward processing are tackled in this experiment, which are of the social and the non-social kind. Little is known about the individuals' explicit and implicit responses to food and touch rewards, but these insights can indeed play an important role in future treatment and further research. The possibly altered processing of rewards in patients suffering from eating disorders may be a turning point in the way we look at eating disorders. Of importance as well is the component of fMRI data that will also be looked at in the large-scale study this thesis was a part of. The combination of already existing literature and research and the new insights this study provides might take an important part in finding better ways to help young girls suffering from this mental illness.

List of Tables

Table 1 Descriptive statistics of the mean values of explicit liking ……………………………39

Table 2 Tests of the within-subject effects of explicit liking ……………………………………40

Table 3 Post-hoc analyses of the main effect in explicit liking …………………………………41

Table 4 Descriptive statistics of the mean values of explicit wanting …………………………42

Table 5 Tests of the within-subject effects of explicit wanting …………………………………43

Table 6 Tests of the main effects of explicit wanting ……………………………………………44

Table 7 Tests of the within-subject effects of implicit wanting …………………………………45

Table 8 Main effects of implicit wanting …………………………………………………………46

Table 9 Tests of the within-subject effects (CS) in the anticipation phase ……………47

Table 10 Descriptive statistics of the activity of the CS in the anticipation phase …..48

Table 11 Tests of the within-subjects effects (ZM) in the anticipation phase ……….48

Table 12 Tests of the main effects (ZM) in the anticipation phase ……………………...49

Table 13 Tests of the within-subject effects (CS) in the consumption phase ……….50

Table 14 Tests of the main effects (CS) in the consumption phase ……………………50

Table 15 Post-hoc analyses of the main effect reward level (CS) in the consumption phase ……………………………………………………………………………………………51

Table 16 Tests of the within-subject effects (ZM) in the consumption phase + main effects ……………………………………………………………………………………………..51

Table 17 Tests of the within-subject effects (CS) in the relaxation phase ……………52

Table 18 Post-hoc analysis: t-tests for equality of means with regard to the groups AN and controls of the CS in the relaxation phase ………………………………………53

Table 19 Tests of the within-subject effects (ZM) in the relaxation phase ……………53

List of Figures

Figure 1 Boxplots showing the comparison of explicit wanting rates of high food rewards and high touch rewards ……………………………………………..…..………43

Figure 2 Boxplots showing the comparison of explicit wanting rates of low food rewards and high touch rewards …………………………………...…………………43

Figure 3 Boxplots showing the comparison of high and low food rewards between the groups AN and control subjects …………………………..…………….………….44

Figure 4 Boxplots showing the comparison of high and low touch rewards between the groups AN and control subjects ……………..………………………….……………44

Figure 5 Boxplots showing the comparison of explicit wanting rates in reward types food and touch on the reward levels high and low …………………….……….…...44

Figure 6 Boxplots showing the comparison of effort exerted in reward types food and touch on the reward levels high and low …..……………………………………….…45

Figure 7 Comparison of CS activation for reward type*reward level in AN patients..48

Figure 8 Comparison of CS activation for reward type*reward level in control patients……………………………………………………………………………48

List of Abbreviations

A

ACC .... anterior cingulate cortex
AN .... Anorexia Nervosa

B

BMI .... body mass index
BN .... Bulimia Nervosa
BTE .... bulimic-type-eating

C

CS .... Corrugator Supercilii

D

DA .... dopamine
DSM-5 .... Diagnostic and Statistical Manual of Mental Disorders 5

E

EDE-Q .... Eating Disorder Examination Questionnaire
EDs .... eating disorders
EMG .... electro myography

F

fMRI .... functional magnetic resonance imaging

G

GWAS .... genome wide associations studies

I

ICD-10 .... International Classification of Diseases 10

M

MVC .... maximum voluntary contraction

S

SIAB-EX .... Structured Inventory for Anorexic and Bulimic Syndromes

V

VAS .... visual analogue scale

Z

ZM .... Zygomaticus Mayor

References

American Psychiatric Association. (2022). *Diagnostic and Statistical Manual of Mental Disorders, Text Revision DSM-5-TR* (5.). American Psychiatric Association Publishing.

Anselme, P., & Robinson, M. J. F. (2016). "Wanting," "liking," and their relation to consciousness. *Journal of Experimental Psychology: Animal Learning and Cognition*, *42*(2), 123–140. https://doi.org/10.1037/xan0000090

Balleine, B. W. (2005). Neural bases of food-seeking: Affect, arousal and reward in corticostriatolimbic circuits. *Physiology and Behavior*, *86*(5), 717–730. https://doi.org/10.1016/j.physbeh.2005.08.061

Barnett, L. (2005). Keep in touch: The importance of touch in infant development. *Infant Observation*, *8*(2), 115–123. https://doi.org/10.1080/13698030500171530

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2016). *Neurowissenschaften Ein grundlegendes Lehrbuch für Biologie, Medizin und Psychologie*. https://doi.org/https://doi.org/10.1007/978-3-662-57263-4

Beck, K. D., & Luine, V. N. (1999). Food deprivation modulates chronic stress effects on object recognition in male rats: role of monoamines and amino acids. *Brain Research*, *830*(1), 56–71. https://doi.org/10.1016/S0006-8993(99)01380-3

Berrettini, W. (2004). The Genetics of Eating Disorders. *Psychiatry*, *1*, 18–25.

Berridge, K. C. (2000). Measuring hedonic impact in animals and infants: Microstructure of affective taste reactivity patterns. *Neuroscience and Biobehavioral Reviews*, *24*(2), 173–198. https://doi.org/10.1016/S0149-7634(99)00072-X

Berridge, K. C. (2009). 'Liking' and 'wanting' food rewards: Brain substrates and roles in eating disorders. *Physiology & Behavior*, *97*(5), 537–550. https://doi.org/10.1016/j.physbeh.2009.02.044.

Berridge, K. C., & Aldridge, J. W. (2008). Decision utility, the Brain and Pursuit of hedonic Goals. *Social Cognition*, *26*(5), 621–646.

Berridge, K. C., & Kringelbach, M. L. (2015). Pleasure Systems in the Brain. *Neuron*, *86*(3), 646–664. https://doi.org/10.1016/j.neuron.2015.02.018

Berridge, K. C., & Robinson, T. E. (2003). Parsing reward. *Trends in Neuroscience*, *26*(9). https://doi.org/10.1016/S0166-2236(03)00233-9

Berridge, K. C., Robinson, T. E., & Aldridge, J. W. (2009). Dissecting components of reward : “liking”, “wanting”, and learning. *Current Opinion in Pharmacology*, *9*, 65–73. https://doi.org/10.1016/j.coph.2008.12.014

Birmingham, C. L., Su, J., Hlynsky, J. A., Goldner, E. M., & Gao, M. (2005). The mortality rate from anorexia nervosa. *International Journal of Eating Disorders*, *38*(2), 143–146. https://doi.org/10.1002/eat.20164

Boehm, I., Flohr, L., Steding, J., Holzapfel, L., Seitz, J., Roessner, V., & Ehrlich, S. (2018). The Trajectory of Anhedonic and Depressive Symptoms in Anorexia Nervosa : A Longitudinal and Cross-Sectional Approach. *European Eating Disorders Review*, *26*(2002), 69–74. https://doi.org/10.1002/erv.2565

Clark Bryan, D., Macdonald, P., Ambwani, S., Cardi, V., Rowlands, K., Willmott, D., & Treasure, J. (2020). Exploring the ways in which COVID-19 and lockdown has affected the lives of adult patients with anorexia nervosa and their carers. *European Eating Disorders Review*, *28*(6), 826–835. https://doi.org/10.1002/erv.2762

Coan, J. A., Schaefer, H. S., & Davidson, R. J. (2006). Lending a hand: Social regulation of the neural response to threat. *Psychological Science*, *17*(12), 1032–1039. https://doi.org/10.1111/j.1467-9280.2006.01832.x

Coniglio, K. A., Christensen, K., Haynos, A. F., Rienecke, R. D., & Selby, E. A. (2019). The posited effect of positive affect in anorexia nervosa : Advocating for a forgotten piece of a puzzling disease. *International Journal of Eating Disorders*, *February*, 971–976. https://doi.org/10.1002/eat.23147

Cowdrey, F. A., Finlayson, G., & Park, R. J. (2013). Liking compared with wanting for high- and low-calorie foods in anorexia nervosa: Aberrant food reward even after weight restoration1-3. *American Journal of Clinical Nutrition*, *97*(3), 463–470. https://doi.org/10.3945/ajcn.112.046011

Craske, M. G., Meuret, A. E., Ritz, T., Treanor, M., & Dour, H. J. (2016). Treatment for Anhedonia: A Neuroscience driven Approach. *Despression and Anxiety*, *938*, 927–938. https://doi.org/10.1002/da.22490

Crucianelli, L., Cardi, V., Treasure, J., Jenkinson, P. M., & Fotopoulou, A. (2016). The perception of affective touch in anorexia nervosa. *Psychiatry Research*, *239*, 72–78. https://doi.org/10.1016/j.psychres.2016.01.078

Crucianelli, L., Demartini, B., Goeta, D., Nisticò, V., Saramandi, A., Bertelli, S., Todisco, P., Gambini, O., & Fotopoulou, A. (2021). The Anticipation and Perception of Affective Touch in Women with and Recovered from Anorexia Nervosa. *Neuroscience*, *464*, 143–155. https://doi.org/10.1016/j.neuroscience.2020.09.013

Datta, N., Van Wye, E., Citron, K., Matheson, B., & Lock, J. D. (2022). The COVID-19 pandemic and youth with anorexia nervosa: A retrospective comparative cohort design. *International Journal of Eating Disorders*, *June*, 1–6. https://doi.org/10.1002/eat.23817

Davidovic, M., Karjalainen, L., Starck, G., Wentz, E., Björnsdotter, M., & Olausson, H. (2018). Abnormal brain processing of gentle touch in anorexia nervosa. *Psychiatry Research - Neuroimaging*, *281*(March 2017), 53–60.

https://doi.org/10.1016/j.pscychresns.2018.08.007

Davis, C., Blackmore, E., Katzman, D. K., & Fox, J. (2005). Female adolescents with anorexia nervosa and their parents : a case-control study of exercise attitudes and behaviours. *Psychological Medicine*, *35*, 377–386. https://doi.org/10.1017/S0033291704003447

Davis, C., & Woodside, D. B. (2002). Sensitivity to the rewarding effects of food and exercise in the eating disorders. *Comprehensive Psychiatry*, *43*(3), 189–194. https://doi.org/10.1053/comp.2002.32356

De Araujo, I. E., Schatzker, M., & Small, D. M. (2020). Rethinking food reward. *Annual Review of Psychology*, *71*, 24.1-24.26. https://doi.org/10.1146/annurev-psych-122216-011643

Dobrescu, S. R., DInkler, L., Gillberg, C., Råstam, M., Gillberg, C., & Wentz, E. (2020). Anorexia nervosa: 30-year outcome. *British Journal of Psychiatry*, *216*(2), 97–104. https://doi.org/10.1192/bjp.2019.113

Dolan, S. C., Brown, T. A., Wierenga, C. E., Kaye, W. H., & Reilly, E. E. (2022). Changes in anhedonia over the course of eating disorder treatment. *International Journal of Eating Disorders*, *July 2021*, 399–405. https://doi.org/10.1002/eat.23673

Dolan, S. C., Khindri, R., Franko, D. L., Thomas, J. J., & Reilly, E. E. (2022). Anhedonia in eating disorders : A meta-analysis and systematic review. *International Journal of Eating Disorders*, *August 2021*, 161–175. https://doi.org/10.1002/eat.23645

Dolan, S. C., Thomas, J. J., Khindri, R., Franko, D. L., Reilly, E. E., & Kamryn, E. T. (2021). Anhedonia in eating disorders : A meta-analysis and systematic review. *International Journal of Eating Disorders*, *November 2021*, 161–175. https://doi.org/10.1002/eat.23645

Eddy, K. T., Keel, P. K., Dorer, D. J., Delinsky, S. S., Franko, D. L., & Herzog, D. B. (2002). Longitudinal comparison of anorexia nervosa subtypes. *International Journal of Eating Disorders*, *31*(2), 191–201. https://doi.org/10.1002/eat.10016

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

Eiber, R., Berlin, I., De Brettes, B., Foulon, C., & Guelfi, J. D. (2002). Hedonic response to sucrose solutions and the fear of weight gain in patients with eating disorders. *Psychiatry Research*, *113*(1–2), 173–180. https://doi.org/10.1016/S0165-1781(02)00232-9

Eisenberger, N. I., Taylor, S. E., Gable, S. L., Hilmert, C. J., & Lieberman, M. D. (2007). Neural pathways link social support to attenuated neuroendocrine stress responses. *NeuroImage*, *35*(4), 1601–1612. https://doi.org/10.1016/j.neuroimage.2007.01.038

Fairburn, C. G., & Harrison, P. J. (2003). Eating disorders. *The Lancet*, *361*, 407–416.

Fichter, M. M., Herpertz, S., Quadflieg, N., & Herpertz-Dahlmann, B. (1998). Structured interview for anorexic and bulimic disorders for DSM- IV and ICD-10: Updated (third) revision. *International Journal of Eating Disorders*, *24*(3), 227–249. https://doi.org/10.1002/(SICI)1098-108X(199811)24:3<227::AID-EAT1>3.0.CO;2-O

Fichter, M. M., Quadflieg, N., Crosby, R. D., & Koch, S. (2017). Long-term outcome of anorexia nervosa: Results from a large clinical longitudinal study. *International Journal of Eating Disorders*, *50*(9), 1018–1030. https://doi.org/10.1002/eat.22736

Fichter, M. M., Quadflieg, N., & Hedlund, S. (2006). Twelve-year course and outcome predictors of anorexia nervosa. *International Journal of Eating Disorders*, *39*(2), 87–100. https://doi.org/10.1002/eat.20215

Frank, G. K., Kaye, W. H., Weltzin, T. E., Perel, J., Moss, H., McConaha, C., & Pollice, C. (2001). Altered response to meta-chlorophenylpiperazine in anorexia nervosa: Support for a persistent alteration of serotonin activity after short-term weight restoration. *International Journal of Eating Disorders*, *30*(1), 57–68. https://doi.org/10.1002/eat.1054

Frank, G. K. W., DeGuzman, M. C., & Shott, M. E. (2019). Motivation to eat and not to eat – The psycho-biological conflict in anorexia nervosa. *Physiology and Behavior*, *206*(October 2018), 185–190. https://doi.org/10.1016/j.physbeh.2019.04.007

Giel, K. E., Friederich, H.-C., Teufel, M., Hautzinger, M., & Enck, P. (2011). Attentional Processing of Food Pictures in Individuals with Anorexia Nervosa — An Eye-Tracking Study. *Society of Biological Psychiatry*, *69*(7), 661–667. https://doi.org/10.1016/j.biopsych.2010.09.047

Girden, E. R. (1992). *ANOVA: repeated measures*. Newbury Park, CA: Sage.

Gorwood, P., Kipman, A., & Foulon, C. (2003). The human genetics of anorexia nervosa. *European Journal of Pharmacology*, *480*(1–3), 163–170. https://doi.org/10.1016/j.ejphar.2003.08.103

Hagerty, S. L., & Williams, L. M. (2020). The impact of COVID-19 on mental health: The interactive roles of brain biotypes and human connection. *Brain, Behavior, and Immunity - Health*, *5*(April), 4–7. https://doi.org/10.1016/j.bbih.2020.100078

Haleem, D. J. (2011). Serotonin Neurotransmission in Anorexia Nervosa. In S. R. Mitchell (Ed.), *Appetite: Regulation, Role in Disease and Control*. Nova Science Publishers, Inc.

Harrison, A., Mountford, V. A., & Tchanturia, K. (2014). Social anhedonia and work and social functioning in the acute and recovered phases of eating disorders. *Psychiatry Research*, *218*(1–2), 187–194. https://doi.org/10.1016/j.psychres.2014.04.007

Hartman-Petrycka, M., Klimacka-Nawrot, E., Ziora, K., Suchecka, W., Gorczyca, P., Rojewska, K., & Blonska-Fajfrowska, B. (2022). Perception of Taste Sensations in Adolescent Females with Anorexia Nervosa. *Nutrients*, *14*(5).

Herpertz-Dahlmann, B., Hagenah, U., Vloet, T., & Holtkamp, K. (2005). Essstörungen in der Adoleszenz. *Praxis Der Kinderpsychologie Und Kinderpsychiatrie*, *54*(4), 248–267.

Higgs, S. (2016). Cognitive processing of food rewards. *Appetite*, *104*, 10–17. https://doi.org/10.1016/j.appet.2015.10.003

Hudson, J. I., Hiripi, E., Pope, 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/10.1016/j.biopsych.2006.03.040

Kaye, W. H., Fudge, J. L., & Paulus, M. (2009). New insights into symptoms and neurocircuit function of anorexia nervosa. *Nature Reviews Neuroscience*, *10*(8), 573–584. https://doi.org/10.1038/nrn2682

Kaye, W. H., Wierenga, C. E., Bailer, U. F., Simmons, A. N., & Bischoff-Grethe, A. (2013). Nothing tastes as good as skinny feels: The neurobiology of anorexia nervosa. *Trends in Neurosciences*, *36*(2), 110–120. https://doi.org/10.1016/j.tins.2013.01.003

Keating, C. (2010). Theoretical perspective on anorexia nervosa: The conflict of reward. *Neuroscience and Biobehavioral Reviews*, *34*(1), 73–79. https://doi.org/10.1016/j.neubiorev.2009.07.004

Keating, C., Tilbrook, A. J., Rossell, S. L., Enticott, P. G., & Fitzgerald, P. B. (2012).

Reward processing in anorexia nervosa. *Neuropsychologia*, *50*(5), 567–575. https://doi.org/10.1016/j.neuropsychologia.2012.01.036

Keel, P. K., Dorer, D. J., Eddy, K. T., Franko, D., Charatan, D. L., & Herzog, D. B. (2003). Predictors of mortality in eating disorders. *Archives of General Psychiatry*, *60*(2), 179–183. https://doi.org/10.1001/archpsyc.60.2.179

Keski-Rahkonen, A., Hoek, H. W., Susser, E. S., Linna, M. S., Sihvola, E., Raevuori, A., Bulik, C. M., Kaprio, J., & Rissanen, A. (2007). Epidemiology and course of anorexia nervosa in the community. *American Journal of Psychiatry*, *164*(8), 1259–1265. https://doi.org/10.1176/appi.ajp.2007.06081388

King, J. A., Geisler, D., Ritschel, F., Boehm, I., Seidel, M., Roschinski, B., Soltwedel, L., Zwipp, J., Pfuhl, G., Marxen, M., Roessner, V., & Ehrlich, S. (2015). Global cortical thinning in acute anorexia nervosa normalizes following long-term weight restoration. *Biological Psychiatry*, *77*(7), 624–632. https://doi.org/10.1016/j.biopsych.2014.09.005

Klein, D. A., Schebendach, J. E., Gershkovich, M., Smith, G. P., & Walsh, B. T. (2010). Modified sham feeding of sweet solutions in women with anorexia nervosa. *Physiology and Behavior*, *101*(1), 132–140. https://doi.org/10.1016/j.physbeh.2010.04.030

Knutson, B., Adams, C. M., Fong, G. W., & Hommer, D. (2001). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *The Journal of Neuroscience*, *21*(16), 1–5. https://doi.org/10.1523/jneurosci.21-16-j0002.2001

Korb, S., Massaccesi, C., Gartus, A., Lundström, J. N., Rumiati, R., Eisenegger, C., & Silani, G. (2020). Facial responses of adult humans during the anticipation and consumption of touch and food rewards. *Cognition*, *194*(August 2019), 104044. https://doi.org/10.1016/j.cognition.2019.104044

Kulke, L., Feyerabend, D., & Schacht, A. (2020). A Comparison of the Affectiva iMotions Facial Expression Analysis Software With EMG for Identifying Facial Expressions of Emotion. *Frontiers in Psychology*, *11*(February), 1–9. https://doi.org/10.3389/fpsyg.2020.00329

Lacey, J. H., Stanley, P. A., & Crutchfield, M. (1977). Sucrose Sensitivity in Anorexia Nervosa. *Journal of Psychosomatic Research*, *21*, 17–21.

Lee, S., Chan, Y. Y. L., & Hsu, L. K. G. (2003). The intermediate-term outcome of Chinese patients with anorexia nervosa in Hong Kong. *American Journal of Psychiatry*, *160*(5), 967–972. https://doi.org/10.1176/appi.ajp.160.5.967

Loades, M. E., Chatburn, E., Higson-Sweeney, N., Reynolds, S., Shafran, R., Brigden, A., Linney, C., McManus, M. N., Borwick, C., & Crawley, E. (2020). Rapid Systematic Review: The Impact of Social Isolation and Loneliness on the Mental Health of Children and Adolescents in the Context of COVID-19. *Journal of the American Academy of Child and Adolescent Psychiatry*, *59*(11), 1218-1239.e3. https://doi.org/10.1016/j.jaac.2020.05.009

Löwe, B., Zipfel, S., Buchholz, C., Dupont, Y., Reas, D. L., & Herzog, W. (2001). Long-term outcome of anorexia nervosa in a prospective 21-year follow-up study. *Psychological Medicine*, *31*(5), 881–890. https://doi.org/10.1017/S003329170100407X

Lucas, A. R., & Holub, M. I. (1995). The Incidence of Anorexia Nervosa in Adolescent Residents of Rochester, Minnesota, During a 50-Year Period. In *Eating Disorders in Adolescence* (pp. 3–20). De Gruyter. https://doi.org/10.1515/9783110808537-005

Mason, W. A., Saxob, S. V, & Sharpe, L. G. (1963). Preferential Responses of Young Chimpanzees to Food and Social Rewards. *The Psychological Record*, *2014*(860), 645–655.

https://repositories.lib.utexas.edu/handle/2152/39127%0Ahttps://cris.brighton.ac.uk/ws/portalfiles/portal/4755978/Julius+Ojebode%27s+Thesis.pdf%0Ausir.salford.ac.uk/29369/1/Angela_Darvill_thesis_esubmission.pdf%0Ahttps://dspace.lboro.ac.uk/dspace-jspui/ha

Massaccesi, C., Korb, S., Skoluda, N., Nater, U. M., & Silani, G. (2021). Effects of Appetitive and Aversive Motivational States on Wanting and Liking of Interpersonal Touch. *Neuroscience*, *464*, 12–25. https://doi.org/10.1016/j.neuroscience.2020.09.025

Matyjek, M., Meliss, S., Dziobek, I., & Murayama, K. (2020). A Multidimensional View on Social and Non-Social Rewards. *Frontiers in Psychiatry*, *11*(August), 1–8. https://doi.org/10.3389/fpsyt.2020.00818

Mayo, L. M., Lindé, J., Olausson, H., Heilig, M., & Morrison, I. (2018). Putting a good face on touch: Facial expression reflects the affective valence of caress-like touch across modalities. *Biological Psychology*, *137*(June), 83–90. https://doi.org/10.1016/j.biopsycho.2018.07.001

Meneguzzo, P., Collantoni, E., Bonello, E., Busetto, P., Tenconi, E., & Favaro, A. (2020). The predictive value of the early maladaptive schemas in social situations in anorexia nervosa. *European Eating Disorders Review*, *28*(3), 318–331. https://doi.org/10.1002/erv.2724

Mertler, C. A. (2004). *Advanced and Multivariate Statistical Methods: Practical Application and Interpretation* (3rd ed.). Pyrczak Publishing.

Micali, N., Hagberg, K. W., Petersen, I., & Treasure, J. L. (2013). The incidence of eating disorders in the UK in 2000-2009: Findings from the General Practice Research Database. *BMJ Open*, *3*(5), 3–10. https://doi.org/10.1136/bmjopen-2013-002646

Mischoulon, D., Eddy, K. T., Keshaviah, A., Dinescu, D., Ross, S. L., Kass, A. E., Franko, D. L., & Herzog, D. B. (2011). Depression and eating disorders:

Treatment and course. *Journal of Affective Disorders*, *130*(3), 470–477. https://doi.org/10.1016/j.jad.2010.10.043

Morales, I., & Berridge, K. C. (2020). “Liking” and “wanting” in eating and food reward : Brain mechanisms and clinical implications. *Physiology & Behavior*, *227*(August), 113152. https://doi.org/10.1016/j.physbeh.2020.113152

Neumann, R., Förster, J., & Strack, F. (2003). Motor Compatibility: The Bidirectional Link Between Behavior and Evaluation. In *The Psychology of Evaluation: Affective Processes in Cognition and Emotion* (pp. 391–412). https://doi.org/10.4324/9781410606853-22

Nozoe, S. I., Masuda, A., Naruo, T., Soejima, Y., Nagai, N., & Tanaka, H. (1996). Changes in taste responsiveness in patients with anorexia nervosa during behavior therapy. *Physiology and Behavior*, *59*(3), 549–553. https://doi.org/10.1016/0031-9384(95)02105-1

Okada, K. (2013). Is Omega Squared Less Biased? a Comparison of Three Major Effect Size Indices in One-Way Anova. *Behaviormetrika*, *40*(2), 129–147. https://doi.org/10.2333/bhmk.40.129

Oswald, L. M., Wong, D. F., McCaul, M., Zhou, Y., Kuwabara, H., Choi, L., Brasic, J., & Wand, G. S. (2005). Relationships Among Ventral Striatal Dopamine Release, Cortisol Secretion, and Subjective Responses to Amphetamine. *Neuropsychopharmacology*, *30*(4), 821–832. https://doi.org/10.1038/sj.npp.1300667

Pauls, C. A., & Stemmler, G. (2003). Substance and bias in social desirability responding. *Personality and Individual Differences*, *35*(2), 263–275. https://doi.org/10.1016/S0191-8869(02)00187-3

Pawling, R., Cannon, P. R., McGlone, F. P., & Walker, S. C. (2017). C-tactile afferent stimulating touch carries a positive affective value. *PLoS ONE*, *12*(3), 1–15.

https://doi.org/10.1371/journal.pone.0173457

Pirke, K. M., & Platte, P. (1995). Neurobiology of Eating Disorders in Adolescence. In *Eating Disorders in Adolescence*. https://doi.org/10.1176/appi.books.9781585623860.as50

Pool, E., Sennwald, V., Delplanque, S., Brosch, T., & Sander, D. (2016). Measuring wanting and liking from animals to humans : A systematic review. *Neuroscience and Biobehavioral Reviews*, *63*, 124–142. https://doi.org/10.1016/j.neubiorev.2016.01.006

Raney, T. J., Thornton, L. M., Berrettini, W., Brandt, H., Crawford, S., Fichter, M. M., Halmi, K. A., Johnson, C., Kaplan, A. S., LaVia, M., Mitchell, J., Rotondo, A., Strober, M., Woodside, D. B., Kaye, W. H., & Bulik, C. M. (2008). Influence of overanxious disorder of childhood on the expression of anorexia nervosa. *International Journal of Eating Disorders*, *41*(4), 326–332. https://doi.org/10.1002/eat.20508

Rolls, E. T. (2015). Taste, olfactory, and food reward value processing in the brain. *Progress in Neurobiology*, *127–128*, 64–90. https://doi.org/10.1016/j.pneurobio.2015.03.002

Salamone, J. D., Correa, M., Farrar, A., & Mingote, S. M. (2007). Effort-related functions of nucleus accumbens dopamine and associated forebrain circuits. *Psychopharmacology*, *191*(3), 461–482. https://doi.org/10.1007/s00213-006-0668-9

Sanders, N., Smeets, P. A. M., van Elburg, A. A., Danner, U. N., van Meer, F., Hoek, H. W., & Adan, R. A. H. (2015). Altered food-cue processing in chronically ill and recovered women with anorexia nervosa. *Frontiers in Behavioral Neuroscience*, *9*(FEB), 1–11. https://doi.org/10.3389/fnbeh.2015.00046

Schlegl, S., Maier, J., Meule, A., & Voderholzer, U. (2020). Eating disorders in times of the COVID-19 pandemic—Results from an online survey of patients with anorexia nervosa. *International Journal of Eating Disorders*, *53*(11), 1791–1800. https://doi.org/10.1002/eat.23374

Schultz, W. (2006). Behavioral theories and the neurophysiology of reward. *Annual Review of Psychology*, *57*, 87–115. https://doi.org/10.1146/annurev.psych.56.091103.070229

Schultz, W., Dayan, P., & Montague, P. R. (1997). A neural substrate of prediction and reward. *Science*, *275*(5306), 1593–1599. https://doi.org/10.1126/science.275.5306.1593

Shin, L. M., & Liberzon, I. (2010). The neurocircuitry of fear, stress, and anxiety disorders. *Neuropsychopharmacology*, *35*(1), 169–191. https://doi.org/10.1038/npp.2009.83

Simon, J. J., Skunde, M., Walther, S., Bendszus, M., Herzog, W., & Friederich, H. C. (2016). Neural signature of food reward processing in bulimic-type eating disorders. *Social Cognitive and Affective Neuroscience*, *11*(9), 1393–1401. https://doi.org/10.1093/scan/nsw049

Simon, Y., Bellisle, F., Monneuse, M.-O., Samuel-Lajeunesse, B., & Drewnowksi, A. (1993). Taste Responsiveness in Anorexia Nervosa. *British Journal of Psychiatry*, *177*(11), 699–700. https://doi.org/10.1097/00005053-198911000-00008

Skowron, K., Kurnik-Lucka, M., Dadánksi, E., Betkowska-Korpala, B., & Gil, K. (2020). Backstage of Eating Disorder — About the Biological Mechanisms behind the Symptoms of Anorexia Nervose. *Nutrients*, *12*. https://doi.org/doi:10.3390/nu12092604

Södersten, P., Nergårdh, R., Bergh, C., Zandian, M., & Scheurink, A. (2008). Behavioral neuroendocrinology and treatment of anorexia nervosa. *Frontiers in*

Neuroendocrinology, *29*(4), 445–462. https://doi.org/10.1016/j.yfrne.2008.06.001

Steinhausen, H. C. (2009). Outcome of Eating Disorders. *Child and Adolescent Psychiatric Clinics of North America*, *18*(1), 225–242. https://doi.org/10.1016/j.chc.2008.07.013

Steinhausen, H. C., Jakobsen, H., Helenius, D., Munk-Jørgensen, P., & Strober, M. (2015). A nation-wide study of the family aggregation and risk factors in anorexia nervosa over three generations. *International Journal of Eating Disorders*, *48*(1), 1–8. https://doi.org/10.1002/eat.22293

Strober, M. (2003). Pathologic Fear Conditioning and Anorexia Nervosa : On the Search for Novel Paradigms. *Clinical and Research Forum*. https://doi.org/10.1002/eat.20029

Strober, M., Freeman, R., Lampert, C., Diamond, J., & Kaye, W. (2000). Controlled family study of anorexia nervosa and bulimia nervosa: Evidence of shared liability and transmission of partial syndromes. *American Journal of Psychiatry*, *157*(3), 393–401. https://doi.org/10.1176/appi.ajp.157.3.393

Taneja, P., Olausson, H., Trulsson, M., Svensson, P., & Hansen, L. B. (2019). Defining pleasant touch stimuli : a systematic review and meta - analysis. *Psychological Research*, *0123456789*. https://doi.org/10.1007/s00426-019-01253-8

Tchanturia, K., Davies, H., Harrison, A., Fox, J. R. E., Treasure, J., & Schmidt, U. (2012). Altered Social Hedonic Processing in Eating Disorders. *International Journal of Eating Disorders*, *45*(8), 962–969. https://doi.org/10.1002/eat.22032

Tibboel, H., De Houwer, J., & Van Bockstaele, B. (2015). Implicit measures of “wanting” and “liking” in humans. *Neuroscience and Biobehavioral Reviews*, *57*, 350–364. https://doi.org/10.1016/j.neubiorev.2015.09.015

Toates, F., & Gray, J. (1987). Motivational Systems. *The Quarterly Review of*

Biology, *62*(3), 346–347.

Trace, S. E., Baker, J. H., Pe, E., & Bulik, C. M. (2013). The Genetics of Eating Disorders. *Annual Review of Clinical Psychology*, *9*, 589–620. https://doi.org/10.1146/annurev-clinpsy-050212-185546

Treadway, M. T., Buckholtz, J. W., Schwartzman, A. N., Lambert, W. E., & Zald, David, H. (2009). Worth the ‘ EEfRT ’? The Effort Expenditure for Rewards Task as an Objective Measure of Motivation and Anhedonia. *PLoS ONE*, *4*(8), 1–9. https://doi.org/10.1371/journal.pone.0006598

Treasure, J., Zipfel, S., Micali, N., Wade, T., Stice, E., Claudino, A., Schmidt, U., Frank, G. K., Bulik, C. M., & Wentz, E. (2015). Anorexia nervosa. *Nature Reviews Disease Primers*, *1*(November), 1–22. https://doi.org/10.1038/nrdp.2015.74

Tuschen-Caffier, B., & Svaldi, J. (2014). Evidenzbasierte Diagnostik und Psychotherapie bei Essstörungen. *Psychotherapeut*, *59*(3), 253–265. https://doi.org/10.1007/s00278-014-1050-8

Via, E., Soriano-Mas, C., Sánchez, I., Forcano, L., Harrison, B. J., Davey, C. G., Pujol, J., Martínez-Zalacaín, I., Menchón, J. M., Fernández-Aranda, F., & Cardoner, N. (2015). Abnormal social reward responses in anorexia nervosa: An fmri study. *PLoS ONE*, *10*(7), 4–8. https://doi.org/10.1371/journal.pone.0133539

Von Mohr, M., Kirsch, L. P., & Fotopoulou, A. (2017). The soothing function of touch: Affective touch reduces feelings of social exclusion. *Scientific Reports*, *7*(1), 1–9. https://doi.org/10.1038/s41598-017-13355-7

Wagner, A., Aizenstein, H., Venkatraman, V. K., Fudge, J., May, J. C., Mazurkewicz, L., Frank, G. K., Bailer, U. F., Fischer, L., Nguyen, V., Carter, C., Putnam, K., & Kaye, W. H. (2007). Altered reward processing in women recovered from anorexia nervosa. *American Journal of Psychiatry*, *164*(12), 1842–1849.

https://doi.org/10.1176/appi.ajp.2007.07040575

Waugh, C. E., & Gotlib, I. H. (2008). Motivation for reward as a function of required effort: Dissociating the “liking” from the “wanting” system in humans. *Motivation and Emotion*, *32*(4), 323–330. https://doi.org/10.1007/s11031-008-9104-2

Wilhelm, F. H., Kochar, A. S., Roth, W. T., & Gross, J. J. (2001). Social anxiety and response to touch: Incongruence between self-evaluative and physiological reactions. *Biological Psychology*, *58*(3), 181–202. https://doi.org/10.1016/S0301-0511(01)00113-2

Winkielman, P., Berridge, K. C., & Wilbarger, J. L. (2005). Unconscious Affective Reactions to Masked Happy Versus Angry Faces Influence Consumption Behavior and Judgments of Value. *Personality and Social Psychology Bulletin*, *31*(1), 121–135. https://doi.org/10.1177/0146167204271309

Zeinstra, G. G., Koelen, M. A., Colindres, D., Kok, F. J., & de Graaf, C. (2009). Facial expressions in school-aged children are a good indicator of “dislikes”, but not of “likes.” *Food Quality and Preference*, *20*(8), 620–624. https://doi.org/10.1016/j.foodqual.2009.07.002

Zhu, Y., Hu, X., Wang, J., Chen, J., Guo, Q., Li, C., & Enck, P. (2012). Processing of Food , Body and Emotional Stimuli in Anorexia Nervosa : A Systematic Review and Meta-analysis of Functional Magnetic Resonance Imaging Studies. *European Eating Disorders Review*, *20*(1999), 439–450. https://doi.org/10.1002/erv.2197

Appendix

Abstract (English)

Anorexia Nervosa is a disorder that is easy to diagnose but difficult to treat. A central starting point in the research of new treatment methods, relates to reward processing. Reward processing itself is a complex topic as well. In particular, its aspects wanting and liking, which are hardly differentiated in everyday use.

In this thesis the two elements, wanting and liking, were investigated based on using social (touch) and non-social (food) rewards in individuals suffering from anorexia nervosa compared to healthy control subjects. The separate aspects of reward processing were measured in explicit and in implicit terms.

The following two research questions were raised in advance. First: Is the hedonistic perception (liking) of food and touch rewards in individuals with anorexia nervosa altered compared to healthy control subjects? Second: Is the motivational aspect (wanting) of reward processing of food and touch rewards altered in AN affected patients compared to healthy control subjects?

31 female subjects were included in an experimental design. The statistical analyses were performed using multiple mixed analyses of variance, when comparing groups (AN: N=19, Ctrl: N=12), as this allows the testing of both within- and between-subject variables.

Overall, no significant group differences could have been shown regarding the explicit liking and explicit wanting of food or touch rewards. It was ascertained that AN patients liked food rewards significantly less than touch rewards. Furthermore, it can be reported that both experimental groups wanted the reward type touch more than the reward type food. Regarding the implicit measurements neither significant differences between the AN patients and the healthy control subjects for liking could have been shown, nor for wanting of the rewards. These findings suggest further research in these areas is needed.

Abstract (German)

Magersucht (Anorexia Nervosa) ist eine Störung, die zwar leicht zu diagnostizieren, aber schwer zu behandeln ist. Ein zentraler Ansatzpunkt bei der Erforschung neuer Behandlungsmethoden bezieht sich auf die Belohnungsverarbeitung. Die Belohnungsverarbeitung selbst ist ebenfalls ein komplexes Thema. Insbesondere die Aspekte des Belohnungssystems „Wollen“ und „Mögen“, die im Alltagsgebrauch kaum unterschieden werden.

In dieser Arbeit wurden diese beiden Elemente „Wollen“ und „Mögen“ anhand der Verwendung von sozialen (Berührung) und nicht-sozialen (Essen) Belohnungen bei Personen mit Anorexia Nervosa im Vergleich zu gesunden Kontrollpersonen untersucht. Die einzelnen Aspekte der Belohnungsverarbeitung wurden sowohl in expliziter und impliziter Form gemessen.

Die beiden folgenden Forschungsfragen wurden im Vorfeld gestellt. Erstens: Unterscheidet sich die hedonistische Wahrnehmung (Vorliebe) von Nahrungs- und Berührungsbelohnungen bei Personen mit Anorexia Nervosa im Vergleich zu gesunden Kontrollpersonen? Zweitens: Unterscheidet sich der motivationale Aspekt (Wollen) der Belohnungsverarbeitung von Nahrungs- und Berührungsbelohnungen bei AN-Patienten im Vergleich zu gesunden Kontrollpersonen?

Es wurden 31 weibliche Probanden in einem experimentellen Design untersucht. Die statistischen Analysen wurden mit Hilfe von gemischten Varianzanalysen durchgeführt, um einen Gruppenvergleich zu ermöglichen (AN: N=19, Ctrl: N=12).

Zusammenfassend lässt sich sagen, dass keine signifikanten Gruppenunterschiede in Bezug auf die explizite Vorliebe und das explizite Verlangen nach Nahrung oder Berührungsbelohnungen gezeigt werden konnten. Es wurde jedoch festgestellt, dass AN-Patienten Belohnungen für Essen signifikant weniger mochten als Belohnungen für Berührung. Des Weiteren kann berichtet werden, dass beide Versuchsgruppen den Belohnungstyp Berührung stärker wollten als den Belohnungstyp Nahrung. Bei den impliziten Messungen konnten weder für das Mögen noch für das Wollen der Belohnungen signifikante Unterschiede zwischen den AN-Patienten und den gesunden Kontrollpersonen nachgewiesen werden. Diese Ergebnisse legen nahe, dass weitere Forschung in diesen Bereichen erforderlich ist.