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When control over food spirals out of control: investigating the cognitive mechanisms of food hyper-selectivity in individuals suffering from anorexia nervosa and orthorexia nervosa

Clara Lakritz

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Abstract in English

While it is common for individuals to monitor their food intake, doing so excessively can lead to a loss of control and potentially result in the development of an eating disorder. The objective of this thesis was to explore how the desire to control one's food intake can lead to a loss of control. To achieve this, two models were examined: anorexia nervosa and orthorexia nervosa.

We identified three types of factors involved: 1) the individual's environment, which can be associated with higher rates of eating disorders and orthorexia nervosa: we found a greater risk of developing eating disorders in culinary arts students compared with dietetics students and the general population; 2) the relationship to the body underlying food categorization: we found a stronger association between food and bodily stimuli in subjects suffering from anorexia nervosa compared with control subjects ; 3) a high perception of risk when making food choices: we found that individuals with anorexia nervosa and high traits of orthorexia nervosa used specific food categorization strategies, which suggested a higher perception of risk when making food choices within these populations compared to control populations..

This thesis provides a better understanding of the categorization processes involved in anorexia and orthorexia nervosa. It paves the way for further studies on risk perception and the accompanying emotional responses, such as fear and anxiety. Additionally, the findings can be used to develop cognitive-behavioral interventions for individuals struggling with anorexia and orthorexia nervosa.

Key words: Eating disorders; food categorization; food restriction; control; body image; risk perception.

Titre en français : Quand le contrôle de son alimentation devient incontrôlable: étude des mécanismes cognitifs de l'hypersélectivité alimentaire chez les personnes souffrant d'anorexie mentale et d'orthorexie mentale

Abstract in French

Le contrôle de son alimentation est devenu une préoccupation majeure, mais qui peut parfois amener à l'individu à perdre le contrôle sur son alimentation et amener jusqu'aux troubles du comportement alimentaire (TCA). Cette thèse s'est intéressée à comprendre comment la volonté de contrôler son alimentation peut mener à la perte de contrôle, en s'appuyant sur deux modèles : l'anorexie mentale et l'orthorexie mentale.

Nous avons identifié trois types de facteurs impliqués : 1) l'environnement de l'individu : nous avons observé des plus grandes prévalences chez les étudiants en arts culinaires par rapport aux étudiants en diététique et à la population générale ; 2) le rapport au corps qui sous-tend la catégorisation des aliments : nous avons trouvé une association plus forte entre les stimuli alimentaires et corporels chez les sujets souffrant d'anorexie mentale par rapport aux sujets témoins ; 3) une perception élevée du risque lors des choix alimentaires : les individus souffrant d'anorexie mentale et d'orthorexie mentale utilisaient des stratégies spécifiques de catégorisation des aliments, suggérant une perception du risque plus élevée lors des choix alimentaires au sein de ces populations par rapport aux populations témoins.

Cette thèse permet de mieux comprendre les processus de catégorisation impliqués dans l'anorexie et l'orthorexie mentale. Elle ouvre la voie pour de nouvelles études sur la perception du risque et des réactions émotionnelles qui peuvent en découler telles que la peur et l'anxiété, et ainsi cibler les interventions de types cognitivo-comportementales dans l'anorexie et l'orthorexie mentale.

Mots clés : Troubles du comportement alimentaire ; catégorisation alimentaire ; restriction alimentaire ; contrôle ; image du corps ; perception du risque.

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Extended abstract in French

Au cours des dernières décennies, une augmentation significative des préoccupations alimentaires au sein de la population générale a été identifiée, accompagnée par des préoccupations liées à l'image de soi et à l'image corporelle, et amplifiée par l'exposition aux médias sociaux. Des marqueurs de l'importance de ces préoccupations sont le développement de nombreux outils de suivi de l'alimentation (par exemple, des applications pour téléphones), et l'explosion du nombre de programmes de régime, relayés par les médias et les influenceurs des médias sociaux.

Cependant, le fait d'exercer un contrôle extrême sur son alimentation et son corps a été décrit comme un symptôme central des troubles des conduites alimentaires tels que l'anorexie mentale, ou des perturbations émergentes des conduites alimentaires tels que l'orthorexie mentale. L'anorexie mentale est une maladie mentale caractérisée par 1) une restriction de l'apport énergétique par rapport aux besoins, conduisant à un poids corporel significativement bas, 2) une peur intense de prendre du poids, et 3) une perturbation par le poids ou la forme du corps, une estime de soi influencée par le poids ou la forme du corps, ou un manque persistant de reconnaissance de la gravité de l'insuffisance pondérale (American Psychiatric Association, 2013). L'orthorexie mentale se caractérise par une obsession de manger des aliments sains, accompagnée de pensées et de comportements rigides (Donini et al., 2022). Dans les deux cas, ce contrôle extrême de l'alimentation est souvent associé à une sélectivité extrême (ou hyper-sélectivité) des aliments, avec l'exclusion de certaines catégories d'aliments. De plus, dans les deux cas la restriction extrême de l'apport alimentaire échappe au contrôle de l'individu, avec une incapacité à modifier les règles et le contrôle de l'alimentation. Cette thèse cumule trois années de recherche répondant à la problématique suivante : comment la volonté de contrôler son alimentation peut-elle aller au-delà du contrôle de l'individu ?

L'objectif principal de cette thèse était d'étudier les mécanismes cognitifs sous-jacents à l'hyper-sélectivité alimentaire dans le contexte d'un contrôle extrême de son alimentation, tel qu'il peut être observé dans l'anorexie mentale et l'orthorexie mentale.

Une première étude a été réalisé dans l'objectif de savoir si le risque développement de troubles des conduites alimentaires ou d'orthorexie mentale chez les individus dépendaient de leur environnement. Plus précisément, si les environnements qui exposent fortement les individus à la connaissance des aliments et où les individus doivent manipuler quotidiennement des

concepts liés à l'alimentation, peuvent être liés à un risque plus élevé de troubles des conduites alimentaires et d'orthorexie mentale. Ces risques ont été évalués grâce à des questionnaires auto-déclaratifs, et comparés dans deux populations étudiantes : une en école d'arts culinaires, et la seconde en écoles de diététique et nutrition (chapitre 5). Ensuite, nous avons cherché à comprendre comment se faisait la perception et le raisonnement au sujet des aliments dans l'anorexie mentale. En utilisant les tâches d'association implicites avec des stimuli visuels, nous avons testé l'association implicite entre les stimuli alimentaires et corporels chez des patients souffrant d'anorexie mentale, en les comparant à des sujets témoins (chapitre 6). Puis nous avons testé l'association implicite entre les stimuli alimentaires et les attributs moraux (chapitre 7). Enfin, nous avons mené trois études successives où nous avons étudié la perception et le raisonnement au sujet des aliments dans la population générale en fonction de la sévérité des traits d'orthorexie mentale des individus (chapitre 8).

Nous avons identifié plusieurs types de facteurs impliqués dans l'hyper-sélectivité alimentaire de l'anorexie mentale et de l'orthorexie mentale. Le premier facteur impliqué que nous avons trouvé est l'environnement de l'individu : nous avons observé des risques plus élevés de troubles des conduites alimentaires et d'orthorexie mentale chez les étudiants en arts culinaires par rapport aux étudiants en diététique et à la population générale. Le deuxième facteur est le rapport au corps qui sous-tend la catégorisation des aliments : nous avons trouvé une association plus forte entre les stimuli alimentaires et corporels chez les sujets souffrant d'anorexie mentale par rapport aux sujets témoins. Il est à noter que le rapport moral à l'alimentation a été retrouvé autant chez les patients souffrant d'anorexie mentale que dans la population générale, quel que soit l'intensité des traits d'orthorexie mentale. Ce rapport moral n'est donc pas discriminant entre nos populations, et ne semble donc pas être lié uniquement à l'hyper-sélectivité alimentaire vu dans l'anorexie mentale et l'orthorexie mentale. Enfin, le troisième facteur trouvé étant impliqué dans l'hyper-sélectivité alimentaire de l'anorexie mentale et de l'orthorexie mentale est une perception élevée du risque lors des choix alimentaires : les individus souffrant d'anorexie mentale et d'orthorexie mentale utilisaient des stratégies spécifiques de catégorisation des aliments, suggérant une perception du risque plus élevée lors des choix alimentaires au sein de ces populations par rapport aux populations témoins.

Cette thèse permet ainsi de mieux comprendre les processus de catégorisation impliqués dans l'anorexie mentale et l'orthorexie mentale. Elle ouvre la voie pour de nouvelles études sur la perception du risque et des réactions émotionnelles qui peuvent en découler telles que la peur et l'anxiété, et ainsi cibler les interventions de types cognitivo-comportementales dans l'anorexie mentale et l'orthorexie mentale.

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This thesis is written in English, except for the acknowledgement section, which is in French. I wrote this section in my native language since it comes straight from my heart.

Le travail de thèse demeure principalement solitaire. Cette solitude s'est vue exacerbée par le contexte pandémique des trois dernières années. C'est donc avec d'autant plus de gratitude que je tiens à remercier les personnes qui m'ont entourée dans ce parcours.

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Contents

General Introduction

Over the last decades, there has been a significant increase in eating concerns among the general population, accompanying the influx of nutritional advice from various media sources and national health programs. As a results, numerous brands and labels now emphasize and guarantee a certain nutritional quality of food, all relayed by the media and social networks. These eating concerns were also associated with major changes in eating habits, including preference for eating organic, eating local, etc., with different aims: ecological, ethical, nutritional, but also with the idea of having a healthy body, or a thin body. These nutritional preoccupations were also accompanied by preoccupations about self-image and body image, amplified by social media exposure on platforms like Instagram and TikTok. Markers of the importance of these preoccupations are the development of numerous tools to track diet (e.g., phone applications), and the explosion of the number of diet programs, relayed by media and social media influencers. One salient example is the alkaline diet, which has even been related by several celebrities. The alkaline diet is based on the theory that some foods cause your body to produce acid, which is harmful. The belief underlying this diet is that by eating certain foods or drinking certain kinds of beverages, you can change the body's acid level, and changing the body's pH level can improve your health, help you lose weight, and even fight cancer. However, to date, no study has demonstrated such an effect (Hamaguchi et al., 2022; Schwalfenberg, 2012). In parallel, these rules and monitoring tools developed for the control of diet were also developed for physical activity, so that today, access to (more or less reliable) information on how to eat healthily and have a healthy or thin body is presented as being extremely easy. The inability to follow a certain diet or certain rules is then perceived as a flagrant lack of willpower and a great weakness.

However, exerting an extreme control over one's diet and body has been describe as a core symptom in eating disorders such as anorexia nervosa, or disordered eating such as orthorexia nervosa. Anorexia nervosa is a mental illness characterized by a restriction of energy intake relative to physical requirements, intense fear of gaining weight or becoming fat, and disturbance by one's body weight or shape, self-worth influenced by body weight or shape, or persistent lack of recognition of severity of underweight (American Psychiatric Association, 2013a). Orthorexia nervosa is characterized by an obsession with eating healthy food accompanied by rigid thoughts and behaviors, leading to emotional, psychological and social distress (Donini et al., 2022). In both disorders, this extreme control over diet is frequently

associated with an extreme selectivity of foods with the exclusion of certain food categories. This exclusion can be based on different food properties. In anorexia nervosa, this exclusion of food is mainly based on calorie content and beliefs, whereas in orthorexia nervosa this exclusion of food is based on the food's presumed effect on health, wherein food considered “unhealthy” are excluded. This food hyperselectivity can be detrimental to the individual’s health, frequently leading to malnutrition and serious nutrient deficiencies.

Another common feature of this extreme control over one’s diet, seen in anorexia nervosa and orthorexia nervosa, lies in the fact that the extreme food intake restriction goes beyond the control of the individual, with an inability to change rules and control over food. The spiral of extreme restriction can sometimes lead, if not stopped in time, to severe consequences, including death.

In fact, anorexia nervosa is considered one of the deadliest mental illnesses with a standardized mortality ratio of 5.86 (Arcelus et al., 2011). Its prevalence is estimated at 0.4% in young women over 12 months (American Psychiatric Association, 2013a), and is much less common in men than in women, with a sex ratio of 1:10 among clinical populations. The earliest data pointed out a lifetime prevalence rates up to 4% among women and 0.3% among men (van Eeden et al., 2021). Orthorexia nervosa is estimated to affect between 0.5 and 8% of the general population (Barthels et al., 2015; Donini et al., 2005; Dunn et al., 2017; Luck-Sikorski et al., 2019), and is considered as leading to negatively affect individual’s health status (both physical and mental health) and quality of life.

This thesis, which began in November 2020, cumulates three years of research responding to the research problem: how can the will to control one's diet goes beyond the individual's control?

The overarching aim was to investigate the cognitive mechanisms underlying food hyperselectivity in the context of extreme control over one’s diet, as it might be observed in anorexia and orthorexia nervosa.

The present Ph.D. project was conducted in collaboration with the Institute Paul Bocuse Research Center (IBPR) and Laboratory of Health, Individuals and Society (P2S) in the Claude Bernard Lyon1 University, along with the financial support from the Apicil Group. In addition, Dr. Sylvain Iceta, Assistant Professor in the Department of Psychiatry and Neurosciences in the Faculty of Medicine of Laval University, also provided an additional scientific supervision and support.

This doctoral dissertation consists of 9 chapters, structured under three sections. Part A comprises four chapters describing the theoretical framework, the objective and hypotheses. Part B presents the four studies we conducted in the form of manuscripts suitable for scientific publication in a peer-reviewed international journal (one published, two submitted, one is a work in progress). Part C provides a discussion and conclusion on the empirical findings and the contribution of this research to understanding mechanisms underlying extreme control over food.

Part A – Theoretical framework

Chapter 1. Controlling your diet can also become pathological

This chapter 1 provides a definition of control over one's diet and examines the various degrees of control over one's diet from healthy eating habits to eating disorders.

1.1 Controlling your diet: Definition and characteristics.

Today's Western environment is qualified as "obesogenic", with its abundance of food, particularly calorie-rich and processed foods. Such an environment may contribute to overeating and poses a serious challenge for maintaining a healthy weight or being/staying healthy (T. W. Smith et al., 2004). For many, controlling one's diet may appears therefore necessary to keep the body healthy and/or within a certain range of recommended weight and shape.

Controlling one's diet has been translated in behavioral terms as restricting food intake. Among different mechanisms, a restriction of food intake implies self-control in decision-making about food choices.

Controlling a certain behavior presupposes one or more motivations for doing so, which in the case of eating behaviour are numerous. The main and most often motivation studied is the desire to lose weight or maintain a weight, and in many cases underpinned by body dissatisfaction and drive for thinness (Dunkley et al., 2001). In these cases, restriction of food intake is both quantitative, with restriction of calories, and qualitative, with avoidance of fat. In fact, a significant number of individuals attempt to regulate their food intake for the purpose of weight loss. A study conducted by French and colleagues (1999) revealed that over 70% of American adults had made efforts to reduce calories, limit food intake, or decrease fat consumption at least once over a four-year span. The rise in popularity of weight-loss diets serves as further evidence of this trend.

But the desire to lose weight is not the only motivation for dietary modification and restriction of food intake. Many other motivations may be involved, such as having a healthy body. The drive for a healthier body encourages one to eat only foods considered "healthy" and to exclude foods considered "unhealthy". Public health programs like the National Program

on Nutrition and Health in France promote this type of diet and encourage people to make healthy food choices. These programs are most often perceived as responding to a demand from consumers and leading public health institutions and target specific food categories, such as reducing meat consumption.

There are also other reasons for restricting food intake, some of which are unrelated to the body, such as ethical motivations like animal welfare, respect for the environment, or religious rites. While there are a variety of motivations for dietary restriction, the literature has focused mainly on the desire to restrict one's diet with the aim of losing weight or maintaining a weight within a certain range and having a healthy body, which is the major issue today in public policies tackling obesity. In this context, diets with reduced intake quantities and the exclusion of certain food groups (e.g., high-fat and ultra-processed foods) have become a major adaptive behavioral strategy in the attempt to control weight, despite diets being far from associated with long-term success (Elfhag & Rössner, 2005). Indeed, in most cases, dieting does not result in long-term weight reduction (Mann et al., 2007). In the literature, people in the general population who try to control their diet have been separated into two categories: those who manage to restrict their eating by limiting their food intake are called "chronic dieters" or "restraint eaters", compared with those who do not try to restrict their diet called “unrestraint eaters” (Herman & Polivy, 1980).

Restrained eaters may experience varying levels of severity in their dietary restrictions, due to various factors (e.g., genetic, social, environmental). Some exclude a few foods and/or slightly reduce quantities, while others exclude a wider range of foods and/or reduce more drastically quantities consumed. This leads to differing degrees of restriction and different consequences within the population. As a result, on the one hand, some individuals restrict themselves by maintaining balanced eating habits with a varied and flexible diet, maintaining food pleasure and being able to afford occasional deviations from this dietary restriction without feeling guilty or anxious. Some adopt diets such as vegetarian or vegan for reasons of bodily health, while maintaining a balanced approach and being able to indulge occasionally in less healthy options without feeling guilty.

However, on the other hand food intake restriction can also be associated with unhealthy behaviors related to food. These unhealthy behaviours can take different forms, as we will see in the next section.

1.2. Restrictive eating

Certain restrained eaters experience greater distress generated by such restriction. Indeed, in addition to food intake restriction, some restrained eaters exhibit rigid and obsessive behaviors that lead to psychological suffering, such as anxiety and fear of breaking an imposed diet, or social isolation. For some individuals among the restrained eaters, periods of restriction are interrupted by periods of overeating (Gorman & Allison, 1995), which may generate compensatory behaviors such as taking laxatives, or vomiting, or excessive physical exercise. All these pathological behaviors are indicative of disordered eating or eating disorders, which often requires treatment. Disordered eating refers to behaviors related to food that can harm physical, mental, or emotional health but do not meet diagnostic criteria for recognized eating disorders.

It is important here to stress the difference between disordered eating behaviors and eating disorders: eating disorders refer to pathological diseases with full-blown diagnosis whereas disordered eating behaviors (which includes restrained eating with harmful consequences) refer to eating behaviors that are disturbed but that fall out of the scope of the DSM or International Classification of Disease criteria. Eating disorders are characterized by a severe disturbance in the relationship with food. This can include caloric restriction, binge eating and purgative behaviors such as vomiting, taking laxatives or diuretics. These behaviors have a significant impact on the individual's physical and psychological health (American Psychiatric Association, 2013a). Here, as we are investigating the control over one’s diet, we focus on eating disorders exhibiting food intake restriction in their diagnostic criteria: anorexia nervosa (AN), Avoidant/Restrictive Food Intake Disorder (ARFID) and some Other Specified Feeding and Eating Disorder (OSFED). Disordered eating behaviors could include subclinical forms of eating disorders.

Interestingly, in both eating disorder and disordered eating (Giordano, 2005; Lawrence, 1979; Wildes & Marcus, 2013), people who exhibit restrictive eating may be trapped in a paradox of control. Indeed, they restrict themselves voluntarily, but they are at the same time trapped and feel obliged to maintain this restriction, so that their condition appears to be both the result of great self-control and of an external force beyond their control. This paradox has been claimed to be one of the maintaining factors of eating disorders (Giordano, 2005, Chapter 5, p., 93).

1.3. Restrictive eating as a continuum from healthy habits to eating disorders

Food intake restriction is present to varying degrees in restrained subjects, with some maintaining a healthy attitude to food, but others exhibiting a disturbed relationship with food. Additionally, longitudinal studies have revealed that restrained eating could be a risk factor for disordered eating and could even lead to eating disorders (Calam & Waller, 1998; Herle et al., 2020; Neumark-Sztainer et al., 2011). In a prospective study, Stice and colleagues (2011) also showed that dietary restriction increased the risk of developing eating disorders in adolescent girls. Moreover, regular caloric deprivation has been shown as a risk of developing disordered eating behaviors (Stice et al., 2008).

As a result, researchers have suggested a dimensional approach to eating disorders (Wildes & Marcus, 2013), which encompasses a range of eating behaviors from "healthy" to eating disorders, including disordered eating behaviors. This dimensional approach highlights common features between subclinical and pathological forms, which could predict evolution from subclinical forms to eating disorders.

In order to better understand the mechanisms underlying how to get from the will to control one's diet to extreme control over diet beyond one's control, we chose to study two instances of control over diet located at different points on the continuum from "healthy" eating behaviors to eating disorders:

- anorexia nervosa, a recognized eating disorder, that can be conceptualized as the most extreme form of eating restriction and can give us clue on mechanisms underlying the paradox of control;
- and orthorexia nervosa, an emergent disordered eating that can evolved to eating disorders (Dell'Osso et al., 2016b) and which is at the crossroads between societal injunctions to eat well and paradoxical control of eating.

Chapter 1 –Summary:

Controlling one's diet often involves limiting food intake through self-control.

However, this self-control can lead to psychological and social suffering, accompanied sometimes by physical impairments, notably with nutritional deficiencies or malnutrition. This can be observed both in disordered eating and eating disorders.

In such cases, many subject will experienced a paradox of control: subjects restrict themselves voluntarily, but at the same time feel obliged to maintain this restriction, becoming both the controller and the controlled.

To better understand this paradox, in the next chapter we will look at two models of food intake restriction that present this paradox of control.

Chapter 2. Two instances of extreme control over one's diet

Chapter 2 delves into the examination of two dietary control conditions that can be considered as pathological: anorexia nervosa and orthorexia nervosa. The definitions of each condition will be clearly outlined and the cognitive mechanisms that drive food intake restriction in both cases will be thoroughly discussed, helping to identify gaps in the literature.

2.1. Anorexia nervosa: a historical instance of extreme control over one's diet

2.1.1. Anorexia nervosa: definition and prevalence

Anorexia nervosa (AN) is not a recently emerged disease; first cases were recorded during the 13th century and reported cases of voluntary dietary restrictions for religious purposes of piety and repentance among women (Schlienger, 2023). The first clinical description was made by Dr. R. Morton in 1689. Its clinical presentation has continued to evolve over time, as have pathophysiological conceptions, sometimes hormonal, sometimes psychiatric. In 1873, Ernest-Charles Lasègue produced a groundbreaking clinical profile which involved three main symptoms: anorexia, emaciation, and amenorrhea. William Withey Gull (1816-1890) simultaneously presented a similarly thorough medical description of the disorder and was the first person to use the term "anorexia nervosa". The symptoms that would become central to the diagnosis of AN, such as a phobia of weight gain and the conviction of being too fat, were first mentioned by European doctors including neurologist Jean-Martin Charcot in 1883 (Habermas, 2015). After many different definitions and classifications, AN was officially considered a mental illness and included in the first edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM) published in 1952. In the 70's and 80's, the American psychiatrist Hilde Brusch shed light on the disorder with two pioneering books: "Eating Disorders: Obesity, Anorexia Nervosa, and the Person Within" (Bruch, 1973) and "The Golden Cage: the Enigma of Anorexia Nervosa" (Bruch, 1978). This raised awareness of eating disorders in the medical and research fields and highlighted the implications of body image and the control paradox in eating disorders.

The lifetime prevalence of AN rates up to 4% among women and 0.3% among men (van Eeden et al., 2021). This disorder mainly occurs in adolescence or early adulthood (18-30 years old) (Godart et al., 2013; Stice et al., 2013; Volpe et al., 2016), and women are much more affected than men, with a man to woman ratio around 1:10 (van Eeden et al., 2021). It is defined in the

Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (American Psychiatric Association, 2013a) by three main criteria:

- Restriction of energy intake relative to requirements, leading to a significant low body weight in the context of the age, sex, developmental trajectory, and physical health (less than minimally normal/expected).
- Intense fear of gaining weight or becoming fat or persistent behavior that interferes with weight gain.
- Disturbed by one's body weight or shape, self-worth influenced by body weight or shape, or persistent lack of recognition of the severity of low bodyweight.

Two subtypes are defined: the restrictive subtype, characterized by not engaging in binge-eating of purging during the previous 3 months, and the binge-eating/purging subtype, in which the patient has regularly engaged in binge-eating or purging in the previous 3 months.

Problematically, these criteria only allow for diagnosis of an eating disorder at an already advanced stage, whereas early detection is a necessary preliminary step to prevent the illness establishment and chronicity (Lavigne, 2016).

AN has also multiple risk and maintenance factors, making it very difficult to prevent and to treat respectively (Carter et al., 2012; Pike, 1998). It is a complex multifactorial disorder, involving predisposing factors (familial, individual and environmental), precipitating factors (e.g., puberty, stressful events, other psychiatric illness) and perpetuating factors (e.g., biological, affective) (see Gorwood et al., 2016), as well as comorbidities (Godart et al., 2002; Riquin et al., 2021).

2.1.2. Anorexia nervosa: restraint eating as a core feature

Severe restrained eating is a core feature of AN, and its severity conflicts with health requirements (American Psychiatric Association, 2013a). Food intake restriction in AN has been claimed to be a quantitative restriction, i.e., subjects significantly reduce their food portion and thus the number of calories ingested. In particular, this has been shown to be a clear distinction between AN and ON, the former being characterized by a focus on quantitative restriction, while the latter is characterized by a focus on qualitative restriction (exclusion of foods considered unhealthy) (Cena et al., 2019). However, dietary restriction in AN also involves the exclusion of certain food categories, especially high-calorie foods with high level

of fat content (Lloyd & Steinglass, 2018; J. Steinglass et al., 2015). Therefore, a restriction on qualitative criteria also seems to occur in AN. This will be explored further in the next chapter. Many authors have addressed the question of what motivates this extreme food intake restriction in AN. The main reasoning seemed to be the intense fear of gaining weight, implying that food intake restriction is underpinned by bodily concerns and related emotional processes. The literature is already extensive on the importance and disturbances of body image in AN (Cash & Brown, 1987; Cash & Deagle, 1997; Dakanalis et al., 2016; D. M. Garner, 1981; Glashouwer et al., 2019). However, it is important to stress that the intense fear of gaining weight is not the sole motivational factor for food intake restriction and in some individuals with AN there appears to be no fear of gaining weight (Becker et al., 2009; Izquierdo et al., 2019). Some authors have pointed out a positive value of starvation among patients suffering from anorexia nervosa (Clarke et al., 2016), and argued that the pleasure of losing weight could also be a motivation for this extreme food intake restriction. Other authors have argued that there are additional reasons, including moral ones. For example, Urdapilleta and colleagues (2005) explicitly asked patients with eating disorders (anorexia, both subtypes, and bulimia nervosa) and control subjects to categorize 27 food names. Results revealed that patients with restrictive anorexia relied more heavily on moral criteria (i.e., deontic terms such as the obligation "I can/can't eat this") to form food categories, compared to other patients. Furthermore, some authors have emphasized the moral aspect of purity that emerges from the dietary choices of subjects suffering from AN, which echoes the religious ascetism seen historically in AN (De Franceschi, 2018). Another moral aspect has been highlighted by Simona Giordano (2005), who has argued that AN is characterized by a desire to lose weight, and therefore by a valorisation of lightness, and a pursuit for lightness, as the aim to be as light as possible.

2.1.3. Cognitive mechanisms of restraint eating in Anorexia nervosa

Food intake restriction in AN involves cognitive mechanisms to maintain it (Treasure & Schmidt, 2013). At the cognitive level, this extreme food intake restriction seems to translate into specificities in executive functions, reward processes and emotion regulation in response to food stimuli, which have been summarized in a systematic review (see Lloyd & Steinglass, 2018).

Like most behaviors, making decisions about food involves cognitive processes known as executive functions to intentionally control and regulate behavior (Miyake et al., 2000). Executive functions refer to a set of cognitive processes that are responsible for higher-level, goal-directed behaviors. They involve a range of mental abilities that allow individuals to plan, organize, initiate, monitor, and adapt their actions to achieve specific goals or tasks (Miyake et al., 2000). The main executive functions are working memory, planning, decision-making, central coherence, cognitive flexibility, and inhibitory control. Executive functions are involved in the most complex activities, for example in problem solving (Chevalier & Chevalier, 2009), categorization (Blaye & Jacques, 2009) or emotion regulation (Carlson & Wang, 2007). As patients suffering from anorexia nervosa showed dysregulation towards food behaviors, it seemed coherent to look for impairments in executive functions in food-choice decision-making task, to see how such individuals make decisions about what they eat. The existing literature has shown deficits in anorexia nervosa patients' executive functions using general tasks (Lang et al., 2014; Reville et al., 2016; Roberts et al., 2007, 2016; Tchanturia et al., 2012). But when focusing on food-choice decision-making task, very few studies have investigated executive functions. A single decision-making task using food images was carried out with patients suffering from AN (J. Steinglass et al., 2015). Participants were asked to evaluate several food images in terms of health and taste. Then, in a food choice task, they had to choose between a food deemed "neutral" in terms of health and taste, and each of the other foods. The results showed that people suffering from anorexia nervosa were less likely to choose high-fat foods than control subjects. Also, health ratings influenced the choices of patients suffering from AN more than those of control subjects. This task highlighted a difference in decision-making in subjects with AN, who showed a preference for low-fat foods compared to control subjects.

Another executive function that seemed to play a role in AN and food-choice task is inhibition. Indeed, some authors have proposed that high self-control in food intake restriction in AN is achieved via strong inhibition process of behavioral impulses and resisting desires (Kotabe & Hofmann, 2015), because it had been shown that inhibitory control was associated with less consumption of high-fat foods, higher resistance to food desires and successful weight loss (Hall, 2012; Price et al., 2016). Surprisingly, when looking at inhibition in AN during food choices, studies have shown lower activations of brain areas known to be engaged in inhibition during food choices (King et al., 2016). One hypothesis put forward was that inhibitory control would require less effort in subjects with AN than in control subjects (King et al., 2016; Kullmann et al., 2014; Oberndorfer et al., 2011).

The reward process refers to the sequence of neural and behavioral events that occur when an individual encounters a stimulus or situation that is perceived as positive, pleasurable, or reinforcing. This process involves the activation of specific brain regions, the release of neurotransmitters (e.g. dopamine), and the modulation of behavior in response to the anticipation or receipt of a rewarding stimulus (Schultz, 2015). Studies conducted on anorexia nervosa have put emphasis on investigating reward processes, as food is a primary reward and as these processes have also been associated with numerous psychiatric disorders (e.g. depression) (Szczypiński & Gola, 2018). Numerous reviews have shown alterations in reward brain circuitry in anorexia nervosa, particularly in the presence of food stimuli (Haynos et al., 2020; Lloyd & Steinglass, 2018; Wonderlich et al., 2021). Studies using reward processing tasks and food images have demonstrated that subjects with anorexia nervosa perceived high-calorie food as less rewarding compared to control subjects. Given the potential impairment of the reward process in AN, it has been suggested that inhibition processes are less required, which could explain why brain functions involved in the inhibition process are less engaged (Fürtjes et al., 2022).

Another cognitive function entangled with executive functions and reward processes that has been hypothesized to play a role in food intake restriction in AN is attention. Attention is a cognitive process that involves the selective allocation of mental resources to specific stimuli or information in the environment (Posner & Petersen, 1990). It enables individuals to focus on relevant sensory inputs, thoughts, or tasks while filtering out irrelevant or distracting information. Attention plays a crucial role in perception, learning, memory, and decision-making. Some authors have hypothesized that the extreme food intake restriction seen in AN might be underpinned by a reduced attentional bias towards calorie-rich foods (Lloyd & Steinglass, 2018). However, studies have shown nuanced results. Some studies showed attentional disengagement and avoidance of calorie-rich foods (Veenstra & de Jong, 2012; Zsoldos et al., 2022). On the contrary, other studies showed an attentional bias towards all foods, which has been interpreted as a response towards threatening stimuli (Neimeijer et al., 2017; Shafran et al., 2008; Smeets et al., 2008). However, the wide variety of attentional bias paradigms and the wide methodological variety (recruitment and tasks used) did not allow the authors to conclude clearly on their hypothesis. Recent studies using eye-tracking have revealed that both patients and healthy individuals initially showed a preference for high-calorie foods. However, subjects with anorexia nervosa do not maintain this preference over time, unlike control subjects (Meregalli et al., 2023; Werthmann et al., 2019). Additionally, when not given

specific instructions to visualize food stimuli, subjects with AN show a disengagement of attention compared to control subjects (Puttevils et al., 2023).

Regarding the emotional aspects toward food, a study analysing brain activity during the visualization of food images found that individuals with anorexia nervosa showed increased activity in regions associated with emotions, such as the amygdala, insula, and hypothalamus, as well as in areas responsible for top-down control, like the prefrontal cortex (Celeghin et al., 2023). Additionally, individuals with anorexia nervosa displayed a greater negative implicit affect towards high-calorie foods compared to control subjects (Spring & Bulik, 2014). Therefore, valence seems to be implicated in the mechanisms. Concerning approach-avoidance, studies using approach-avoidance tasks did not show evidence of approach or avoidance towards food stimuli among patients with anorexia nervosa (Kollei et al., 2021; Paslakis et al., 2021), contrary to control subjects which showed evidence of an approach bias towards food stimuli (Paslakis et al., 2021). However, a recent study that asked participants to rate their levels of avoidance towards food categories on Likert scales revealed that high avoidance of high-calorie foods was associated with greater severity of anorexia nervosa symptoms (Di Lodovico et al., 2023). This suggests that explicit avoidance is seen towards food categories, but there is no evidence of implicit approach or avoidance. A pilot study has suggested that the neural circuits involved in food-related anxiety may also play a role in the relationship between anorexia nervosa and food (Young et al., 2020). The authors measured neural reactivity (fMRI) and self-report anxiety level among 16 subjects with AN and 21 control subjects during presentation of food pictures. Subjects with AN demonstrated significantly greater anxiety reported level and impaired functioning of brain regions involved in the regulation of negative emotional reactions (anterior cingulate cortex) compared to control subjects. Considering the small sample size, replication studies are needed to confirm these findings.

To summarize, individuals with anorexia nervosa often present with cognitive dysfunctions that manifest in the reward, attention, and emotion regulation processes related to food. Research has demonstrated that high-calorie foods are frequently perceived as less appealing and associated with negative emotions and avoidance, requiring less effort to inhibit executive functions. However, patients with anorexia nervosa showed hyperactivity in the neural circuits responsible for top-down control, such as the prefrontal cortex, compared to control subjects (Celeghin et al., 2023). Although these alterations appear to be initial clues to understanding the maintenance of this extreme restriction on eating in anorexia nervosa, they do not explain

the extreme food hyper-selectivity, specifically how foods are perceived and what underlies the exclusion of certain foods in anorexia nervosa.

2.2. Orthorexia nervosa: emerging instance of extreme control over one's diet in the general population

2.2.1. Orthorexia nervosa: definition and characteristics

Orthorexia nervosa (ON) is a relatively new concept, first introduced by Dr. Steven Bratman in 1997. Dr. Bratman coined the term "orthorexia" from the Greek words "orthos" meaning right or upright, and "orexis" meaning appetite (Bratman, 1997). The condition describes an obsessive preoccupation with healthy eating, wherein individuals develop an extreme fixation on consuming only foods they perceive as healthy. Orthorexia nervosa was proposed as a subclinical condition falling outside the scope of traditional eating disorders. As awareness of the phenomenon grew, researchers and clinicians recognized its potential clinical significance, leading to further investigations into its prevalence, impact, and diagnostic criteria.

As ON gained attention, experts aimed to establish a consensus on its definition and diagnostic criteria. In November 2022, a group of researchers and clinicians specializing in eating disorders gathered to discuss and outline the consensus definition for ON (Donini et al., 2022). The consensus definition emphasized that ON involves a pathological fixation on the quality and purity of food, leading to severe dietary restrictions and disruptions in daily functioning. The condition is characterized by an obsessive pursuit of a healthy diet, to the detriment of one's social, occupational, and emotional well-being. They argued that ON should be recognized as a distinct and clinically relevant eating disorder.

Assessing orthorexia nervosa requires reliable diagnostic tools before delving into its pathophysiology. Orthorexia nervosa has been mostly explored with self-report questionnaires. At first, the Bratman Orthorexia Test (BOT) (Bratman & Knight, 2001) and the ORTO-15 questionnaire (Donini et al., 2005) were developed, using a dichotomous approach with a cut-off to distinguish "non pathological" from "pathological" relation to healthy eating. As the exploration and research on ON went one, overlapping features with obsessive-compulsive disorders (e.g. intrusive thoughts) and with anorexia nervosa (e.g. over-concern about food) was found (Koven & Abry, 2015). These overlaps, accompanied by psychometrics limitations of BOT and ORTO-15 tests, led to the development of six other questionnaires investigating ON with dimensional approaches. A two-dimensional approach according to Dunn and

Bratman's recommendations was put forward by Barrada and Roncero (2018) with the development of the Teruel Orthorexia Scale (TOS), distinguishing healthy eating from negative consequences of the preoccupation with healthy eating by two subscales: Healthy Orthorexia and Orthorexia Nervosa. The Healthy Orthorexia subscale investigates the healthy interest in diet without being related to pathology, whereas the Orthorexia Nervosa subscale evaluates negative social and emotional impacts. Some multi-dimensional approaches have also been investigated focusing on impairments found in ON such as in the Eating Habits Questionnaire (EHQ) (Gleaves et al., 2013) which investigate rigid eating behaviors, positive feeling of control and problems of attention, control and social relationships. However, each of these tools have their limitations considering their dimensions: EHQ seems to miss some aspects of orthorexia such as negative emotionality (i.e., anxiety, fear, sadness, and distress) or compulsive behavior (Koven & Abry, 2015); TOS does not allow to study each impairment precisely with different subscales. To date, no tool has emerged as the one to use when exploring ON, even if the most recent ones (EHQ, TOS and DOS) have satisfactory psychometric properties. A summary of all the tools can be seen Table 1.

It is important to note that, as ON is not officially recognized as a distinct eating disorder and is still an emerging phenomenon, in this thesis, we will be examining it (see Part B) as a disposition that can manifest in different intensities (i.e., degree), as indicated by scores on ON self-report questionnaires.

Table 1. Orthorexia Nervosa detection tools – description and properties (two pages).

Name	Author	Year	Country	Number of Items	Number of adaptation	Dimensions	Answers	Psychometric properties	Main criticisms
BOT: Bratman Orthorexia Test	Bratman S.	2000	USA	10	2	/	yes/no	No initial psychometric validation	Lacks of validation: no psychometric properties were found in the literature.
ORTO-15	Donini et al.	2005	Italy	15	10	3 factors related to eating habits are: − rational— 6 items − clinical— 5 items − emotional— 4 items	A 4-point Likert scale (always, often, sometimes, never)	Sensitivity of 100%, specificity of 73.6%, Psychometric quality (i.e., reliability and validity) not established	Overestimation of ON prevalence and weak psychometric properties (Varga et al., 2013).
EHQ : Eating Habits Questionnaire	Gleaves, Ambwani and Graham	2013	USA	21	4	3 dimensions : 1) problems associated with healthy eating - 12 items 2) knowledge of healthy eating - 5 items 3) feeling positively about healthy eating - 4 items	A 4-point Likert scale (False, not at all true; Rarely true; Often true; Very true)	Reliability α = 0.90, 0.82 and 0.86 for the Problems, Knowledge, and Feelings factors, respectively. Test-retest correlations of r= 0.81, r= 0.81, and r= 0.72	Very little emphasis on negative emotional aspects(i.e., anxiety, fear, sadness, and distress) or compulsive behavior (Koven & Abry, 2015).
DOS : Düsseldorf Orthorexia Scale	Barthels, Meyer, and Pietrowsky	2015	Germany	21	8	/	4-point likert scale (1-“this does not apply to me”; 4-“this applies to me”).	High internal consistency (α = 0.84); High retest reliability (r = 0.67–0.79, p = .001 between three time points).	Inability to differentiate between patients suffering from anorexia nervosa and orthorexia nervosa.

Name	Author	Year	Country	Number of Items	Number of adaptation	Dimensions	Answers	Psychometric properties	Main criticisms
BOS : the Barcelona Orthorexia Scale	Bauer et al.	2018	Spain	64	0	6 domains or content areas : Cognitive Domain: 14 items Emotional Domain: 16 items Behavioural Domain: 14 items Negative Consequences – Health: 6 items Negative Consequences – social functioning: 9 items Differential Diagnosis Domain: 5 items	5-Likert Scale (1 = Totally disagree; 5 = Totally agree)	Internal consistency (α = .80–.90), and temporal stability (r = .62–.88) (Navarro et al., 2023).	Only validated in Spain.
TOS : the Teruel Orthorexia Scale	Barrada and Roncero	2018	Spain	17	7	2 dimensions: - healthy orthorexia - 9 items - orthorexia nervosa - 8 items	4-point Likert scale (0 = Completely disagree to 3 = Completely agree)	Reliability : - healthy orthorexia α = 0.85 ; - orthorexia nervosa α = 0.81	Very recent : need more validations; TOS does not allow to study each impairment precisely with different subscales.
ONI : Orthorexia Nervosa Inventory	Oberle et al.	2021	USA	24	2	3 dimensions: − physical and social impairment—10 items − behaviour and absorption—9 items − emotional stress—5 items	4-point Likert scale: 1-“not at all true“, 2-“slightly true“, 3-“mainly true“, 4-“very true”	Reliability α = 0.94 Each factor: − physical and social impairment α = 0.90 − behaviour and absorption α = 0.89 − emotional stress α = 0.88	Very recent: need more validations
EFO : Echelle Française d'Orthorexie	Dajon et al.	2021	France	12	/	4 dimensions: - excessive eating behaviour - 3 items - time spent on food - 2 items - negative emotional consequences - 3 items - social impact of healthy eating - 4 items	A 4-point Likert scale (0-Doesn't suit me at all ; 4-Fits me perfectly).	General reliability α = 0.82; Convergent validity (r = 0,57 ; p < 0,001 with the BOT; r = −0,55 ; p < 0,001 with the ORTO12-FR)	Very recent : need more validations

Due to the lack of standardized diagnostic criteria and assessment tools, estimating the prevalence of orthorexia nervosa is challenging. Many studies have attempted to assess its prevalence using various screening measures (eight questionnaires currently exist). ON prevalence differ according to the country of origin of the study, the group of participants and the screening tool used, resulting in a large range of prevalence of ON. In the Western general population, the prevalence was mainly estimated from less than 1% to 8% (Niedzielski & Kaźmierczak-Wojtaś, 2021). Some groups showed a higher prevalence, such as medical or dietetic students with an estimated prevalence between 35.9% and 45% (Bo et al., 2014; Memon et al., 2012), or people who have to control their diet due to physical pathologies such as people with type 1 diabetes showing an estimated prevalence between 13.4% and up to 81.3% in children and adolescents (Anil et al., 2015; Fidan et al., 2017). Also, groups who adopt a specific diet, such as vegans/vegetarians, tend to have a higher prevalence of orthorexia nervosa (Barthels et al., 2018). Indeed, Barthels and colleagues (2018) conducted a study comparing the rates of individuals exceeding the cutoff of orthorexic eating behaviour detected by the Düsseldorfer Orthorexie Skala (Barthels et al., 2015) between 114 vegans, 63 vegetarians, 83 individuals with rare meat consumption and 91 individuals with frequent meat consumption. They found that the difference between rates were significant [$\chi(3)2 = 7.84$, $p < 0.05$], with 7.9% of the vegans, 3.8% of the vegetarians, 3.6% individuals with rare meat consumption and 0% individuals with frequent meat consumption were detected.

Even if the relationship between socio-demographic factors and the prevalence of ON has been studied, their results are not consistent and prevent to conclude whether gender, age, BMI or level of education have any influence on ON (Niedzielski & Kaźmierczak-Wojtaś, 2021).

Orthorexia nervosa is characterized by an intense fixation on the perceived *healthiness or purity* of food choices. Individuals with ON often adopt strict and rigid dietary patterns, excluding entire food categories deemed as "unhealthy" or "impure". The definition of what is healthy or unhealthy includes a set of beliefs whose specific content may vary according to the individual and his or her culture. The primary motivation for these restrictions is the individual's belief that consuming unhealthy foods may lead to negative health consequences (e.g., cancer, cardio-vascular diseases). The exclusion of foods considered as unhealthy can lead to severe dietary restrictions, including the avoidance specific food groups such as dairy, gluten, and/or processed foods. The intensity and rigidity of this restriction can lead to detrimental

consequences such as social isolation, psychological distress, and sometimes malnutrition (Donini et al., 2022).

The strict adherence to dietary beliefs in ON may be a way of coping with underlying anxieties and insecurities, providing a sense of control in an uncertain world (Valente et al., 2020). Indeed, one study has showed a relationship between ON and intolerance of uncertainty (Giles et al., 2021), defined as "a dispositional characteristic that results from a set of negative beliefs about uncertainty and its implications and involves the tendency to react negatively on an emotional, cognitive, and behavioral level to uncertain situations and events" (Buhr & Dugas, 2009, p. 216).

Interestingly, the idea of adherence to strict and rigid rules about food as a way to cope with anxieties due to uncertainty has also been developed as a feature of anorexia nervosa by Hilde Brush who argued that the extreme food intake restriction and self-imposed rigid rules in AN was a way for patients to cope with anxiety from not being able to control anything in the world around them (Bruch, 1978).

Other overlaps between anorexia nervosa and orthorexia nervosa have been highlighted such as obsessive-compulsive personality traits (rigidity, perfectionism), the over-concern about food leading to eating dominating one's life, ego-syntonic behaviors (which correspond to one's personal values and the ideal conception of the self), the impact of food intake restriction on identity and self-esteem, as well as deleterious consequences due to the extreme restriction on food: anxieties, guilt, social isolation and sometimes somatic problems (not always found in ON) (Dell'Osso et al., 2016b; Łucka et al., 2019). In addition, a sense of moral superiority and self-righteousness regarding their dietary habits has been highlighted in both AN and ON, with the belief that their strict adherence to a very restricted diet makes them morally superior to others (Banks, 1996; Koven & Senbonmatsu, 2013). The question of morality underpinnings food perception will be further explored in AN and in the general population considering ON dispositions in the Chapter 7.

2.2.2. Food intake restriction and its cognitive mechanisms in Orthorexia nervosa

Considering all these overlaps between ON and AN and considering that AN behaviors are associated to impaired executive functions (Lang et al., 2014; Reville et al., 2016; Roberts et al., 2007, 2016; Tchanturia et al., 2012), authors have made hypotheses that ON would also exhibit impairments in executive functions (Koven & Senbonmatsu, 2013). To test these hypotheses, Koven and colleagues used two kinds of measures. The first measure is based on a

self-reported questionnaire, the Behavior Rating Inventory of Executive Functioning, Adult version (BRIEF-A) (Roth et al., 2005), a 75 items self-report questionnaire to assess the experience of executive functions in daily life with nine subscales: Working Memory, Ability to Plan, Ability to Task Monitor, Ability to Organize Materials, Ability to Inhibit, Task Initiation, Shifting, Emotional Control, and Self-Monitoring. The second kind of measures was neuropsychological battery of tests including the Wide Range Achievement Test, Fourth Edition (WRAT-4) (Wilkinson & Robertson, 2006) Reading subtest, the Delis-Kaplan Executive Function System (D-KEFS) (Delis et al., 2001) and the California Verbal Learning Test, Second Edition (CVLT-II) (Delis et al., 2000) and the Wisconsin Card Sorting Card (Grant & Berg, 2003). To assess ON symptoms, they used the ORTO-15 questionnaire (L. Donini et al., 2005a). Results showed that ON score was associated with self-reported weaknesses in Set-Shifting, Emotional Control, Self-Monitoring, and Working Memory. However, no significant correlation was found between ON score and scores on the other test, except a significant difference between high- and low-ON groups in total correct trials on the Wisconsin Card Sorting Test (Grant & Berg, 2003). Therefore, impairment in executive functions was only seen on self-reported measures in this study.

Other authors have recently examined specific executive functions (cognitive flexibility and inhibition) and attention in orthorexia nervosa (Albery et al., 2020, 2022; Hayatbini et al., 2020; Hayatbini & Oberle, 2019). In a first study, Hayatbini and colleagues investigated cognitive flexibility abilities in ON using the Wisconsin Card Sorting Test and the Trail Making Test (Hayatbini & Oberle, 2019). In a second study, they investigated inhibitory control (as the inability to suppress an action or thought about healthy eating in ON) using the Go/No-Go Task, the Flanker Task, and the Stroop Task (Hayatbini et al., 2020). They used the Eating Habits Questionnaire (Gleaves et al., 2013) to detect orthorexia nervosa traits in both studies. Contrary to what was expected, the results showed neither impairment of cognitive flexibility nor deficits or other differences in inhibitory control in ON.

Albery and colleagues (2020) explored attentional bias in ON using a modified food-Stroop task to assess the relationship between attentional preference for healthy/unhealthy food-related words over matched neutral words with ON tendency scores with the ORTO-15 scale in a non-clinical sample of individuals (Albery et al., 2020). Results revealed that people with higher ON tendencies exhibited an increased attentional bias for healthy food-related words and not for unhealthy food-related words relative to participants with lower ON tendencies. Then in another study, the authors replicated this effect (Albery et al., 2022) using alternative measures

of attentional bias (i.e., the dot probe task with words related to healthy and unhealthy food) in a sample of self-defined vegans/vegetarians, a population previously argued to have inflated tendencies towards ON (Barthels et al., 2018). They used the Teruel Orthorexia Scale (Barrada & Roncero, 2018) to detect orthorexia nervosa traits. In addition to replication, they showed that slowed disengagement from healthy food-related words provided significant independent explanatory variability for the increase in Orthorexia Nervosa. This finding extends results reported in Albery (2020) by locating attentional bias effects on Orthorexia Nervosa specifically in a slowed disengagement from healthy food-related words. Curiously, in both studies the authors did not show attentional bias for unhealthy food-related words whereas, in ON, unhealthy food elicits high anxiety and guilt if eaten, and anxiety-provoking stimuli have been shown to induce attentional biases (Bar-Haim et al., 2007; Mathews et al., 1996; Mogg & Bradley, 1998).

Therefore, studies examining the cognitive profile of individuals with orthorexia nervosa using neuropsychological tests have failed to report deficits in executive functions, except attention. Attention function might play a role in ON with an increased attentional bias effects for healthy food-related words in ON and a slower disengagement from healthy food-related words.

When it comes to emotion regulation concerning food choices, to date, no studies have investigated these mechanisms in ON, whereas it has been reported that eating unhealthy food triggers guilt and anxiety in ON (Donini et al., 2022).

To summarize, the literature is not conclusive about cognitive underpinnings in ON, except that there is an attentional bias towards food healthy-related words, which are not sufficient to explain ON symptoms. The cognitive mechanisms underlying ON are therefore still poorly understood, leaving the field open for further research.

Chapter 2 – In a nutshell:

Many similarities are observed between ON and AN at a clinical level, including severe food intake restriction leading to psychological and social sufferings. However, the cognitive mechanisms behind the maintenance of an extreme food hyper-selectivity in both ON and AN are not well understood. In the following chapter, we will see how the investigation of food categorization can help to better understand the cognitive mechanisms behind the maintenance of an extreme food hyper-selectivity.

Chapter 3. Food Categorization, a mechanism underlying food selectivity and sensitive to indicators of excessive control over eating.

Interestingly, ON shares similarities with AN in its manifestation of extreme food selectivity. As previously mentioned, the nature of food intake restriction (quantity in AN versus quality in ON) has been claimed as a criterion that distinguish ON from AN (Cena et al., 2019). However, the exclusion of entire food categories in AN raises doubts about this differentiation. This raises important questions regarding how individuals with AN or ON categorize food compared to healthy control subjects, and whether there exist similarities between AN and ON that warrant further investigation. Chapter 3 presents food categorization and explores its potential to offer insights into the underlying mechanisms of food hyperselectivity in AN and ON.

3.1. Categorization and food categorization: definition

Categorization is an essential process by which individuals organize stimuli, objects or concepts into distinct groups or categories based on shared attributes. This process allows to organize and partition the world in order to better apprehend and understand it (Rosch, 1978). For instance, the category "table" consists of objects (i.e., inanimate things) with one or more legs and a flat section at the top, which enables other things to be placed on it without making direct contact with the ground. Based on these shared attributes, permits the assignment of properties to new objects and their classification into a specific category, which helps to understand both their nature and function. For example, if we observe an inanimate object consisting of four legs and a flat piece of wood, we can assign it to the table category, and we can infer that it serves as a surface for placing objects. Another example is if we see a new object of the length of one's hand, with a width equivalent to a finger (i.e., a tapered object) and made up of a single welded part and a section with various spikes, it is likely that based on its visual properties, we will assign it to the fork category, and we can infer that it is used for picking up food and bringing it to your mouth.

Food is a domain in which categorization is essential, as it allows us to know which foods are edible and which are not, and to have a reliable list of edible and non-edible items (Ross & Murphy, 1999). Given that some fruits (e.g. certain berries), plants, fungi or animals can be toxic to humans, it is imperative to have an accurate categorization system to avoid any mistakes while searching for food to eat.

While food categorization is an essential process for survival, the fact remains that food categorization is not always easy. For example, certain foods can have different colors, as evidenced by the different possible colors of tomatoes or carrots, or certain foods can be eaten raw or cooked depending on the type of dish. The properties may change or be exacerbated depending on use, for example, endive is much more bitter when cooked. The intrinsic properties of foods, the degree of processing (which can affect these properties) and the context in which they are eaten are all factors that lead to a great deal of confusion in the ability to categorize foods.

The desire to eat only a certain type of food, for example only low-calorie foods or only healthy foods, taps into this capacity for food categorization. However, as we have just mentioned, the food domain is highly complex. Detecting only a certain type of food is sometimes challenging.

In the case of ON, individuals must be able to detect "healthy" foods; self-imposed and rigid rules underpinned by beliefs constrain the detection criteria for considering a food to be "healthy" or "unhealthy". In the case of anorexia nervosa, food selection has been claimed to be based mainly on the calorie content of the food: patients suffering from anorexia nervosa seek to eat only extremely low-calorie foods because of their fear of gaining weight (Drewnowski et al., 1988, 2009). They therefore seek to detect foods based on the calories contained in the food. But at what calorie level is a food considered to be low in calories? And do we consider calories per 100g, or calories per portion eaten? Eating a potato chip does not represent many calories, yet can we consider crisps to be low-calorie? We can see here that relying on a single criterion seems very complicated when it comes to setting a dietary rule. Other criteria must be at play (e.g., sensory, moral, social), particularly in the case of AN. Hypotheses on other criteria at play with energy density in the food hyper-selectivity observed in AN will be tested in Chapters 6 and 7.

3.2. Food categorization performance vs strategy: two facets of food categorization

The identification of certain foods based on a specific criterion, such as detecting "healthy" foods in cases of orthorexia nervosa, can be studied using the Signal Detection Theory (Green & Swets, 1966). This theory is commonly used in decision-making, specifically in situations where the subject needs to locate a target signal among distractors - in the case of orthorexia

nervosa, identifying healthy food among other types of food (Lynn & Barrett, 2014; Macmillan & Creelman, 2005).

Using the Signal Detection Theory, food categorization abilities embed two conceptually distinct components:

1) The first component is the performance in categorization. Categorization performance can be understood as the subject's general ability to detect the signal as such, for example, the ability to identify healthy foods among foods in ON. The performance component might be captured with several variables, including reaction time (how rapid an individual is at detecting a target stimulus), accuracy (the number of correct detections among the number of signals), or response consistency (for the same stimulus repeated several times, the number of times the individual will correctly detect the stimulus as a signal). Going back to the detection of healthy foods, a subject with good performance will detect them quickly, accurately, and consistently. This hypothesis will be tested in Chapter 8.

2) The second component of food categorization abilities is the response strategy. This component is the disposition to avoid a certain type of error, a disposition that might bias your responses. This component is influenced by the perception of uncertainty and by the perceived consequences of different types of error. For instance, when missing the target signal carries substantial negative outcomes, individuals might lean toward identifying more stimuli as targets to prevent missing any (a more liberal strategy). Conversely, if incorrectly identifying stimuli as targets carries high costs, individuals might opt to identify fewer stimuli as targets to prevent such errors (a more conservative strategy). For instance, in ON, where incorrectly identifying unhealthy foods as healthy ones can lead to anxiety and guilt, we could hypothesize that individuals with high ON scores will lean toward identifying fewer foods as healthy. This approach aims to decrease the likelihood of making this type of error and aligns with a more conservative strategy. This hypothesis will be tested in Chapter 8.

These two components, performance and response strategy, are generally considered to be independent, although this has been discussed in the literature (Macmillan & Creelman, 2005), particularly as their respective calculations depend on the ratios of hits and false alarms (MacMillan and Creelman, 2005). Interestingly, it has been shown that both components, performance and response strategy, are sensitive to individual characteristics, as we will see in the next paragraph.

3.3. Food categorization abilities and individual characteristics

Research has shown that an individual's mental processes regarding food perception and categorization can be influenced by their personal characteristics, such as their body mass index (BMI). This has been demonstrated by Pergola and colleagues (2017) using neurophysiological task, including electroencephalography (EEG) and event-related potentials (ERPs) recorded in response to visual stimuli. The authors specifically studied the amplitude and latency of the N400 ERP, in response to food stimuli. The amplitude and latency of the N400 reflect neuronal involvement depending on whether the stimuli are congruent or incongruent (Kutas & Federmeier, 2011; Kutas & Hillyard, 1980b, 1980a). In their study, the authors used pictures of a natural or processed food (e.g., pineapple or pizza, respectively) and sentences describing either a sensory attribute (e.g. "It tastes sweet") or a functional attribute defined as the context in which the food is consumed (e.g. "It is suitable for a wedding meal"). In this task, a sentence was followed by a picture, and the sentence-picture pairs were either congruent ("It tastes sweet" with pineapple) or incongruent ("It tastes salty" with pineapple). The results revealed modulations in N400 amplitude and latency caused by sensory-functional primers only for processed foods (e.g., lasagne) in overweight participants, and only for natural foods in underweight participants (e.g. an apple).

In addition to body mass index, food categorization has also been shown to be sensitive to individual characteristics relating to dispositions towards food. In particular, food categorization has been shown to be sensitive to the presence of dietary restriction for the purpose of weight loss or maintenance measured with the dietary restriction scale (Coricelli et al., 2019). Indeed, Coricelli and colleagues (2019) showed that restricted eaters (defined as individuals who strictly control their tendency to eat for a prolonged period in order to lose or maintain their body weight) were significantly slower to categorize processed foods as such compared to unrestricted eaters. The impact of dietary restriction with the aim of losing weight on food categorization was investigated in anorexia nervosa in one social psychology study conducted by Urdapilleta and colleagues (2005). The authors explicitly asked patients suffering from eating disorders (AN restrictive subtype, AN binge-eating/purging subtype, and bulimia nervosa) and control subjects to categorize 27 food names. Results revealed that patients suffering from the restrictive subtype of AN relied more on moral criteria (i.e., deontic terms such as obligation and permission "I can/cannot eat this") and functional properties of the food (i.e.,the impact on health "this is indigestible") to form food categories compared to other

subjects, which relied more on the composition of foods (carbohydrates, complex sugars, animal fats, proteins, etc.), their method of consumption (cooked, raw, cold, hot, as an accompaniment, etc.) and the circumstances of consumption of these foods (any time, in winter, as a snack, in a restaurant, etc.). This study showed that patients suffering from anorexia nervosa relied on different criteria to categorize food items compared with control subjects. To date, no other study has examined how food is categorized in anorexia nervosa, although this would contribute to a better understanding of food hyperselectivity in this illness. The idea of a function-oriented approach to food in subjects suffering from eating disorders will be explored further in Chapter 5 with a prevalence study, and in Chapter 8 with a food categorisation task based on functional and sensory attributes.

More specifically, the components of food categorization, the performance and response strategy, were shown to be sensitive to individual characteristics relating to dispositions towards food. In particular, they are sensitive to the presence of food rejection in children. Indeed, Rioux and colleagues (2016) tested 79 children aged between 2 and 6 years on their ability to categorize fruit and vegetables, by measuring their food rejection score. The results showed that food rejection was negatively correlated with children's performance, i.e., the higher the score of food rejection, the poorer the performance. The results showed no relationship between food rejection scores and response bias (variable reflecting the subject's strategy). However, the authors argued that as the task consisted of categorizing fruit and vegetables, the errors had no obvious costs or benefits, and may therefore have no effect on response bias, which is known to vary as a function of perceived risk (Lynn & Barrett, 2014). In another study by Foinant and colleagues (2021), 137 children were tested on a food categorisation task between food vs non-food. The results showed that the children's performance was negatively correlated with their food rejection scores (i.e., the more a child rejected food), the poorer their performance. Furthermore, children with a high food rejection score displayed a more conservative categorization strategy (i.e., they were more likely to classify as non-food) compared to children with a lower food rejection score. Here, misclassifying non-food items as edible is very risky as it can lead to costly consequences such as poisoning; thus the task presented some risk and was therefore more prone to response bias variation.

Studies have revealed overlaps between food rejection, ON and AN symptoms. Indeed, as previously seen in ON and AN, individuals with food rejection present a food hyper-selectivity with the exclusion of certain food categories (Rioux et al., 2017). In addition, the increased perception of uncertainty and risk in food rejection also appears to be increased in AN and ON.

Indeed, patients suffering from AN expressed uncertainty as being extremely stressful for them and wished to avoid situations of uncertainty at all costs, resulting in an intense desire for control (Sternheim et al., 2011). Research shows that patients with AN had a higher intolerance of uncertainty score than control subjects (Frank et al., 2012), and individuals with ON exhibited a significant correlation with intolerance of uncertainty score (Waterman et al., 2022).

To summarise, food categorization and its components, performance, and response bias, have been shown to be sensitive to certain individual characteristics such as BMI, or certain dispositions towards food such as food rejection. Given the overlaps and links between these dispositions, anorexia nervosa and orthorexia nervosa, investigating food categorization seems essential and needed in the study of cognitive mechanisms underlying food hyper-selectivity in anorexia nervosa and orthorexia nervosa.

Chapter 3 – In a nutshell:

Food hyper-selectivity involves selecting foods based on various criteria. For this, food hyper-selectivity relies on the process of food categorization. Categorization is a process that helps individuals classify and partition the world to better understand it. However, categorizing food is challenging due to fact that the food domain is extremely ambiguous. Two components, performance, and response strategy, help account for an individual's ability to categorize, their perception of uncertainty and their perception of the risk it represents. Moreover, the ability to categorize and perceive uncertainty and risk is influenced by an individual's disposition towards food, including the presence of eating disorders. Therefore, studying these components opens up interesting perspectives for investigating the mechanisms behind AN and ON's food selectivity.

Chapter 4. Investigating food perception and categorization abilities in anorexia nervosa and orthorexia nervosa: research, objectives, and hypotheses

The desire for food intake restriction can sometimes lead to a form of control that escapes the individual, resulting in both extreme self-control over eating and the suffering with it. The objective of the present doctoral thesis is to explore potential mechanism underpinning the way in which the desire to control one's diet can result in food intake restriction becoming uncontrollable, with harmful consequences.

We will examine the control paradox at the level of perception using the presented conceptual framework.

As previously mentioned, it is important to note that, as orthorexia nervosa is not officially recognized as a distinct eating disorder and is still an emerging phenomenon, in this thesis, we will be examining it as a disposition that can manifest in different intensities indicated by scores on orthorexia nervosa self-report questionnaires.

The studies carried out and presented in the following chapters investigated food perception in AN and ON to try to answer our problematic.

To begin to answer our question, we first looked at whether the risk of developing eating disorders or orthorexia nervosa in individuals depends on their environment. Since orthorexia nervosa involves the preoccupation with the healthiness of foods, we may wonder whether environments that highly exposed individuals to food knowledge and where individuals have to daily manipulate concepts related to food, may be linked to a higher risk of developing of eating disorders and ON. To do so, we looked at symptoms of eating disorders of ON among young adults of culinary arts schools and young adults of dietetics schools, and compared them. Indeed, both curricula include a large proportion of food-related content, but with a significant difference: the first focuses on pleasure and art, the second on health. Results are presented in Chapter 5.

We then investigated our most extreme model of dietary restriction and the one most documented in the literature: anorexia nervosa. In anorexia nervosa, it was previously stated that perceiving food is associated with perceiving the effects it has on the body. Therefore, in a second study (Chapter 6), we looked at the association between food and bodies stimuli in patients suffering from anorexia nervosa, comparing them with control subjects.

In anorexia nervosa, food perception is also influenced by moral values as previously mentioned. We then conducted a third study on patients suffering from anorexia nervosa and control subjects to explore the association between food and moral attributes in this population (Chapter 7).

We finally conducted three successive studies where we investigated the perception of food in the general population in relation to individuals' orthorexia nervosa traits severity (Chapter 8). More specifically, we looked at whether food categorization and more specifically performance and strategy of food categorization, according to healthy/unhealthy categories, were associated with orthorexia nervosa tendencies.

We will thoroughly discuss all of our findings in Chapter 9.

Part B – Empirical Research

Chapter 5. Comparing the risk of developing eating disorders and orthorexia nervosa tendencies between dietetics student population and culinary arts student population

This chapter (Part B, chapter 5) presents the first study as a written article in journal format, it has not been submitted yet.

Comparing the risk of developing of eating disorders and orthorexia nervosa tendencies between in students in dietetics and culinary arts.

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Abstract

Some student populations have shown higher prevalence of eating disorders (EDs) and orthorexia nervosa (ON) than the general population. This is the case for dietetics and nutrition students, whose course of study focuses on the effects of food on health. Another field of study, culinary arts, also focuses on food, but is more concerned with sensory and hedonic aspects. However, there has been limited research on symptoms of EDs and ON in culinary arts field. This study investigated symptoms of EDs and ON among students in culinary arts compared to dietetics students and the general student population.

A total of 144 culinary arts students and 123 dietetics and nutrition students from France participated in the study. The SCOFF questionnaire and the Eating Disorders Examination Questionnaire were used to assess EDs symptoms, while ON tendencies was measured using the Eating Habits Questionnaire.

Results indicated that culinary arts students exhibited more symptoms than the general population, which suggested a higher risk of EDs and ON compared to the general population. Furthermore, the risk would be higher in culinary arts students (especially women) compared to than dietetics students.

These findings suggest a link between food-related educational approaches and the risk of EDs and ON. Further research is needed to deepen our understanding of this relationship and eventually implement targeting interventions for culinary arts students.

Introduction

Eating disorders (EDs) are serious mental illnesses that are characterized by an individual's problematic relationship with food and body, which leads to significant physical and psychological harm (American Psychiatric Association, 2013a).

While the causes of EDs are multi-factorial and still poorly understood, some at-risk eating behaviors and potential precursors have been identified in the general population such as orthorexia nervosa (ON) (Bratman, 1997). ON is an emerging phenomenon characterized by an obsession with healthy eating, which can have detrimental impacts on an individual's psychological and social well-being (Donini et al., 2022). Early identification of these at-risk behaviors is crucial to prevent the worsening of symptoms, which can have severe consequences on an individual's overall well-being, including their social life and academic success (Keel & Brown, 2010; Maxwell et al., 2011).

Research has indicated that the lifetime prevalence of EDs in Western countries is approximately 1.89%, with a higher rate of 2.58% reported among women (Qian et al., 2022). They often manifest during adolescence or early adulthood (Stice et al., 2013; Volpe et al., 2016). The estimated prevalence of ON is around 6.9% (Donini et al., 2005; Luck-Sikorski et al., 2019); however, this figure is subject to debate due to variations in diagnosis and tools used to detect the disorder (Dunn et al., 2017). It is worth noting that specific populations, particularly the population of university students, have been identified as being more susceptible to developing EDs and ON, leading to higher prevalence rates. In particular, the prevalence of risk factors for EDs among university students was estimated at 19.7% (Alhaj et al., 2022).

Furthermore, students in certain curriculum are much more affected than others. Indeed, the literature highlighted that university sports programs with elite athletes have an increased risk of developing EDs, with rates ranging from 6 to 45% for EDs (Bratland-Sanda & Sundgot-Borgen, 2013; Torstveit et al., 2008). This is in line with the fact that intensive sports practice and body dissatisfaction (i.e. the gap between the perceived body and the desired body; (Cash & Deagle, 1997) are also correlated with a high prevalence in both EDs and ON (Clifford & Blyth, 2019; Kiss-Leizer et al., 2019), and are therefore essential factors to take into account when screening for EDs. The prevalence of EDs and ON was also higher among individuals pursuing degrees in dietetics, with rates of EDs and ON reaching 18.9% and 35.9%, respectively

(Bo et al., 2014). Korinth and colleagues (2010) also reported that these students scored higher on food restriction tendencies (i.e. tendencies to limit food intake in order to lose or maintain weight) compared to students in fields outside of health sciences. Although to date no causality can be established, it has been suggested that students may be drawn to these fields due to pre-existing obsessive relationships with food, possibly with the aim of understanding or treating their EDs (Korinth et al., 2010). In line with this hypothesis, medical students also exhibited high rates of EDs and ON: 17-23% for EDs and 45% for ON (Bağcı Bosi et al., 2007; Memon et al., 2012).

Among the factors that may explain a higher prevalence of EDs and ON among dietetics and nutrition students, this curriculum focuses on the functional aspects of food, i.e. the nutritional contribution that food provides to the body, and its impact on individual health and body, which have been shown to be the central aspects of obsession in EDs and ON. Indeed, subjects suffering from EDs are extremely anxious about the impact that food will have on their bodies (Evans et al., 2011). Interestingly, there is another field that takes a close look at food: the culinary arts and gastronomy field. Indeed, the culinary arts and gastronomy curriculum trains students on all aspects of food, emphasizing sensory aspects (texture, consistency, taste, smell, etc.) as well as cooking techniques and nutrition.

Both curricula are closely related to food and, considering the obsessive thoughts about food in EDs and in ON, we may presume that individuals in these two curricula exhibit a higher risk of EDs and ON than in other fields. While numerous studies have shown high prevalence of EDs and ON among dietetics students (Bo et al., 2014; Rocks et al., 2017; Tremelling et al., 2017; Yilmaz, 2023), just one study has explored the prevalence of EDs in the population of culinary arts students (Hodges et al., 1999), showing a prevalence of 30.8% in women and 10.9% in men, which is higher than in the general population. The global aim of the present study was then to assess at-risk behaviors for EDs and ON in culinary arts students' population.

It is important to highlight the difference between these two curricula: while dietetics and nutrition focus on teaching students how to make optimal food choices for specific bodily effects (such as renutrition or weight loss), culinary arts students are mainly trained to create meals that provide pleasure in eating and stimulate the senses when tasting a dish.

Therefore, considering this difference, we also aimed to compare these two student populations: a population from dietetics and nutrition courses, and a population from gastronomy and culinary arts courses. Through this research, we aim to gain a better understanding of the

association between food-related education and at-risk behaviors for EDs and ON. Three hypotheses were tested:

H1: Culinary arts students have more at-risk behaviors for EDs and ON than the general population.

H2: Culinary arts students are more at risk of developing eating disorders than dietetics and nutrition students.

H3: The importance of at-risk behaviors for EDs and ON is positively correlated with the intensity of sporting activity in both populations.

Ethics statement

This study was performed in line with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants. Approval was granted by the Ethics Committee of University Lyon 1 (n° 2022-09-15-005). This study was registered on Open Science Framework (DOI: https://osf.io/hvux9/?view_only=c66c68fbb70642bfafc3b8804c1f6766).

Methods

Participants

No previous research directly compared EDs and ON at-risk behaviors between culinary arts students and dietetics and nutrition students, so power analysis was based on research from Bo and colleagues (2014) comparing the prevalence of EDs between student populations from different curricula: dietetics and nutrition students (N = 53), biology students (N = 187) and sports students (N = 200). The prevalence of EDs was 18.9%, 8.6%, and 7% in each curriculum respectively. As the comparison of proportions was significantly different between dietetics students and the others, these values were used to calculate the necessary size of each group. Power calculation was performed with G*Power © software (Faul et al., 2007) and led to the need to recruit between 100 and 150 participants in each sample.

Participants were 267 students aged 18–30 years old, including 144 students from culinary arts and gastronomy field (51 women, 92 men, 1 did not want to answer; mean age = 19.92, SD age = 2.16; mean BMI = 22.57, SD BMI = 3.55) recruited from the Paul Bocuse Institute, and 123 students from dietetics and nutrition field (106 women and 15 men, 2 others; mean age = 19.71, SD age = 2.09; mean BMI = 21.74, SD BMI = 3.09) recruited from dietetics and nutrition

department of the Claude Bernard Lyon 1 university and mailing lists of French university students during the 2022-2023 school year.

Measures

Data were collected through anonymous self-administrated questionnaires, implemented using the Qualtrics © (2005) survey software.

Demographic questionnaire. Participants completed a demographic questionnaire that collected information on age, gender, weight, height, type of education (nutrition or culinary arts), diet, food-related pathology, and actual level of hunger.

SCOFF questionnaire. Participants completed the French version (Garcia et al., 2011) of the (Sick, Control, One stone, Fat, Food) SCOFF questionnaire (Morgan et al., 2000), a 5-item screening tool used to identify the risk of EDs. It is scored from 0 to 5, according to the number of positive answers. Two or more positive responses indicate a likely ED. In the present study, Cronbach's α was 0.47. This questionnaire is the most widely used questionnaire to detect the risk of EDs.

Eating Disorder Examination – Questionnaire (EDE-Q). In addition to the SCOFF, we added the French version (Carrard et al., 2015) of the EDE-Q (Fairburn & Beglin, 1994), in order to assess EDs dimensions more precisely. The French version of the EDEQ consists of 28 items, with four subscales specifically addressing the core features of EDs, made up of 22 items. The four subscales are: restraint (5 items, e.g. "Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?"), eating concern (5 items, e.g. "Over the past 28 days, how concerned have you been about other people seeing you eat? Do not count episodes of binge eating."), shape concern (8 items, e.g., "Has your shape influenced how you think about (judge) yourself as a person?") and weight concern (5 items, e.g. "How much would it have upset you if you had been asked to weigh yourself once a week (no more, or less, often) for the next four weeks?"). One item belongs to both shape concern and weight concern subscales. Furthermore, there are 6 items that measure how often binge eating episodes and inappropriate compensatory behaviors occur within the past 28 days. Each item is rated on a scale from 0 (no days) to 6 (every day) using a Likert-type scale. The mean of the four subscale scores is calculated to obtain a global score, with a higher score indicating more severe symptoms of EDs. In the present study, global Cronbach's α = 0.96, and Cronbach's α of the subscales were respectively 0.85, 0.82, 0.92 and 0.87 for the

restraint, eating concern, shape concern and weight concern subscales. These scores showed good internal consistency of the questionnaire.

Eating Habits Questionnaire. The participants filled out the validated French version (Godefroy et al., 2021) of the Eating Habits Questionnaire (Gleaves et al., 2013). This questionnaire has 16 questions and is used to detect ON tendencies. Each question includes a statement, and the participant responds using a 4-point Likert-type scale, ranging from "False, Not at All True" to "Very True." A higher score on this scale indicates a higher likelihood of exhibiting ON tendencies. The French version measures three dimensions of ON: rigid eating behavior (REB) (e.g., “I follow a health-food diet rigidly.”); positive feeling of control (PFC) (e.g., “I prepare food in the healthiest way.”); problem of attention control and social relationships (PACSR) (e.g., “I spend more than three hours a day thinking about healthy food.”). In the present study, global Cronbach’s $\alpha = 0.85$, and Cronbach’s $\alpha = 0.72$, 0.75, and 0.72 for REB, PFC and PACSR subscales respectively. These scores showed good internal consistency.

Physical activity and body dissatisfaction. Additionally, participants were asked questions about their physical activity, including the type of sport and the number of hours practiced per week. Moreover, body dissatisfaction was also assessed using the 9-item body dissatisfaction subscale (EDI-BD) of the French version (Archinard et al., 1996) of the Eating Disorders Inventory questionnaire (Garner, 2004). In the present study, EDI-BD Cronbach’s $\alpha = 0.87$. This body dissatisfaction subscale was added as weight concern and shape concern have been showed to be distinct from body dissatisfaction with different predictors and consequences (Allen et al., 2008).

Procedure

Data collection took place through a cross-sectional design. Participants from both courses were invited to participate voluntarily in the study. The questionnaires were administered in a classroom setting or via an online survey platform, depending on the participants' preferences and availability. Participants were provided with clear instructions on how to complete the questionnaires and were assured of the confidentiality and anonymity of their responses. The completion of the entire study required between 10 and 15 min.

Data Analysis

Statistical analyses were conducted using R software version 3.6.0 (R Core Team, 2019), RStudio version 1.4 (RStudio Team, 2021), and Python version 3.7 (Van Rossum & Drake, 2009). The significance level was set at $p < 0.05$.

Descriptive statistics, such as means, standard deviations, frequencies, and percentages, were calculated to describe the characteristics of the two populations and EDs and ON at-risk behaviors. Scores of the questionnaires were computed for each individual for each sub-dimension and overall.

H1: Culinary arts students have more at-risk behaviors for EDs and ON than the general population.

H2: Culinary arts students are more at risk of developing eating disorders than dietetics and nutrition students.

H3: The importance of at-risk behaviors for EDs and ON was positively correlated with the intensity of sporting activity in both populations.

To test our first hypothesis (H1) of more at-risk behaviors for EDs and ON in culinary arts students compared to the general student population previously studied in the literature, we followed the same method as Freizinger et al. (2010) (2010) and compared the scores between our sample and community norms using the SCOFF, EDEQ and EHQ questionnaires (Fairburn & Beglin, 1994; Mond et al., 2004; Tavolacci et al., 2020). A Chi-square test was assessed to compare rates of students with a putative diagnosis of ED using the SCOFF questionnaire (SCOFF score > 2). In addition, comparison tests (Student's unpaired tests and Mann-Whitney U tests) were used to compare the mean EDEQ and EHQ total scores.

To test our second hypothesis (H2) of more at-risk behaviors for EDs and ON in dietetics and nutrition students compared to culinary arts students, we conducted the same tests as for H1 between the two groups (nutrition vs. culinary arts students).

To test our third hypothesis (H3) of a positive correlation between the importance of EDs and ON at-risk behaviors and the intensity of sports practice in both populations, Pearson correlation coefficients were computed between EDEQ, EHQ and SCOFF scales, subscales and the mean number of hours of sports per weeks (with and without hours of walking) within each population. Values of $r < 0.20$ were considered weak, $0.20 < r < 0.50$ were considered moderate, and $r > 0.50$ were considered strong correlations (Cohen, 1988).

Considering that a gender-effect exist in the prevalence of EDs, we compared results by gender. Considering that the non-binary gender did not have a sufficient number of subjects in each field to make comparisons, the gender comparisons we have made concern only men and women and will hereafter be described as "comparison by gender". Concerning the sports practice, we decided to exclude "walks" from the list of sports as it is considered more of a leisure activity than a sport. We kept however “active walking without calorie focus”.

Results

Participants’ characteristics and scales scores are available in Table 1 and 2.

Table 1. Participants’ characteristics in the two fields

	Whole population tested			Culinary Arts and Gastronomy students			Dietetics and Nutrition students		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
	267			144			123		
Age		19.82	2.12		19.92	2.16		19.71	2.09
BMI		22.19	3.36		22.57	3.55		21.74	3.09
Gender :									
women	157 (58.8%)			51 (35.4%)			106 (86.2%)		
men	107 (40.1%)			92 (63.9%)			15 (12.2%)		
other	3 (1.1%)			1 (0.7%)			2 (1.6%)		
Presence of food-related pathology:									
Yes, an eating disorder	13 (4.9%)			8 (5.6%)			5 (4.1%)		
Yes, a non-eating disorder	10 (3.7%)			3 (2.1%)			7 (5.7%)		
No, but diet restricted by personal convictions (ethical, religious, etc.)	28 (10.5%)			12 (8.3%)			16 (13%)		
Other	9 (3.4%)			5 (3.4%)			4 (3.3%)		

Note. SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; In the gender category, other include non-binary gender, and participants who did not respond.

Table 2. Descriptive statistics with scores on the questionnaires, assessing EDs symptoms (SCOFF and EDEQ), ON (EHQ) and body dissatisfaction (EDI BD).

	Whole population tested			Culinary Arts and Gastronomy students			Dietetics and Nutrition students		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
SCOFF score		1.61	1.18		1.81	1.24		1.39	1.05
SCOFF number of participants with 2 or more positive items	125 (46.8%)			76 (53.0%)			49 (40.0%)		
EDEQ global score		1.94	1.44		2.05	1.51		1.82	1.36
EDEQ Subscales :									
EDEQ Restraint		1.20	1.42		1.44	1.56		0.92	1.19
EDEQ Eating concern		1.30	1.28		1.36	1.33		1.23	1.23
EDEQ Weight concern		2.56	1.78		2.63	1.83		2.47	1.72
EDEQ Shape Concern		2.72	1.83		2.77	1.85		2.66	1.82
EHQ global score		33.15	7.73		32.99	7.80		33.34	7.69
EHQ Subscales :									
EHQ PACSR		8.43	3.09		8.56	3.11		8.29	3.07
EHQ PFC		17.06	3.58		16.86	3.84		17.30	3.26
EHQ REB		7.66	2.87		7.57	2.57		7.76	3.19
EDI BD (Body dissatisfaction subscale)		7.79	6.87		7.97	7.02		7.59	6.70

Note. SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; EDI BD: Eating Disorders Inventory Body Dissatisfaction subscale

Hypothesis 1 - Results

The SCOFF scores indicated that 76 students among 144 (53.0%) in the culinary arts field had a risk of EDs, which was significantly higher compared to 24.8% in the general population of students in France (Tavolacci et al., 2020) [$\chi^2(1,1635)=25.22, p<.001$].

A difference of gender showed higher SCOFF scores among women (76.5%) than among men (40.2%) in culinary arts students [$\chi^2(1,143)=5.02, p=.025$], which was also seen in the general population [Women 31.6%; Men 17%; $\chi^2(1,1493)=23.09, p<.001$]. When comparing the culinary arts and the general population by gender, women showed higher SCOFF scores in the culinary arts group than in the general population [$\chi^2(1,995)=16.56, p<.001$], and also did men [$\chi^2(1,637)=15.31, p<.001$].

Regarding EDEQ scores, to our knowledge the community norms of the EDEQ questionnaire in France has not been assessed, therefore with used as a comparison the most used community

norms in the literature (Mond et al., 2004), assessed among women only. Among women, results indicated a significant higher EDEQ mean score in comparison with the general population [$t(244) = 8.77$, $p < .001$]. Table 3 indicates the results for EDEQ global score and each EDEQ subscales.

Table 3. Comparison of EDEQ scale and subscale means between culinary arts students and the general population, among women only (Mond et al., 2004)

	Women in Culinary arts (N=51)		Women in the general population (N=195)		t	p
	Mean	SD	Mean	SD		
EDEQ Global score	3.04	1.59	1.42	1.04	8.77	<.001***
EDEQ Restraint	2.31	1.71	1.29	1.27	4.73	<.001***
EDEQ Eating concern	2.15	1.48	0.59	0.84	9.87	<.001***
EDEQ Weight concern	3.92	1.87	1.64	1.31	10.05	<.001***
EDEQ Shape Concern	3.78	1.91	2.16	1.44	6.65	<.001***

Note. SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; t = statistic test for Student's test; p = p-value adjusted with the Bonferroni correction. * <.05, ** <.01, ***<.001

Concerning EHQ, we failed to find a significant difference in EHQ global score means between the culinary arts group (M = 32.99, SD = 7.8) and the general population (Godefroy et al., 2021) (M = 33.00, SD =8.3); [$t(181) = -0.27$, $p = .789$]. When looking at EHQ subscales, the culinary arts group exhibited a higher mean score for the Problem of Attention, Control and Social Relationship subscale than the general population [$t(181) = 5.14$, $p < .001$], however they exhibited a lower mean score in the Rigid Eating Behaviour EHQ subscale than the general population [$t(181) = -8.70$, $p < .001$]. Considering gender (see Supplementary Materials 1), women exhibited higher EHQ global score [$t(465) = 4.12$, $p < .001$] and higher score for the Problem of Attention, Control and Social Relationship EHQ subscale than the general population [$t(465) = 6.22$, $p = .005$]. On the contrary, men exhibited lower EHQ global score [$t(465) = -2.75$, $p = .006$] and lower score on the Rigid Eating Behavior EHQ subscale [$t(465) = -4.37$, $p < .001$].

Hypothesis 2 – Results

Considering the SCOFF, results revealed that culinary arts students exhibited higher SCOFF scores than dietetics students [Culinary Arts 52.8%; Dietetics: 39.8%; $\chi^2(1,265)=4.46, p=.035$]. Comparison by gender revealed that women in culinary arts exhibited higher SCOFF scores

than men in Culinary Arts [Women 76.5%; Men: 40.2%; $\chi^2(1,141)=5.02, p=.025$] and also than women in Dietetics (38.7%) [$\chi^2(1,155)=5.95, p=.015$]. There was not enough men in dietetics (n=15) to see a significant difference between them (46.7%) and women in culinary arts [$\chi^2(1,64)=0.97, p=.325$].

Considering EDEQ and EHQ scales, only the EDEQ Restraint subscale showed a significant difference between the two fields, the culinary arts student group exhibited higher score than the dietetics and nutrition student group [$W = 10545$, $p = .007$]. Considering results by gender, women in culinary arts exhibiting higher EDEQ scores than the other subjects (Figure 1). They also exhibited higher EHQ scores than man in culinary arts [W=1548, p = .005]. Detailed scores are available in Supplementary Materials (SM2).

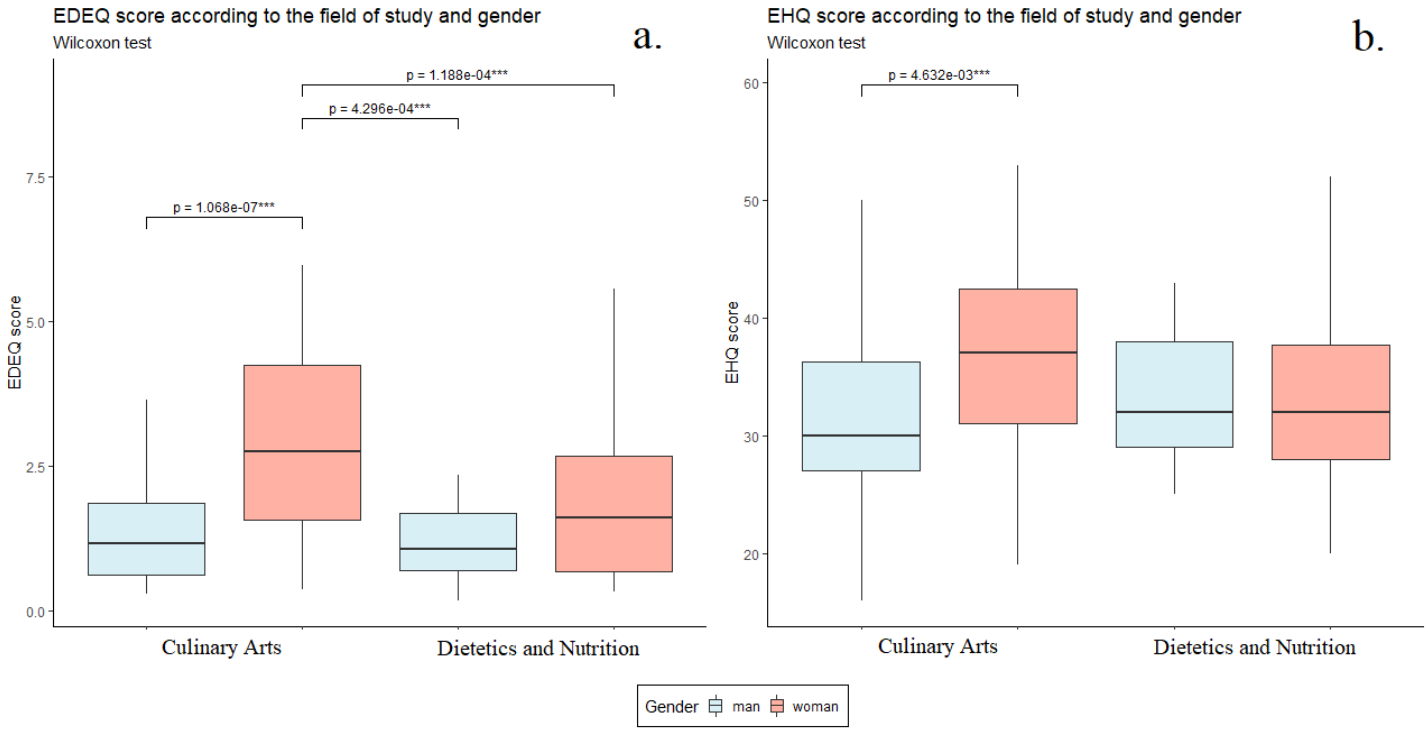

Figure 1. Comparison of scores of EDEQ (a) and EHQ (b) scales according to the field of study and gender

Hypothesis 3 – Results

Results of descriptive data on the type of sports practice and the amount of sports practice per week are available in Supplementary Materials (SM3).

Results revealed that only culinary arts students showed moderate correlations between the number of hours of sports per weeks and the EDEQ Restraint subscale scores [r=0.21, p=.012], as well as between the number of hours of sports per weeks and the EHQ global score [r=0.27, p=.001]. Considering results by gender, moderate correlations between the number of hours of sports per weeks and the EDEQ Restraint subscale, and the EHQ scales and subscales were found only among women in culinary arts (Table 4). Considering men in culinary arts, women in dietetics and man in dietetics, we failed to find any significant correlation regarding the number of hours of sports per weeks and the scales.

Table 4. Correlation coefficient and significance of correlation tests between the number of hours of sport per week and the various scales, subscales and questionnaire items, among students by field and by gender.

	Culinary Arts		Dietetics and Nutrition	
	Women	Men	Women	Men
SCOFF score	-0.01	0.04	0.06	-0.09
EDEQ Global score	0.25	0.04	0.11	-0.05
EDEQ Subscales :				
EDEQ Restraint	0.33*	0.08	0.13	-0.17
EDEQ Eating concern	0.26	-0.002	0.05	0.03
EDEQ Weight concern	0.17	0.02	0.12	-0.17
EDEQ Shape concern	0.16	0.05	0.12	0.10
EHQ global score	0.45***	0.15	0.17	0.03
EHQ Subscales :				
EHQ PACSR	0.51***	0.12	0.17	-0.07
EHQ PFC	0.34*	0.12	0.09	0.09
EHQ REB	0.33*	0.11	0.14	0.09
EDI BD	0.06	-0.12	-0.07	-0.18

Note. EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problem of Attention, Control and Social Relationship; EDEQ = Eating Disorder Examination Questionnaire; EDI BD: Eating Disorder Inventory Body Dissatisfaction subscale; * = p-value of the Pearson correlations <.05.

Discussion

This study is the first to assess EDs and ON at-risk behaviors in the population of culinary arts and gastronomy students, and to test the comparison with dietetics students. Culinary arts students exhibited higher scores on the scales assessing EDs and ON than the general student population, which confirmed our first hypothesis.

However, contrary to what we expected with our second hypothesis, culinary arts students also exhibited higher scores on the scales assessing EDs and ON than among dietetics students. It is important to note a gender discrepancy in the results: the scores were higher among women

students in culinary arts. Culinary students also scored higher on the Problems of Attention, Control, and Social Relationships subscale of the orthorexia nervosa assessment tool (EHQ questionnaire) than dietetics students. This trend was observed not only when compared to men students in culinary arts but also across both genders within the dietetics discipline. It is worth noting that students in dietetics were mostly women (women n=106, men n=15), making it impossible to test for gender differences.

This gender discrepancy is well-known in the prevalence of EDs (Smink et al., 2012), women exhibiting higher prevalence than men. But what is interesting here is that even when comparing with women students in dietetics, women students in culinary arts exhibited higher scores than women students in dietetics. Regarding ON, no consensus was made on a gender difference in the general population (Donini et al., 2022). More work is needed to understand this gender difference regarding EDs and ON at-risk behaviors in this population of students in culinary arts.

In addition to the gender difference, the difference between fields of study raised questions. While both fields revolve around food, their emphasis and orientation differ significantly. While we thought that, because of the importance of nutritional aspects of food in dietetics field, EDs and ON at-risk behaviors would be higher than in culinary arts, results revealed that it seemed to be the other way around. One interpretation would lie on the importance of rigour and perfectionism in culinary arts and gastronomy. Indeed, culinary arts is an art of extremely high standards, and EDs have been shown to be correlated with perfectionist aspiration and behaviour (Stackpole et al., 2023). Understanding the nuanced differences between these two fields could contribute to a more comprehensive interpretation of the study's outcomes and guide future research in unravelling the intricate connections between academic pursuits, food, and eating-related behaviors.

Moreover, a fundamental question remains unanswered: whether individuals with pre-existing EDs or ON are more predisposed to select such courses, or if these fields possess propensities to induce disorders in susceptible individuals. To unravel this question, longitudinal studies that meticulously assess EDs or ON both before and after engagement in these academic fields are needed.

Considering our third hypothesis on possible correlations between EDs or ON and the intensity of sports practice, results revealed that the correlations were mainly significant only among women in the culinary arts. Indeed, among women students in culinary arts, the intensity of

sports practice (seen with the number of hours of sports per week) was correlated with the ON assessment scale (EHQ questionnaire), as well as the EDEQ Restraint subscale. This was consistent with the literature, which also pointed out correlations between the intensity of sports practice and ON (Rudolph, 2018), or EDs (Sundgot-Borgen & Torstveit, 2010). We failed to find any correlation considering men in culinary arts as well as for women and men in dietetics.

Curiously, we found no correlation between intensity of sporting activity and body dissatisfaction, whereas the literature gave some evidence of this correlations (Alcaraz-Ibáñez et al., 2021). As sport is not at the core of both curricula (dietetics and culinary arts), one hypothesis could be that body dissatisfaction in these populations is more correlated with attitudes and behaviours towards food than with their sport practice, but more research is needed to explain it.

In summary, this study offers valuable insights into the prevalence of EDs and ON within the culinary arts and gastronomy academic field, and open doors for the investigation of the relation between food-related fields and EDs and ON at-risk behaviors.

Limitations

A first limitation of this study arises from the low number of male participants in the dietetics stream, with only n=15 individuals compared to the total cohort of n=123. This insufficient male representation prevents a comprehensive comparison between men and women within the dietetics discipline, restricting the ability to draw robust conclusions about gender-based differences in this field.

More generally, larger sample sizes and more diverse samples are needed and would enhance the generalizability of the findings, allowing for more confident interpretations of the results.

Supplementary Materials

Supplementary Materials are available in Appendices section.

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Chapter 6. Measuring implicit associations between food categories and body silhouettes in Anorexia Nervosa

This chapter presents the second study in the form of a scientific article, which is currently under review.

Whereas the previous chapter looked at the food-related environment in which individuals evolved, this new chapter focuses on food perception. Indeed, another way of approaching our control paradox is to look for the cognitive foundations of it, particularly at the level of perception, in the way subjects perceive food.

AN is the most extreme model of food intake restriction and the most documented in the literature. In AN, it was previously stated that the perception of food is associated with the perception of the effects it has on the body. Despite extensive research on body image in AN, the association between food categorization and body image remained relatively unexplored. We examined, in a second study (Chapter 6), the association between food and body stimuli in patients suffering from AN (n=28) and control subjects (n=27).

To measure the associations between stimuli belonging to distinct domains, such as the association between faces of different ethnicities and moral descriptions like 'good' and 'bad' (Greenwald et al., 1998), the commonly used methods are implicit association tests (Greenwald et al., 1998) and similar methods like the Go/No-Go Association Task (Nosek & Banaji, 2001). Implicit methods are particularly advantageous in situations where self-presentation or social desirability biases may influence results. Given the significant stigmas surrounding eating disorders (Brelet et al., 2021; Holliday et al., 2005; Zwickert & Rieger, 2013), we considered these measures to be appropriate for our study of patients suffering from AN. Furthermore, the design of the Go/No-Go Association Task allows for the application of Signal Detection Theory in food categorization, which enables us to investigate whether the association reveals specific food categorization patterns that are associated with subjects suffering from AN.

The results revealed specific association strength and specific categorization strategy in the subjects suffering from AN, compared to control subjects.

Measuring implicit associations between food and body stimuli in anorexia nervosa: a Go/No-Go Association Task

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Abstract

Purpose: The present study aimed to explore the implicit associations between food and bodily stimuli in patients with anorexia nervosa (AN) and control subjects (HC).

Methods: A Go/No-Go Association Task was administrated to 55 participants (28 AN and 27 HC), using food stimuli (low-calorie food vs. high-calorie food) and body stimuli (underweight vs. overweight bodies).

Results: We evidenced an implicit association between food and body stimuli in the AN group whereas the HC group only showed a tendency. AN and HC groups also exhibited different categorization strategies: the AN group tended to categorize stimuli as low-calorie foods and underweight bodies less than the HC group, and they tended to categorize stimuli as high-calorie foods and overweight bodies more than the HC group.

Conclusion: The present study revealed for the first time specificities of the AN population's implicit association between food and body stimuli in terms of association strength and categorization strategy. Furthermore, the results suggest that combining implicit methodologies with other methods could contribute to a better characterization of the physiopathology of AN.

Keywords: Categorization, Food, Body image, Anorexia nervosa, Implicit association.

Level of evidence: Level I, experimental study.

Introduction

Anorexia nervosa is one of the deadliest psychiatric illnesses (Arcelus et al., 2011; van Eeden et al., 2021), characterized by severe restriction of energy intake relative to requirements, an

intense fear of gaining weight, and a disturbance in the way in which one's body weight or shape is experienced (American Psychiatric Association, 2013b). Two subtypes exist in AN: the binge-eating/purging subtype, which is characterized by regularly engaging in binge-eating or purging, and the restrictive subtype, which does not engage in these behaviors. For a decade, research on anorexia nervosa (AN) has shifted from studying overt behaviors to examining cognitive underpinnings that may contribute to the disorder's development, course, and treatment (Treasure et al., 2011). Among the set of cognitive factors potentially involved in the expression of AN, most research has focused on the reward system (Bischoff-Grethe et al., 2013; Keating et al., 2012; J. E. Steinglass et al., 2012), executive functions (Lang et al., 2014; Roberts et al., 2007; Tchanturia et al., 2012; Treasure & Schmidt, 2013), emotion regulation (Meule et al., 2019; Oldershaw et al., 2015), attentional bias (Berthoz et al., 2022; Gillberg et al., 2010),and body perception (Gardner & Brown, 2014; Mölbert et al., 2017). Body perception has been investigated the most, with research showing that patients suffering from AN tend to overevaluate shape and weight (Gardner & Brown, 2014) and exhibit high body dissatisfaction (Juarascio et al., 2011). Cognitive factors in AN have been investigated at both explicit and implicit levels. Implicit mechanisms are appropriate in populations that might exhibit self-presentation biases or social desirability biases, which is true of the population suffering from anorexia nervosa (Gustafsson et al., 2011; McCabe et al., 2001). These biases might lead, under certain circumstances, to a discrepancy between declarative data, which participants report directly (e.g., questionnaire responses), and data obtained using implicit methods, such as timing measurements to assess associations. However, only a few studies have investigated how patients suffering from AN perceive and reason about food, while patients suffering from AN exhibit obsessive thought about eating (Cooper & Fairburn, 1992).

Most research about food perception and reasoning in AN has focused on the reward system and has revealed a decreased preference for high-fat/calorie foods at explicit and implicit levels (Lloyd & Steinglass, 2018; Uher et al., 2003). Studies have also shown that anxiety traits and fear of gaining weight lead to food avoidance and limitation of caloric intake, specifically calories derived from fat (García-García et al., 2013; Lloyd & Steinglass, 2018). Studies on attentional bias, which is the tendency to focus on certain elements while ignoring others, toward food did not come to a consensus (Lloyd & Steinglass, 2018), even if recently Paslakis and colleagues (Paslakis et al., 2021) evidenced reduced implicit attentional bias toward food in AN in their systematic review. One study in social psychology conducted by Urdapilletta and colleagues (Urdapilleta et al., 2005) revealed that when patients suffering from AN classified

food items, one criterion was their effect on the body, for example several items were grouped together because they were all considered difficult to eliminate, as they were too rich or too fatty and therefore indigestible. This literature suggests that patients with AN may perceive food based on its real or alleged effects on the body (regardless of the accuracy of these effects), and this is driven by the intense fear of gaining weight. However, no one has tested the association between the food and body domains, even though this association could be a distinctive feature of AN.

Methods that test the strength of associations between stimuli in distinct domains (e.g., between faces varying in ethnicity and moral predicates such as "good" and "bad") are called implicit association methods. They have been used in AN to investigate body perception or food perception separately. Izquierdo and colleagues (Izquierdo et al., 2019) investigated body perception with tests of the implicit associations between pro-dieting vs. non-dieting and true vs. false in a first task, and pictures of underweight vs. normal-weight models and positive vs. negative words in a second task. Results revealed pro-thin/anti-fat implicit biases in AN that were predictive of disordered eating and body image dissatisfaction, over and above the corresponding explicit biases. The same tasks helped Borgers and colleagues (Borgers et al., 2021) to discover that the severity of symptoms in AN correlated with a higher implicit drive for thinness. Moreover, Smith and colleagues (A. R. Smith et al., 2014) used these methods to show stronger associations between emaciation and both beauty and ugliness. Concerning food perception, one study has examined the association between food and moral attributes in AN without finding any difference between the AN group and the control subjects (Lakritz et al., 2022). Another looked into the association between food and body image, specifically examining the relationship between meal portions and body size using an implicit association task (Vartanian et al., 2004). However, it did not explore this link within the context of AN, but between restrained and unrestrained eaters. Contrary to what the authors expected, restrained and unrestrained eaters showed equally strong automatic associations between large meals and fat words, and between small meals and thin words.

Given the available evidence suggesting that food perception and body concerns are especially entangled in subjects with AN, the present study aimed at filling two gaps: a theoretical gap, as the strength of the relationship between food perception and body image has not been studied in AN, and a methodological gap, investigating the strength of this association using implicit association methods.

Based on the existing literature on the food and body variables that might trigger emotional responses or rejection in patients with AN, we tested the following hypotheses:

(H1): all participants (HC and patients with AN) implicitly associate high-calorie foods with overweight bodies and low-calorie foods with underweight bodies;

(H2): Patients with AN associate body stimuli with food stimuli more strongly than HC.

In addition, we explored the categorization strategies in subjects with AN compared to HC. Categorization strategies are response biases that avoid a particular type of error problematic for the subject (Green & Swets, 1966). For instance, if you must decide whether the thing you see is a snake or a stick in a forest, you might have the tendency to avoid thinking a snake is a stick, rather than mistaking a stick for a snake, due to the higher risk involved in the former. As seen in this example, risk influences categorization strategies. Uncertainty influences them also, as the tendency to avoid one type of error might be higher in a very uncertain situation. Indeed, in the same example, if the forest is in a deep fog, the tendency to avoid mistaking a snake for a stick might be higher than if you walk in the forest in a sunny day where you are able to clearly see each stick. Categorization strategy is worth exploring in the present study as patients with AN can experience both risk and uncertainty when classifying food and body stimuli according to calorie content and BMI.

Methods

Participants

No previous research investigated the strength of the implicit association between food and body stimuli in AN, so power analysis estimates was determined based on research that assessed implicit associations between meal sizes and body sizes among restrained and unrestrained eaters (Vartanian et al., 2004). Following their results, a sample of 27 participants in each group (AN and HC) would be needed to obtain a similar effect size with a power of 80 and an alpha level of .05.

Sixty-nine women (28 with AN and 41 HC) completed this experiment. A first recruitment took place in June and July 2019 before the COVID-19 pandemic: 15 women with AN (33% binge/purging subtype; 67% restrictive subtype) and 25 HC completed the experiment. A second recruitment took place in December 2022 after the COVID-19 pandemic: 13 women with AN (40% binge/purging subtype; 60% restrictive subtype) and 16 HC completed the

experiment. The participants in the two recruitments did not differ significantly in age or BMI (all p values > .05).

In the first recruitment, psychiatrists recruited the patients with AN. Patients with any severe comorbidity (e.g., major depressive disorders), with a BMI below 12, or having a prescription of benzodiazepine or an antipsychotic were excluded. All 15 patients were included in the analyses (mean age = 23.10, SD = 4.7, mean BMI = 16.70, SD = 1.5). One patient did not complete the age, height and weight, and questionnaire information but was included in the task analyses. Researchers recruited the HC through email databases of French universities and compensated them with a 10€ voucher. All HC group recruits were evaluated with psychometric scales to exclude participants with eating disorders or orthorexic characteristics. The HC completed the ORTO-15 (L. Donini et al., 2005b) with the revised scoring suggested by Meule and colleagues (Meule et al., 2020) (Cronbach's alpha (α) was 0.78) and the Eating Disorder Inventory II – Short Form (EDI-II-24, (Maïano et al., 2009a)) (α = 0.74), to assess respectively orthorexic and eating disorders traits. The HC who presented eating disorder symptoms (ORTO-15 < 35 or EDI > 52) were excluded from the analyses. Of 25 respondents, 15 were included in the HC group (mean age = 23.50, SD = 3.1, mean BMI = 22.00, SD BMI = 2.6).

In the second recruitment, psychiatrists recruited 13 patients with AN who were included in the analyses (mean age = 27.60, SD = 6.6, mean BMI = 16.10, SD = 1.4) using the same exclusion criteria. We refined the screening of the HC group on the basis of recent publications (Godefroy et al., 2021; Missbach et al., 2017; Opitz et al., 2020) and chose the following reliable questionnaires: the French version of the Eating Habits Questionnaire (Godefroy et al., 2021) to assess orthorexic traits (α = 0.93), and the French versions of the Eating Disorder Examination Questionnaire (EDEQ) (Carrard et al., 2015) (α = 0.91) and the SCOFF questionnaire (Luck et al., 2002) (α = 0.83) to assess eating disorders traits. The HC who presented eating disorder symptoms (SCOFF > 2, after the 95th percentiles of EDE-Q and EHQ scores) were excluded from the analyses. Of 16 respondents, 12 were included in the HC group (mean age = 26.00, SD = 5.4, mean BMI = 18.64, SD BMI = 3.2).

With both recruitments, 55 participants were included in the analyses (mean age = 24.33, SD = 4.6, mean BMI = 19.06, SD BMI = 3.32). We found no difference between the participants recruited before and after the COVID-19 pandemic on age, BMI, satiety level, and the variables used, except on reaction times: we found an average increase of almost 73ms for all the participants of the second recruitment. Because the results were compared between the AN and HC groups, this difference did not change the outcome of our results.

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University Lyon 1 (2019/ ID-RCB Number: 2019-1A01595 52) and Paris (2015-A01194-45). Informed consent was obtained from all individual participants included in the study.

Stimuli

The test stimuli were 40 colour photographs, including 32 food items and 8 images of bodies (see Supplementary Materials Table 1 and OSF repository).

Food stimuli

Food stimuli were taken from the FoodPics database (Blechert et al., 2014). Stimuli were categorized in terms of their energy density (calories per 100g and calories per image). We included 16 low-calorie stimuli (mean Kcal/100g = 47.6, SD = 25.6; mean Kcal/image = 52.9, SD = 32.8) and 16 high-calorie stimuli (mean Kcal/100g = 355.3, SD = 184.3; mean Kcal/image = 594.7, SD = 375.0). Because people perceive foods that are more processed to be more caloric (Foroni et al., 2016), the degree of processing was controlled by including 8 perceived natural and 8 perceived processed foods in both the low- and high-calorie groups, following Blechert and colleagues' classification within each category of energy density.

Body stimuli

We used a subset of 3D-graphics body stimuli taken from a larger database of computer-generated pictures of women's bodies constituted by Moussally and colleagues (Moussally et al., 2017). Among the body items, we included 4 perceived to be underweight (BMI 13.2 to 19.6) and 4 perceived to be overweight (BMI 21.6 to 120.2). A pre-test we conducted on 5 control participants indicated that the body stimuli were well discriminated.

Go/No-Go Association Task

We administered a Go/No-Go Association Task (GNAT) (Nosek & Banaji, 2001) to the participants through the E-Prime 3.0 (Psychology Software Tools, 2016) and Labvanced (Finger et al., 2017) software. Participants were asked to press the space bar when they detected items that belonged to the target categories and to not press any key when presented items did not belong to the target categories. The GNAT is designed to measure the association between a target category and two poles of an attribute dimension (e.g., good/bad). In this GNAT, the two target categories are low-calorie food and high-calorie food and the two poles of the attribute correspond to underweight and overweight bodies. The GNAT included 4 practice single blocks and 4 combined blocks (Supplementary Materials Table 2). In the 4 practice

blocks, participants learned to discriminate between two categories: low-calorie food from high-calorie food and underweight bodies from overweight bodies.

In each combined block, a target category (e.g., low-calorie food) was paired with an attribute (e.g., underweight body). In Block 1, participants had to press the bar if they saw a low-calorie food or an underweight body on the screen (target categories), and not press the bar if any other stimulus appeared on the screen (Block 1). Target categories for the second combined block were high-calorie food and overweight bodies (Block 2); they were low-calorie food and overweight bodies for the third one (Block 3); and they were high-calorie food and underweight bodies for the fourth one (Block 4). Among the 4 combined blocks, 2 represented the congruent conditions, in which the association between the target categories was hypothesized to be stronger (Blocks 1 and 2). For each block (practice or combined), distractor stimuli were the opposite of the target stimuli. Each stimulus was presented several times (2 times for food stimuli and 8 times for body stimuli). The stimulus sequences can be seen in Fig. 1.

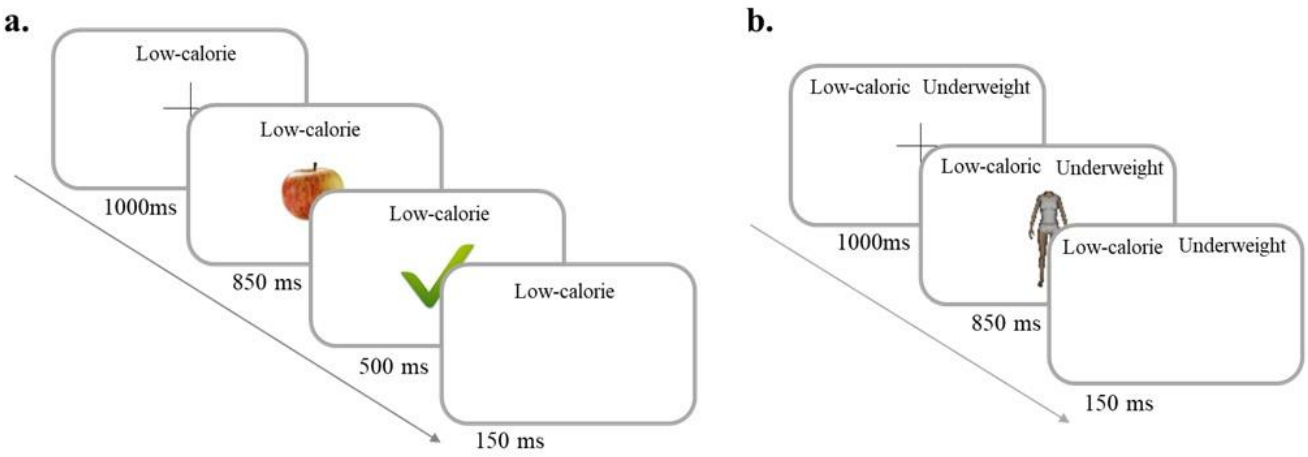

Fig. 2 Stimulus sequences during practice block (a) and combined block (b)

Note. Interstimulus Interval (ISI): 1650ms in practice blocks with feedback, 1150ms in combined blocks. For the purpose of this paper, this figure is an English translation of the task, whereas it was administered in French.

Procedure

We conducted the experiment was conducted in a quiet testing room. The participants' level of satiety was evaluated on a 7-point Likert scale ranging from "not at all" to "extremely" hungry. The following instructions were given to the participants: "Press the space bar only for images belonging to the following categories (e.g., Low-calorie food or Underweight body). Otherwise, do nothing. Answer WITH AS FEW ERRORS AS POSSIBLE, and as quickly as possible." We

used capital letters to emphasize accuracy over speed as we wanted to favor analyses of errors based on previous work in the same population (Lakritz et al., 2022). During the practice single blocks, participants were given feedback after each trial: a green circle or a red cross corresponding to a correct or an incorrect response, respectively. The purpose of the practice single blocks was simply to accustom the participant to the task. No information on the rate of correct answers or the average response time was given to the participant at the end of each training block. The 4 combined blocks were presented in a random order across participants, without feedback.

Confirmation of stimulus choices: After the task, we asked participants to classify each body stimulus as underweight or overweight. In addition, in the second recruitment, we asked them to also classify each food stimulus as low-calorie or high-calorie. The stimuli were presented one by one in a randomly assigned order.

Finally, participants had to complete the questionnaires mentioned above. They had a total of one hour to complete the experiment and the questionnaires. Each individual session lasted approximately 35 min.

Data recording and analyses

Individual response times (ms) and response were recorded. Analyses were conducted on the critical trials using Rstudio 3.6.0 R © software. The effects were considered significant when $p < .05$.

Confirmatory analyses

Reaction times (RT) and type of responses were analysed. Data analyses assigned each block for each participant a score for hits (i.e., pressing the space bar when stimuli were in the target category) and a score for false alarms (i.e., when stimuli were distractors). Based on signal detection theory, we computed A', an index of discriminability (Grier, 1971a; Stanislaw & Todorov, 1999). The A' index ranges from 0 to 1, with .5 indicating responses at chance level, and 1 indicating maximum discriminability. To test our hypothesis of an association between energy density and visual BMI (H1), we tested whether a facilitating effect on participants' responses (shorter RT or higher A') occurred in congruent conditions. To test our hypothesis of a difference of strength of association between our groups, we computed two indices, one with the RT and one with A' (H2). Regarding RT, we computed the D-measure, which reflects the effect-size and is conceptually similar to Cohen's d (Cohen, 1988). D-measure was compared between groups with Student's test. Regarding discriminability, we computed the difference in A' between conditions and compared it between the AN and HC groups with a Mann-Whitney

U test. Effect sizes were computed with the Cohen's d formula (Cohen, 1988). An effect size of 0.2 to 0.5 is considered small, 0.5 to 0.8 is considered medium, and greater than 0.8 is considered large.

For the confirmation of stimulus choices, we calculated the percentage of errors made by each participant and each group and computed Chi-squared tests between groups.

Analyses were controlled for age, BMI, and satiety level.

Exploratory analyses

According to Signal Detection Theory (Grier, 1971b; Stanislaw & Todorov, 1999), another index can be computed from hit and false alarm rates: the participant's decision criterion (β''), which is distinct from the discriminability index (A'). β'' ranged from -1 to +1: -1 indicates a liberal criterion, the participant exhibits a tendency to say that the signal is present; +1 indicates a conservative criterion, the participant exhibits a tendency to not say that the signal is present. In other words, the β'' captures the *personal* response strategy in the presence of risk and/or uncertainty. In the present study, β'' means were compared between groups in each condition and in each block to see if each group exhibited a specific strategy depending on the condition or block.

Results

Participants' Characteristics

Participants from the AN and HC groups did not differ in age or in state of satiety, but they differed in BMI, ORTO15 score, EDI-II-24 score, EHQ score, EDE-Q score, and SCOFF score (Supplementary Materials Table 3).

Results of confirmatory analyses

Detailed results are available in Supplementary Materials, Tables 4 and 5. Mean RT were significantly different between conditions in the AN group [AN: $U(28) = 232$, $\beta = 30.5$, $p = .016$, *95% CI [8.27;56.8]*] with a moderate effect size of 0.68, whereas in the HC group, it was not significantly different [HC: $U(27) = 254$, $\beta = 23.7$, $p = .113$; *95% CI [-1.03;50.8]*]. Discriminability was significantly different between conditions in the AN group [AN: $U(28) = 542$, $\beta = -0.022$, $p = .014$, *95% CI [-0.041;-0.005]*] with a moderate effect size of 0.78, whereas in the HC group, it was not significantly different [HC: $U(27) = 449$, $\beta = -0.013$, $p = .146$; *95% CI [-0.032;0.005]*].

To evaluate whether the differences between incongruent and congruent conditions were different between the two groups, we looked at D-measures and A'. D-measures showed no significant difference [*t(54)* = 1.42, *β* = 9.01, *p = .161, 95% CI [-3.730;21.800]*] between the AN and HC groups, but A' showed a significant difference [*U(54)* = 499, *β* = 0.013, *p = .042, 95% CI [0.001;0.029]*] with a small effect size of 0.48.

Overall, the results showed a facilitating effect on participants' responses (lower RT or higher A') in the congruent condition compared to the incongruent condition in the AN group but not in the HC group, with a larger discriminability effect size in the AN group than in the HC group.

Results of exploratory analyses

Taking each block separately, only the congruent blocks showed differences between AN and HC groups (see Figure 1). Mean β'' was positive and significantly higher in Block 1 (low-calorie food and underweight body as target categories) for the AN group than for the HC group [*U(55)* = 692, *β* = 0.642*, p < .001, 95% CI [0.457;0.830]*] with a large effect size of 0.88. It indicated that the AN group's decision strategy was more conservative in Block 1 (i.e., they tended to categorize fewer stimuli as low-calorie food and as underweight bodies than the HC group). On the contrary, in Block 2 (high-calorie food and overweight body as target categories), mean β'' was significantly lower in the AN group than in the HC group [*U(55)* = 229*, β* = -0.366*, p = .012, 95% CI [-0.632;-0.080]*] with a moderated effect size of 0.53. It indicated that the AN group was more liberal in Block 2 (i.e., they tended to categorize more stimuli as high-calorie food and as overweight bodies than the HC group). To summarize, the results revealed decision criterion differences between the AN group and the HC group in Blocks 1 and 2.

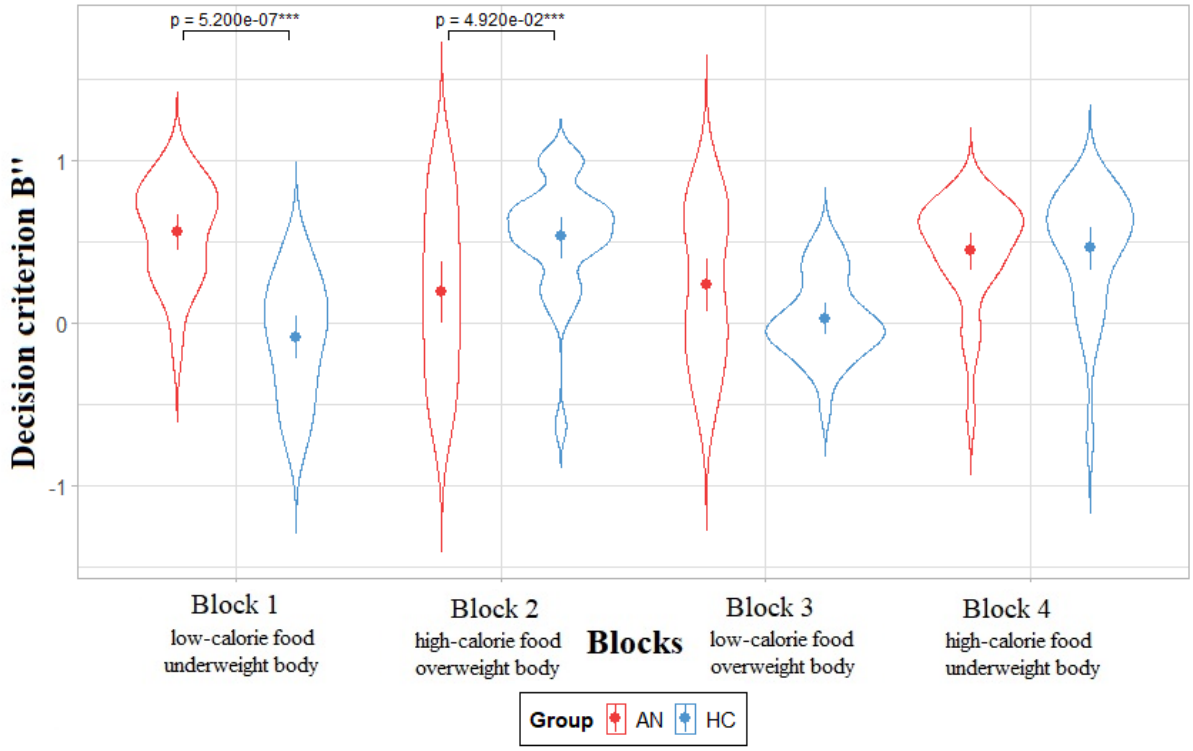

Fig. 3 Decision criterion according to the groups and blocks

Note. AN group = 28 patients with Anorexia Nervosa; HC group = 27 control participants; p = p value of Mann-Whitney U test performed between groups; *** < .001

Confirmation of stimulus choices

Regarding body stimuli, the AN group categorized significantly more underweight bodies as overweight than the HC group (AN: 36%, HC: 16%; $\chi^2(1,2) = 9.28$, $p = .002$, *95% CI [0.077;0.338]*). The difference between the two groups in terms of overweight bodies taken as underweight bodies was not significant (AN: 8%; HC: 15%; $\chi^2(1,2) = 1.96$, $p = .162$, *95% CI [-0.182;0.022]*). Regarding food stimuli, the AN group categorized significantly more low-calorie food as high-calorie food (AN: 17%; HC: 8%; $\chi^2(1,2) = 7.69$, $p = .006$, *95% CI [0.009;0.081]*), and they categorized significantly less high-calorie food as low-calorie food than the HC group (AN: 9%; HC: 27%; $\chi^2(1,2) = 18.2$, $p < .001$, *95% CI [-0.143;-0.057]*).

Discussion

We studied the implicit association between food and body stimuli in a group of patients with AN compared to control participants. We used energy density and visual BMI as main variables. To the best of our knowledge, this experiment is the first to assess the association between

energy density and visual BMI in a population suffering from AN. Our data revealed the existence of this association in the AN group, without finding it in HC group. Findings also revealed that the AN group tended to avoid categorizing a high-calorie food for a low-calorie food, and to avoid categorizing an overweight body for an underweight body.

Results revealed the existence of the association between energy density and visual BMI in the AN group with moderate effect sizes, whereas we failed to find it in the HC group. Our finding emphasizes that the association investigated in this paper might be a distinctive feature of the population suffering from AN.

Our findings also shed light on a crucial aspect of AN that has often been overlooked: the heightened perception of risk associated with food choices. Our study demonstrated that individuals suffering from AN displayed a distinctive cognitive pattern (with moderate to large affect sizes compared to healthy control subjects), characterized by a strong inclination to avoid certain types of errors when categorizing food and body stimuli. They were more likely to avoid misclassifying high-calorie foods as low-calorie foods, which could conflict with their core objective of calorie restriction. They also were more likely to avoid misclassifying overweight bodies as underweight bodies, which is consistent with the intense fear of gaining weight in anorexia nervosa (American Psychiatric Association, 2013b). This heightened risk perception is consistent with previous research that highlighted anxiety-related tendencies in individuals with AN (White et al., 2016). Indeed, White and colleagues (White et al., 2016) showed that anxious individuals were more likely to categorize threatening and neutral words as threatening than non-anxious individuals. It stands to reason that this elevated risk perception may contribute to the rigorous dietary restrictions observed in AN, as individuals strive to minimize any potential threat to their established eating patterns. Given the profound impact of anxiety on food-related decision-making, our results emphasize the importance of targeting anxiety-related interventions in AN. Such interventions could help individuals suffering from AN overcome the fear associated with food choices and develop healthier eating behaviors.

Strengths and limits

This study measured, for the first time, implicit associations between body (visual BMI) and perceived energy density of food in people with anorexia nervosa. Results demonstrate that implicit methods can be used to detect AN and to explore the decision-making strategies of patients with AN in the presence of risk and uncertainty in the food and the body domains.

Several limitations of the present study need to be addressed in further research. First, the sample sizes were small and replication on larger sample sizes is needed to confirm the results. Moreover, a larger sample size could allow us to distinguish different AN subtypes, for example to distinguish participants with the restrictive type of AN from participants with binge-eating/purging AN.

In addition, the exclusion of people with orthorexia nervosa from the HC group did not allow us to explore this population and to contribute to the ongoing debate about the similarities and differences between orthorexia nervosa and other eating disorders (Łucka et al., 2019). Further research will have to include subjects with orthorexia nervosa who might exhibit body dissatisfaction and drive for thinness (Barnes & Caltabiano, 2017; Brytek-Matera et al., 2015).

What was already known on this subject?

Patients with AN seem to exhibit a relationship to food driven by bodily concerns. Indeed, studies have shown that fear of gaining weight leads to food avoidance and limitation of caloric intake, and food categories were explained by bodily considerations among patients with AN. However, the strength of the association between body and food categories had not been clearly investigated in AN. This study aimed at filling this gap by measuring the strength of the associations between food and body stimuli within these populations, and by exploring their respective food and body categorization strategies.

What does this study add?

Our study is the first to reveal implicit associations between food and body stimuli in participants with AN. As our data revealed specific patterns of the AN group, this opens the door for a better understanding of food perception at an implicit level in AN. In addition, results revealed heightened perceived risk in AN in the food and body domains. These findings demonstrate that implicit methods can be fruitfully used to measure the cognitive markers of AN and pave the way for further studies on the way food and bodily concerns and perceptions are intertwined in patients with AN. These results also give evidence for targeting anxiety-related interventions in the population suffering from AN to reduce perceived risk concerning food choices.

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Statement and Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

The study was designed by Jérémie Lafraire and Clara Lakritz. Data collection was performed by Clara Lakritz and under the supervision of Dr. Sylvain Iceta, Dr. Vincent Masetti, Dr. Philibert Duriez, Dr. Maxime Makdassi, and Dr. Olga Davidenko. Data analyses were performed by Clara Lakritz. The first draft of the manuscript was written by Clara Lakritz and Jérémie Lafraire. Sylvain Iceta commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability statement

The stimuli, datasets, and R code generated and analysed are available in the OSF online repository at https://osf.io/tgxm4/?view_only=880dad413258489f8f368221504b4b3e and upon request from the corresponding author.

Ethics approval

As written in the Methods section, this study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University Lyon 1 (2019/ ID-RCB Number: 2019-1A01595 52) and Paris (2015-A01194-45).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Chapter 7. Measuring implicit associations between food categories and moral attributes in Anorexia Nervosa

This chapter presents the third article, which includes two consecutive experiments and has been published in June 2022. This chapter explores the implicit association between food and moral attributes in patients suffering from anorexia nervosa and among the general population.

As described in Part A, moral considerations come also into play in the food choices of patients suffering from AN. Thus, the aim of this chapter is to investigate the implicit association between food and moral attributes in patients suffering from AN and in the general population.

The first study looked at the implicit association between food stimuli and moral attributes (purity/impurity) in patients suffering from anorexia nervosa (n=32) compared with control subjects (n=32), using the same task as in the previous chapter: the Go/No-Go Association Task. The findings revealed an association between food stimuli and moral criteria, but this was observed equally in both the anorexia nervosa and general populations.

This prompted us to conduct a second study in the general population only. We then studied the association between food stimuli and moral attributes in the general population, to determine whether the association between food stimuli and moral criteria could distinguish the population with ON tendencies from the control population. A total of 143 participants from the general population were tested. They were divided into four groups according to their score on the ORTO-12-FR orthorexia scale (Babeau et al., 2020) and the EDI-II-24 eating disorders scale (Maïano et al., 2009b). The results suggested that this association was present in subjects suffering from AN, in subjects with ON tendencies and in control subjects.

These findings revealed an association between food stimuli and moral criteria in all groups, which raised the question of the distinction between the population suffering from ON and the general population in their perception of food.

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Sinful Foods: Measuring Implicit Associations Between Food Categories and Moral Attributes in Anorexic, Orthorexic, and Healthy Subjects

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Recently, neurocognitive studies have shown that food categorization is sensitive to both the properties of the food stimuli (e.g., calorie content) and the individual characteristics of subjects (e.g., BMI, eating disorders) asked to categorize these stimuli. Furthermore, groups of patients with eating disorders (ED) were described as relying more on moral criteria to form food categories than were control subjects. The present studies built on these seminal articles and aimed to determine whether certain food properties might trigger moral categories preferentially in subjects suffering from ED and in the general population. Using a Go/No-Go Association Task, Study 1 focused on the extent to which food categories are laden with moral attributes in ED patients compared to control subjects. Study 2 was a follow-up with a different design (an Implicit Association Test), another food variable (calorie content), and two non-clinical subgroups (orthorexic and healthy control subjects). Results revealed for the first time implicit associations between food variables cueing for energy density and moral attributes in the general population, the population suffering from anorexia nervosa, and subjects suffering from disordered eating such as orthorexia nervosa. These findings suggest that moralization of food is a pervasive phenomenon that can be measured with methods reputed to be less vulnerable to self-presentation or social desirability biases.

Keywords: food categorization, moral judgment, cognition, eating disorders, anorexia nervosa, orthorexia nervosa

INTRODUCTION

Categorization is a fundamental ability that we rely on to organize sensory information into entities or categories of entities we might refer to. From such categories, we then generalize information to novel instances and act accordingly. For example, if an object is categorized as a blackberry, you are entitled to ascribe the edibility property to that object and then decide to eat it (1). Recent

studies that investigated the nature of food categorization revealed that food categorization is far from simple and that the term actually uncovers manifold processes: from early and automatic discrimination of food depending on the sensory properties (2) to the building of elaborate morally-laden conceptual representations about foods (3). A further complication comes from the fact that food categorization seems very sensitive to both the properties of the food stimuli and the individual characteristics of subjects asked to categorize these stimuli.

At a very early stage of cognitive processing, the mere sight of food triggers a wide range of physiological, emotional, and cognitive reactions (4). For instance, in an electroencephalogram (EEG) study using visual evoked potentials, Toepel et al. (2) obtained evidence of early discrimination of subclasses of food images by manipulating their reward value (e.g., low fat food versus high fat food). They identified two discrimination stages: an early stage of categorization at ∼165 milliseconds (ms) and a second at ∼300 ms post-stimulus. The calorie content and the degree to which the food has been processed are also rapidly discriminated by the cognitive system. Analyzing event-related potentials, Pergola et al. (5) evidenced different neuronal activity depending on the degree of food processing and calorie content: natural (e.g., an apple) versus processed (e.g., lasagna).

In addition to the properties of the food, an individual's characteristics influence food categorization as well. In the EEG study mentioned above, Pergola et al. (5) showed that the distinctive neuronal activity underpinning food processing is modulated by the body mass index (BMI) of participants. Specifically, they investigated the N400 amplitude and latency in response to food stimuli. N400 amplitude and latency reflect the incongruence or congruence between stimuli, and is measured by placing electrodes at specific locations on the scalp. Its amplitude and latency reflect the strength of the signal and the delay between the stimuli and the signal, respectively (6–8). In their study these stimuli were photographs depicting either a natural or a processed food (e.g., pineapple or pizza, respectively) and sentences that described either a sensory attribute (e.g., "It tastes sweet") or a functional attribute defined as the context in which the food is eaten (e.g., "It is suitable for a wedding meal"). In the task, a sentence was followed by an image, and the sentence-image pairs were either congruent ("It tastes sweet" with pineapple) or incongruent ("It tastes salty" with pineapple). Results revealed modulations of N400 amplitude and latency caused by sensory-functional primes only for processed food (e.g., lasagna) in participants with obesity, whereas only for natural food in underweight participants (e.g., an apple).

Furthermore, interactions between these two types of variables that influence food categorization, namely those cueing energy density and an individual's characteristics have been recently evidenced in behavioral studies. Coricelli et al. (9) conducted an exploratory analysis that revealed that restrained eaters (individuals who strictly control their tendency to eat for an extended period to lose or maintain body weight) were significantly slower at categorizing processed food as such compared to unrestrained eaters. The authors explained this effect by referring to work conducted by Papies et al. (10) who put forward that in restrained eaters, the attraction of food palatability might have interfered with their goal of dieting. Coricelli and colleagues argued that a similar conflict between enjoying food transformation and dieting could be what increased the reaction times of the restrained eaters in their study [see (11) for the background theory about such a conflict].

Restrained eating is considered to be a core symptom of anorexia nervosa (12). Interestingly, an interaction between an individual's characteristics and food categorization in subjects suffering from anorexia nervosa has been documented by Urdapilleta et al. (3) in a social psychology study. The authors explicitly asked eating disorder patients (restrictive anorexic, binge/purge anorexic, and bulimic) and control subjects to categorize 27 food names. Results revealed that restrictive anorexic patients relied more on moral criteria (i.e., deontic terms such as obligation and permission "I can/cannot eat this") to form food categories compared to other patients. This observation echoed religious asceticism that is historically deeply connected to what is sometimes called "holy anorexia", illustrated by the case of Catherine of Siena or food deprivation that monks and clerics voluntarily endured in early Catholicism, anchored in ascetic practices defined at the end of Antiquity (13).

Morally-laden food perception and reasoning in anorexia nervosa has been highlighted in particular by Giordano (14), who put forward the idea that eating disorders are a particular expression of some moral beliefs. Especially anorexia nervosa could be driven by the pursuit of lightness and moral purity. Nowadays, words such as purity, decadence, heaven, and temptation are even recurrent in advertisements about food and in Western societies. The constant use of the lexicon of holy anorexia in advertisements has even been suspected to contribute to the maintenance of associations between eating certain foods and moral values, which might represent a risk factor of developing eating disorders (15). Interestingly, negative moral attributes such as "luscious", "decadent", and "temptation" in advertisements are generally associated with highly processed foods (14, 15). Furthermore, it has been suggested that similar mechanisms (e.g., disgust) might underpin the impurity judgments resulting from the transgression of moral laws, and the impurity judgments resulting from the transgression of regulation of eating or hygienic rules (16). The hypothesis that a same cognitive system anchored originally in distaste is now recruited by the moral domain would explain why some attributes might occur both in the food and the moral domain (e.g., lightness and purity). A similar theory that cultural domains such as morality invade older brain circuits such as disgust has been put forward by Dan Sperber [Sperber and Hirschfeld, (17)] and discussed in neuroimagery studies (18, 19).

This idea of an incursion of the moral judgment of food into the general population can be supported by the emergence of a specific eating attitude which has received a great deal of attention in recent decades: Orthorexia Nervosa, ON hereafter (20). This refers to an obsession about healthy eating that leads to emotional and psychosocial consequences such as anxiety and social isolation. Orthorexic traits are measured by self-declarative questionnaires, one of the most commonly used being the ORTO15 questionnaire (21). People suffering from ON

exhibit a food restriction based on the healthiness and quality of food. Furthermore, they tend to exclude foods not considered sufficiently healthy or pure, two food attributes that seem to fall more into the category of pseudo-moral aspects than into the category of objective qualities of food (22).

The present studies aimed to determine whether certain food properties (especially those related to the energetic value of food) might trigger moral categories in subjects suffering from eating disorders and in the general population. More precisely, Study 1 aims to test whether patients suffering from anorexia nervosa (AN) would be more prone to lade food with moral properties than would the general population. Two specific research hypotheses have been tested in Study 1:

> H1: Processed foods are implicitly associated with moral impurity whereas natural foods are associated with moral purity.
>
> H2: Patients suffering from AN associate moral attributes with food more strongly than control subjects.

Study 2 further explored the relationship between food and moral attributes in the general population with and without orthorexia nervosa, by manipulating the objective calorie content (kcal/100 g) of the food instead of food processing as in Study 1. Two specific hypotheses were tested in Study 2:

> H1': High-calorie foods are implicitly associated with moral impurity whereas low-calorie foods are implicitly associated with moral purity.
>
> H2': Subjects exhibiting disordered eating behaviors associate moral attributes with food more strongly than control subjects.

STUDY 1

Method

Participants

A total of 75 participants completed the experiment. The patients with anorexia nervosa (AN group) were recruited by psychiatrists from three mental health units hosting patients suffering from eating disorders between March and August 2018. The inclusion criteria were (1) to be a woman aged from 18 and 35 years old, (2) to be diagnosed as suffering from anorexia nervosa (restricting or binge/purge types) according to the DSM-5 (23), (3) to not present any severe comorbidity (e.g., major depressive disorders), and (4) mastery of the French language. Moreover, participants with a BMI below 12 as well as those who were too heavily medicated (e.g., having a prescription of benzodiazepine that can alter reaction time), according to the psychiatrists, were not asked to participate. A total of 32 patients were included in the AN group, all with high education. All were diagnosed at least 1 year prior to testing, 2 were in remission, 17 were in relapse. The duration of the condition ranged from 1 to 18 years.

A first control group was formed from May to June 2018 with 32 students from the Paul Bocuse Institute, a school of management in hospitality and culinary arts, therefore students had background knowledge in nutrition and cooking. According to the literature, students in food-related studies, especially nutrition, have a higher prevalence (between 35 and 57%) of dysfunctional eating behaviors than the average of the general population (6.9%), particularly orthorexia nervosa (24, 25). Orthorexia nervosa appears to share a number of characteristics with anorexia nervosa, such as the presence of intrusive thoughts about food and a subordination of lifestyle and behavior to food imperatives (22). Considering these similarities and the fact that the present study focused on the relationship to food and on comparing healthy subjects with subjects suffering from AN, the orthorexic traits that were potentially present in the control group could bring a confounding variable to the study, and therefore needed to be assessed. The orthorexic traits of the students in the first control group were not tested. It was therefore decided to set up a second control group in the same population or in populations with a similar prevalence of orthorexia nervosa, such as medical students or students innutrition or agronomy, with an evaluation of orthorexic traits using the ORTO15 questionnaire. Participants included in the second healthy control group (HC group) were recruited through several email databases of French universities (AgroParisTech and Ecole Normale Supérieure Ulm) between May and July 2019. The inclusion criteria for the control group were (1) to be a woman from 18 to 35 years old and (2) to not present a potential eating disorder. This age group was targeted in order to have a sufficiently small age range to avoid a confounding factor of age on reaction times, and also to be able to compare the results of the HC group with those of a population suffering from anorexia nervosa (AN group), this mental illness affecting mainly adolescent and young adult populations. Of 43 respondents, 11 respondents presented eating disorder symptoms (i.e., with a score higher than the cut-off of 18 on the symptom index of the EDI-II short form) and were removed from the analyses. A total of 32 respondents were included in the HC group; they were students (65%) in agronomy, health, philosophy or psychology studies and employees (35%). A total of 64 participants were included in the analyses, 32 patients in the AN group and 32 in the HC group.

The experiment was approved by the local ethics committee (ID-RCB Number: 2015-A01194-45).

Measures

Participant Information

Data of patients with AN were collected through anonymous medical questionnaires filled out by the referring psychiatrist. This medical questionnaire comprises questions in order to document age, body mass index (BMI), type of anorexia nervosa, and other relevant anorexia nervosa-related information. Age and BMI of participants from the HC group were documented through anonymous questionnaires filled out by the participants themselves.

Eating Disorder Inventory II—Short Form

The short form of the Eating Disorder Inventory is a self-administrated questionnaire including 24 items that included 8 subscales (26). In this study, only symptom index score (mean score of the bulimia, body dissatisfaction, and drive for thinness

subscales) was used. The respondent answered through a Likert scale ranging from 0 (Never) to 5 (Always). In the present study, Cronbach's alpha (α) was 0.74. Only respondents in the HC group were asked to complete this questionnaire.

Food Questionnaire

The subject's reaction time may be altered depending on the frequency of exposure to the food, which is itself related to its consumption. In order to avoid any recognition bias, the participants in the HC group filled out a questionnaire asking them to mention the foods they do not eat and the reasons why.

ORTO-15

ORTO-15 was used to assess orthorexic traits (21) among the HC group. The lower the scores, the higher the intensity of orthorexic behavior (21). All of the respondents in the HC group were asked to complete this questionnaire. The range of scores went from 31 to 43. In the present study, Cronbach's alpha (α) was 0.56. During the development and validation procedure, ORTO-15 questionnaire reached satisfactory values for the cut-off point of 40 points (sensitivity = 100%, specificity = 73.6%, positive predicative value = 17.6%, and negative predicative value = 100%) (21). However, according to Dunn et al. (27) the frequency of ON as measured by ORTO-15 is too high. Cut-off point of 40 does not reflect the real prevalence of ON (28). Therefore, in some studies the cut-off point was lowered to 35 points (29, 30). In our study, 1 control subject had a score under 35, and 14 subjects had a score between 35 and 40. It is also important to mention that psychometric properties of the ORTO–15 scored as Donini et al. (21) suggested seemed to be poor (25, 31–33). Meule et al. (34) suggested that the poor psychometric properties of the ORTO–15 were largely due to the originally proposed scoring procedure. It consisted of having the items scored with the following response options: 1 = always, 2 = often, 3 = sometimes, 4 = never, except for six items: four of them were reversely coded (items #2, #5, #8, and #9) and two items (#1 and #13) had a rather unusual recoding procedure: 2 = always, 4 = often, 3 = sometimes, 1 = never. According to Meule and colleagues, who examined the psychometric properties of ORTO15 among 511 adults, principal component analysis revealed that only two items (#5 and #8) should be inverted, other items being scored as 1 = always, 2 = often, 3 = sometimes, 4 = never. After recoding, they found that internal reliability of the ORTO–15 items was acceptable (Cronbach's α = 0.72) (34). Therefore, in the present study Meule and colleagues' recommendations were followed.

Go/No-Go Association Task

A go/no-go association task (GNAT) described by Nosek and Banaji (35) was administrated to the participants through E-prime© software (Psychology Software Tools, Version 2.0 Professional). The GNAT assesses the strength of association between a target category and two poles of an attribute dimension (35). In this GNAT, the two target categories are natural food and processed food and the two poles of the attribute correspond to the notion of purity or impurity. Throughout the experiment, attributes referring to the notion of purity are called "pure words", and those referring to the notion of impurity are called "impure words."

Food stimuli were selected from the FoodPics database validated by Blechert et al. (36). Two sets of stimuli were created: one with 24 natural foods and the other with 24 processed foods, following Blechert and colleagues' classification. Moreover, it has been shown that green might cue low energy density and that red is associated with a higher level of arousal compared to other colors (37). Thus, our two sets of stimuli (natural and processed) included the same proportion of green and red foods (12 green and 12 red food stimuli). To determine the extent to which these food variables are associated with the moral dimension of purity/impurity, we used a subset of attributes taken from a larger list of words constituted by Graham et al. (38). Graham and colleagues used the Linguistic Inquiry and Word Count program (LIWC; see Pennebaker et al. (39) to analyze liberal and conservative sermons. Then for each uses of these word, the consistency between the 2–3 sentences surrounding context of the word with the moral dimension (e.g., purity/impurity) was assessed by four independent raters who achieved a reliability of 0.79. Two sets of attributes were used in the present experiment, 12 attributes referring to moral purity and 12 attributes referring to impurity, to match the number of word attributes with the number of food stimuli and to have a balanced stimuli design. The stimuli are available in **Supplementary Table 1**.

The GNAT included four practice single blocks, and four combined blocks (see **Figure 1**). For each block, participants had specific instructions. Depending on the instructions, participants were asked to press the space bar if they saw a stimulus in a specific target category, and not to press the bar if they saw any other stimulus.

The four practice single blocks consisted of two blocks with visual food stimuli, and two blocks with word stimuli. In the first practice block, participants had to press the bar if they saw a natural food on the screen, and not to press the bar if any other stimulus appeared on the screen (Practice 1), so the target category was natural food. In the second practice block, the target category was processed food (Practice 2), in the third practice block it was words associated with purity (Practice 3), and in the fourth practice block it was words associated with impurity (Practice 4).

The four combined blocks each had instruction aimed at two target categories. In Block 1, participants had to press the bar if they saw a natural food or an impure word on the screen, and not to press the bar if any other stimulus appeared on the screen, the target categories therefore being natural food and impure words (Block 1). Target categories for the second combined block were natural food and pure words (Block 2). For the third combined block, target categories were processed food and impure words (Block 3), and for the fourth combined block, processed food and pure words (Block 4). Among the four combined blocks, two were congruent blocks and represented the congruent condition, in which the association between the target categories was hypothesized to be stronger (Block 2 and Block 3). The two other blocks represented the incongruent condition, where the association between the target categories was hypothesized to be weaker (Blocks 1 and 4). For each block (practice or combined), distractor stimuli were the opposite of the target stimuli. For example, if the target stimuli were natural

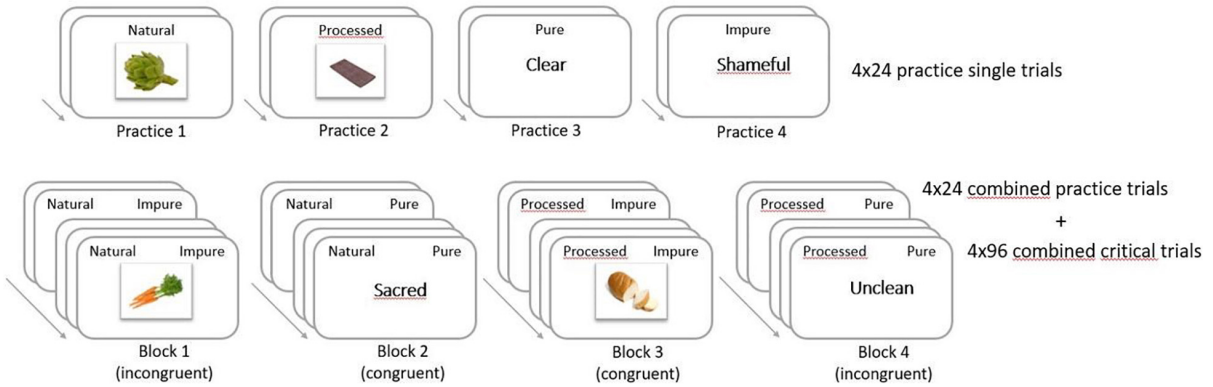

FIGURE 1 | Design of the Go/No-Go Association Task to determine the strength of association between processed versus natural foods and morally "pure" versus "impure" attributes. In this study, the GNAT was administrated in French. For the purpose of this paper, this figure is an English translation of the task.

foods and pure words, then processed foods and impure words were both distractor stimuli.

Each practice block consisted of 24 stimuli with 12 stimuli from the target category and 12 distractor stimuli. Each combined block consisted of 120 trials with 120 stimuli, with first a familiarization phase and then a critical phase. The familiarization phase consisted of 24 stimuli with 6 training stimuli from each category of stimuli (i.e., natural food, processed food, pure words, and impure words). Then, following the same instructions, participants had to complete the critical phase consisting of 96 stimuli with 24 critical stimuli from each category of stimuli randomly presented to participants once each, with a ratio of 50% go stimuli and 50% no-go stimuli.

Each stimulus from the practice blocks and the combined blocks was visually presented for 1,000 and 850 ms (respectively) or until the participant decided to "go" and press the space bar. For the time window, a pre-test on 5 control subjects led us to choose a stimulus presentation duration of 850 ms, the performance obtained being relevant and consistent for this duration (error rate $< 30\%$, success rate 84% on average) according to the literature (40, 41).

Prior to the task, participants were instructed to press the space bar of the keyboard as quickly as possible (GO) when the stimulus belonged to one of the two categories they were instructed to detect (e.g., Pure word or Natural food). If the stimulus did not belong to one of the target categories, then the participant had to inhibit the response (NO-GO). Emphasis was put on rapidity over accuracy. However, participants were also instructed to make as few mistakes as possible. Only for the practice single blocks, a green circle appeared on the screen when the participant had pressed the space bar when a target stimulus was shown (hit) or inhibited the response when a distractor was shown (correct rejection). A red cross appeared on the screen when the participant categorized a distractor as a target and pressed the space bar (false alarm) or missed a target stimulus by not pressing the space bar (miss). The green circle or the red cross were presented for 500 ms followed by a blank screen for 150 ms.

The reaction times (RT hereafter) in the practice single blocks and the RT in the familiarizing phase of each of the combined blocks were not recorded. Only RT in the critical phase were recorded and used in the statistical analyses.

Procedure

The experiment was conducted in a quiet testing room. The participants sat on a chair 70 cm from a liquid-crystal display (LCD) computer monitor with a resolution of 1,600 × 900 pixels (60 Hz refresh rate). After answering questions about which foods they did not eat and why, participants of both groups rated their state of satiety on a 7-point visual scale ranging from "not at all" to "extremely". The GNAT instructions were verbally provided to participants by the experimenter and the GNAT was performed. To avoid the influence of task order highlighted by Nosek et al. (42), the order of the blocks was counterbalanced between participants. At the end of the experiment, the participants were asked to rate their level of familiarity of the words presented in the GNAT. The rating was made through a 5-point visual scale ranging from "Not known at all" to "Perfectly known." The entire procedure took about 35 min.

Data Analysis

Analyses were conducted using Rstudio® software (Version 3.6.0). Nosek and Banaji (35) and Greenwald et al. (43) recommend removing RT equal to or less than 300 ms as well as participants with more than 10% of trials faster than 300 ms. After examination, 19 trials met this criterion and were removed, and no participants were removed. Likewise, data were examined to verify that no participant exhibited an error rate greater than 40% on a given block or a 30% error rate overall. On the basis of these criteria, no participant was removed either. Reaction time and type of responses were recorded during the task. To analyze RT data, it was firstly screened for normality. The results of the Shapiro–Wilk [$W(142) = 0.99$, $p = 0.387$] indicated normal distribution for RT means, results of Anderson-Darling for the residuals ($A = 470.03$, $p < 2.2e\text{-}16$) analysis of linear model with RT as dependent variable indicated a non-normal distribution of the residuals.

The mean and standard deviation of age, BMI, satiety score, and word familiarity scores were computed and compared

TABLE 1 | Study 1 participants' characteristics by group and comparison of scores between groups.

Sample characteristics	AN group		HC group		*t*	*p*
	M	SD	M	SD		
Age	24.56	4.77	23.15	3.23	1.36	0.180
BMI	16.03	1.79	20.79	1.93	−10.21	<0.001
EDI-II-24	–	–	36.63	10.55	–	–
ORTO-15	–	–	39.38	4.04	–	–
Satiety score	2.09	1.58	3.31	1.79	−2.83	0.006
Word familiarity score	4.16	0.87	4.31	0.73	−0.77	0.405

M, mean; SD, standard deviation; BMI, Body mass index; EDI-II, Eating Disorder Inventory−24 items; t, test statistic for the comparison test of each variable between the two groups; p, p value of each test.

between groups, and Spearman correlations were calculated to check for correlations between satiety scores and RT.

In order to test hypothesis H1, according to which food processing is implicitly associated with impurity whilst food naturalness is implicitly associated with purity, the RT were analyzed. As RT were normally distributed, Student tests were computed on RT, between the congruent associations and the incongruent associations in each group. With the same test, RT were analyzed between conditions (congruent versus incongruent) and groups, then between blocks to see whether an effect is driven by particular block(s). Power analysis was performed *post hoc* on each group with G*Power© software (44).

To measure the influence of group (AN or HC group) and condition (congruent or incongruent) factors on RT, a linear mixed model was conducted, because our data are repeated measures with the participant and the item as random factors. As the residuals are not normally distributed, a log transformation was made on RT. The models were constructed by iteratively adding predictive variables to the null model (M0, the intercept and no predictor), using the Akaike Information Criterion [AIC; (45)] as a basis for model selection. Group and condition were included in all models as fixed effects as well as possible interaction terms. Item and subject were included in all models as random effects. The R-squared (R^2) was computed to determine the proportion of the variance explained by the model.

To test hypothesis H2, according to which the strength of the associations differ between AN and HC groups, D-measures were calculated as effect-size measures from the participants' RT. Conceptually similar to Cohen's d, the D-measure is the difference between the means of the RT in critical incongruent blocks and critical congruent blocks divided by the standard deviation of all the RT in these blocks (43). Since the D-measure does not seem to be improved by the deletion of responses faster than 400 ms in the Greenwald paper, all responses were kept.

Results Study 1

Participants' Characteristics

A total of 32 female participants with AN (Age: M = 24.40, SD = 4.7; BMI: M = 16.10, SD = 1.8) and 32 matched female control participants (Age M = 23.20, SD = 3.20; BMI: M = 20.8, SD = 1.9) were included in the analysis. The participants' characteristics are presented in **Table 1**. Participants from the AN and HC groups did not differ in age, but differed in BMI. Results indicated also that state of satiety was significantly lower in the AN group. The Spearman correlation coefficient between state of satiety and RT ($Rhô$ = −0.12, p = *0.403*) indicated that state of satiety was not significantly related to RT. The familiarity of the words did not differ between AN and HC groups.

Level of Purity and Naturalness of Food

In both groups, the means of RT in congruent conditions were significantly shorter than for incongruent conditions [AN group: $t(63)$ = −4.12, p < *0.001*; HC group: $t(62)$ = −4.30, p < *0.001*] (see **Figure 2**). This result was also found in each group (AN and HC group) with statistical powers of the association of 0.58 and 0.52 in each group, respectively. Then, the same analyses were conducted to compare RT between blocks for each group (see **Supplementary Table 2**). The means of the AN group's RT were significantly shorter when natural foods were paired with words belonging to the pure moral category (Block 2) than when natural foods were paired with words belonging to the impure moral category (Block 1) [$t(62)$ = −3.45, p = *0.012*, D-measure = 0.35]. The same result was found in the HC group: RT means were significantly shorter in Block 2 than RT means in Block 1 [$t(61)$ = −4.26, p = *0.001*, D-measure = 0.38].

Concerning the attitude toward processed food, RT means were significantly shorter when processed foods were paired with words belonging to the impure moral category (Block 3) than when paired with words referring to the pure moral category (Block 4) [AN group: $t(62)$ = −4.54, p < *0.001*, D-measure = 0.45; HC group: $t(61)$ = −3.82, p = 0.003, D-measure = 0.35].

The mixed model conducted showed a significant effect of the condition [$\chi^2(1,64)$ = 500.82, p < 2e-16] with the incongruent condition being significantly and positively different from the congruent condition [*beta* = 3.23, 95% CI (3.05, 4.08), $t(10,481)$ = 16.18, p < *0.001*). The model showed neither an influence of the group on RT $\chi^2(1,64)$ = 2.82, p = *0.093*], nor an influence of the interaction between the group and the condition [$\chi^2(1,64)$ = 0.32, p = 0.572] on RT. Results are gathered in **Supplementary Table 3**. The model's total explanatory power was: R^2_C = 0.27.

D-measure (effect size) was also computed for each group according to the blocks and conditions. Results, presented in **Supplementary Table 4**, revealed that D-measures of each group were in the same target range, indicating a small effect size in all groups.

Discussion, Study 1

The first hypothesis of this study (H1) was that food transformation is implicitly associated with impurity whereas food naturalness is implicitly associated with purity. Our results confirmed this hypothesis by revealing a facilitating effect on RT (shorter RT) in congruent compared to incongruent conditions. These results echoed Rozin and colleagues' conclusions that consumers tend to exhibit a strong preference for natural foods over processed foods when they have the same chemical composition, the same taste, or when they are considered equally healthy (46). Indeed, according to Rozin and colleagues this preference could be grounded in beliefs that natural food would

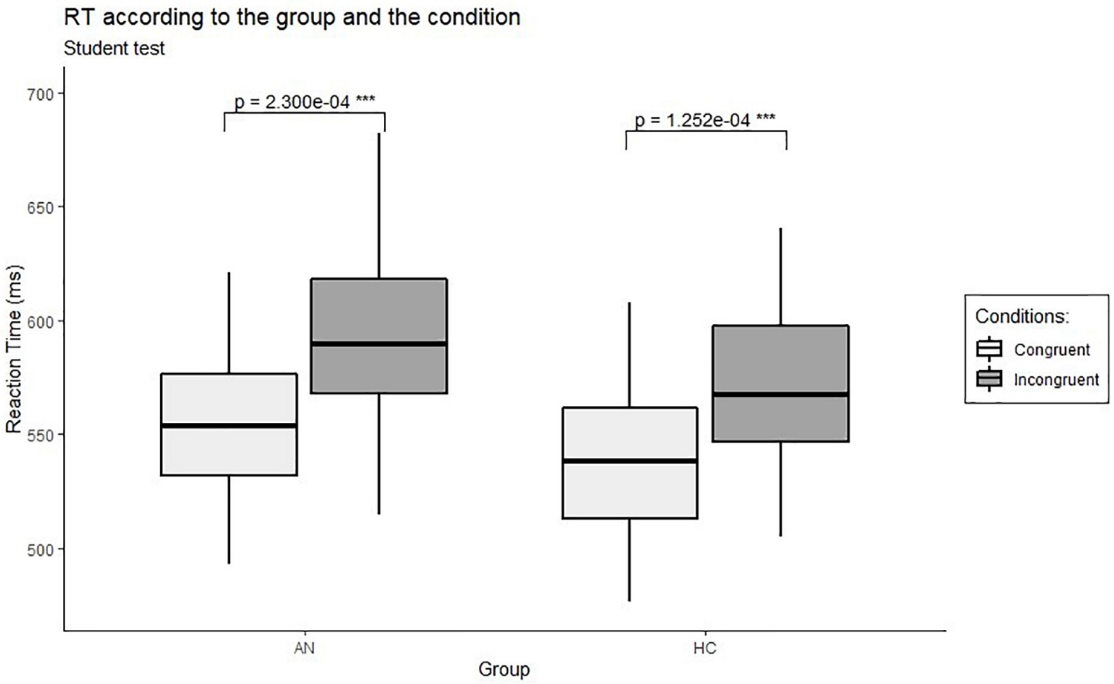

FIGURE 2 | RT (ms) comparisons between conditions within-group. RT, reaction times; AN, AN group; HC, HC group. ***$p < 0.001$, the difference between the two groups designated by the trait is significant.

be purer and "morally superior" because it is "prior to human intervention" [(46), p.2]. However, these results seem to run counter to the findings of Coricelli et al. (47) that processed foods have been shown to trigger higher reward value and are more advantageous in terms of nutrients than unprocessed foods, so they have been favored as resource foods throughout evolution (47). Nevertheless, the study here explored the relation of food processing with morality, which is quite different from the nutritional aspects. Whereas processed foods are preferred in terms of taste and nutrients, morality speaking natural foods seemed to be more prone to be preferred as they are directly linked to nature and healthiness (46).

Furthermore, it is worth mentioning that the congruence effect does not result from the association between naturalness and purity only. This effect is also driven by the association between transformation and impurity. This result is consistent with the general belief that processed foods are more likely concealing unhealthy properties compared to natural counterparts. Such an unfavorable stance toward processed food could result from the principle of contagion, according to which the contact with an undesirable entity can render an object less desirable (48). Human intervention being considered to damage nature in modern Western societies (46), the contagion principle could lead one to associate processed food with negative moral attributes such as "decadent," which are commonly used nowadays in advertisements (14, 15). Therefore, the association found in Study 1 between food transformation and morality corroborate the observations made by Rozin and colleagues. However, our findings revealed for the first time the existence of such an association at an implicit level. An association is automatic or implicit if it can occur even if participants do not have particular goals, a substantial amount of cognitive resources, a substantial amount of time or awareness (49, 50).

The second hypothesis of this study (H2) was that the strength of the implicit associations differs in patients suffering from anorexia nervosa and healthy control subjects. More precisely, and consistently with the literature on morally-laden food categories in patients with AN, we expected a stronger association in patients with AN than in healthy control subjects. As shown by the analysis of the D-measures and the generalized mixed model on the RT where no difference between groups was observed, the results did not confirm our second hypothesis.

Limitation and Perspectives, Study 1

One of the limitations could lie on the fact that the subjects included were all young women with high level of education. Therefore, no conclusion can be made for the general population regarding the results of the study. This choice was made because patients suffering from AN are described in the literature as mainly being adolescent or young women with high level of education (51, 52). Therefore, the population taken as a control group had to match these criteria in order for the two groups to be comparable.

Another limitation lied on the effect size of the mixed model: condition (congruent or incongruent) was considered to significantly influence reaction time, however, the effect size seemed to be relatively low: the incongruent condition being significantly and positively different from the congruent

condition with an estimate of 3.23 [95% CI (3.05, 4.08)], compared to the intercept, which had an estimate of 1,445.32 [95% CI (1,433.29, 1,464.26)]. Therefore, these results should therefore be put into perspective.

Also, the initial ambition was to designed an implicit association task that was sensitive enough to capture individual characteristics of persons suffering from anorexia nervosa. Even if we confirmed the existence of an association between food transformation and morality, the strength of the association did not differ between control subjects and patients suffering from anorexia nervosa. One hypothesis why we might have failed to see such a difference lies in the food processing/naturalness variable, which might be a too subjective variable and therefore not the most appropriate here. We then decided to design a second task on the general population only to determine whether associations between objective energetic value and moral purity could be discriminant between ON and HC. This time we chose to test the second version on the general population before testing it on patients. Indeed, we wanted to confirm first that the task was properly calibrated and sensitive enough to capture disordered eating before using it to predict eating disorders relying on the assumption that if the task might detect ON it will detect a far more severe form of eating disorder.

Finally, the degree of processing is a subjective variable as it is highly dependent on the subject's interpretation (53) and might therefore hide some subtleties about inter-individual differences in the studied association of moral attributes with food. Thus, a second study seemed necessary to disambiguate and extend the results found in Study 1.

STUDY 2

According to Foroni et al. (37) who conducted a rating scale study in which participants were asked to rate the perceived calorie content and the arousal of food items, results reveal that the degree of processing is interpreted as an indicator of the energy density of food. The more processed a food is perceived to be, the more calories it is perceived to contain. In Study 2, we decided to conceptually replicate the association between energy density and moral categories by manipulating an objective food variable (calorie content per 100 g) as it is less open to interpretation by the subject and could help us to disambiguate the results generated by Study 1.

This replication was carried out using another technique measuring implicit associations: the Implicit Association Test (IAT). Indeed, as Nosek and Banaji (35) pointed out during the development of the GNAT, IAT and GNAT both measures the implicit attitudes toward concepts and attributes with the same variable (RT), and they tend to generate comparable results. The difference lies on the fact that the structure of the IAT constrains evaluations to be relative comparisons between two opposing categories, and therefore being a relative measure, whereas the GNAT allows for a separable assessment of categories, with framing evaluation of a target concept in a context of other concepts. As significant differences were found in Study 1 between congruent and incongruent blocks with the GNAT, we decided to replicate using an IAT in order to see if this technique would also show a significant difference between our categories in a relative comparison. Indeed, as the authors pointed out, "experimental reports that replicate implicit effects across techniques provide extra confidence that the effects are not due to a particular procedural aspect of any single tool" [(35), p.661].

As the present COVID-19 pandemic came across, the research had to be done online with the IATgen (54) and the Qualtrics (55) software.

Method Study 2

Participants (Recruitment)

Participants were recruited through several French university mailing lists. The survey was circulated on June 1, 2021 and was available through June 30, 2021. Women and men from 18 to 35 years old were included. Indeed, as the prevalence figures show an equal proportion of men and women with orthorexia nervosa (27, 56, 57), men were first included in the recruitment. Of 180 respondents, 29 were excluded because of missing data and 8 were excluded due to aberrant response times. A total of 143 participants (116 women and 27 men) were included in the analysis. Participants were students (85%) in agronomy, health, or gastronomy studies; employees (5%); executives (9%); or inactive (1%). Four groups were formed: the "Orthorexic" group of participants (N = 21) with a high level of orthorexia-related symptoms (i.e., having an score on the ORTO-12-FR scale $<$ 30), the "Pathologic" group of participants (N = 17) with a high level of eating disorder symptoms (i.e., having a score on the EDI-II-24 scale $>$ 52), the "Ortho_Patho" group of participants (N = 43) with a high level of both orthorexia-related symptoms and eating disorder symptoms, and the "Control" group of participants (N = 62) not detected by either the ORTO-12-FR or the EDI-II-24 (score above 30 on the ORTO-12-FR and score below 52 on the EDI-II-24 scale).

Measures

Demographics Measures

The participants anonymously answered questions regarding their gender and age. They were asked to indicate their height and weight as well as their socio-professional category (58).

ORTO-12-FR

In this present study, ORTO-12-FR was used to assess orthorexic traits among the sample (59). ORTO-12-FR is a shorter French version of the ORTO15 developed by Donini et al. (21), with three items deleted after a confirmatory factor analysis (items 5, 6, and 8). All of the respondents were asked to complete this questionnaire. As in Study 1, Meule and colleagues' recommendations (2020) (34) were followed for the scoring procedure. The range of scores went from 21 to 38. In the development of the ORTO-12-FR, no cut-off was established. However, Agopyan et al. (60) found that a cut-off of 30 could separate people exhibiting orthorexic traits (score below 30) and people without orthorexic traits (score above 30). As cut-off scores are not well established yet, we used both

Agopyan and colleagues' cut-off and ORTO-12-FR total score as a continuous variable. In the present study, Cronbach's alpha (α) was 0.76.

Eating Disorder Inventory II - Short Form (EDI-II-24)

As in Study 1, participants completed this short form of the Eating Disorder Inventory including 24 items (26). In Study 2, Cronbach's alpha (α) was 0.73. All of the respondents were asked to complete this questionnaire, and total scores ranged from 18 to 96. Respondents with a score higher than the cut-off of 52 (26), indicating the presence of an eating disorder or an unusual concern about body weight, were considered as pathologic.

Assessment of Their Satiety State

Participants were asked about their satiety level with a 7-point Likert scale ranging from "not hungry at all" to "very hungry".

Implicit Association Task

A slightly modified version of the IAT described by Greenwald et al. (61) was programmed with IATgen software (54). The IAT was then imported on Qualtrics© software. The IAT created was based on the original IAT described by Greenwald et al. (61) with further guidance from Greenwald (62). The first block of 24 trials consisted of practice on the calorie-content food classification task. The second block of 24 trials consisted of practice on the moral attribute classification task. The third and fourth blocks consisted of the first combined task (16 and 48 trials, respectively), including the classification of both foods and words related to morality. Half of the participants started with the same key for low-caloric food and impurity. For the other half of participants, the low-caloric food and words related to purity were initially associated with the same response key. The fifth block of 24 trials consisted of practice, this time for the low-caloric/high-caloric food classification task with reversed response key associations. The sixth block consisted of the second (reversed) combined task. As was suggested by Nosek et al. (42), the number of trials in this block was increased to 32 trials. The seventh and final block was made of 48 trials of the reversed combined task (see **Figure 3** for a summary of the IAT blocks). It should be noted that blocks three and six served as practice for blocks four and seven, respectively. The participants completed 216 trials in total.

For the food stimuli, 24 food pictures were selected from the database FoodPics of Blechert et al. (36) with their energy density per 100 g and per stimulus (see **Supplementary Table 5**). Through this information, the selection of food stimuli was made to have two groups of 12 stimuli each, one representing low-caloric food and the other high-caloric food, and with the most contrasting averages and significant differences of kcal/100 g [$H(1) = 252.00$, $p < 0.001$] and kcal/picture [$H(1) = 256.00$, $p < 0.001$] between the low-calorie food and high-calorie food (see **Table 2**). Moreover, the selection was also made to ensure similar values within low-calorie and high-calorie food groups for both kcal per 100 g and kcal per stimulus.

Regarding the word stimuli, the same 24 words selected from Graham et al. (38) in Study 1 were used: 12 words related to the notion of moral purity and 12 words related to the notion of impurity.

Participants were instructed to categorize as rapidly and accurately as possible the visual stimuli by pressing one of the two response keys (E or I) on the computer keyboard with their left and right index fingers. Emphasis was put primarily on rapidity over accuracy; however, the participants were instructed to also

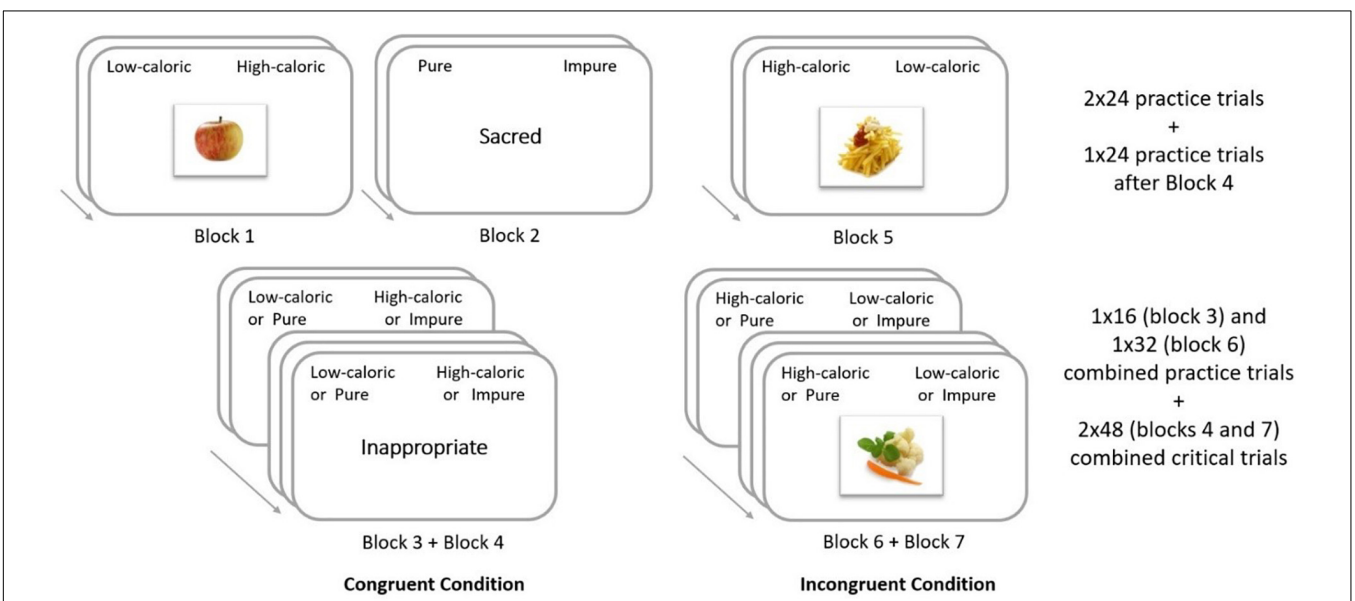

FIGURE 3 | Design of the Implicit Association Test between low-caloric versus high-caloric foods and morally "pure" versus "impure" attributes. Interstimulus Interval (ISI): 1,650 ms in practice blocks with feedbacks, ISI: 1,150 ms in combined blocks. In this study, the IAT was administrated in French. For the purpose of this paper, this figure is an English translation of the task.

TABLE 2 | Study 2 means (M) and standard deviation (SD) Kcal per 100 g and Kcal per picture for each of the two groups of food stimuli constituted.

	Kcal per 100 g		Kcal per picture	
Food stimuli groups	**M**	**SD**	**M**	**SD**
Low-caloric	47.05	25.58	49.88	32.84
High-caloric	355.27	184.30	594.70	375.05

try and avoid errors as much as possible. Instructions about the mapping between the categories and the relevant response keys consisted of a schematic representation of the two response keys with the corresponding categories that was displayed on the screen. There was no time limit to learn the new categories–response mapping that remained in written form at the top-left and top-right corners of the screen as a reminder throughout each block of the experiment. In each trial, the participants started by looking at a fixation cross at the center of the screen for 1,000 ms. Then, a target stimulus was displayed. Feedback, consisting of a red cross, was provided after each incorrect target-response and remained on the screen for 500 ms. Each trial was separated by a blank screen corresponding to the inter-trial stimulus interval (ISI) of 1,000 ms. Participants' RT and accuracy were recorded.

Post-test Categorization Task

Participants were asked to classify each stimulus as either low-caloric/high-caloric or pure/impure.

Procedure

After all participants gave their informed consent, participants were asked to answer gender and age questions. The IAT experiment was then performed by participants. To avoid the influence of task order (61), the key-response attribution of the qualifiers ("Low-caloric"/"High-caloric"; "Impure"/"Pure") were counterbalanced across participants. Then, participants were asked to perform the post-test categorization task. Then, they completed the self-reported questionnaires (ORTO-12-FR and EDI-II-24) and some socio-demographic information. Finally, they indicated their satiety state. The entire procedure took about 15 min.

The procedure was in accordance with the Declaration of Helsinki and followed institutional ethics board guidelines for research on humans.

Statistical Analysis

Demographic Data Analysis

BMI was calculated from the height and weight reported by the participants. Pearson correlations were calculated between the BMI, the satiety level, the age, ORTO-12-FR score, and EDI-II-24 total scores.

IAT Analyses

All statistical analyses were performed using R. 3.6.0 studio software. The significance level was set to 5% ($p < 0.05$). According to Greenwald's suggestions for improvement, RT under 300 ms or above 3,000 ms were also excluded. The normality of the RT distributions was checked with Q-Q plots and tested with the Shapiro test for each group in every block analyzed, which were the critical blocks (blocks 4 and 7). As the distributions did not follow the normality law, the Wilcoxon test was used to compare RT means in the two IAT conditions (congruent and incongruent) for each group. A Kruskal–Wallis test was also assessed to measure the differences between all groups.

To measure the IAT effect, D-measures were also calculated as effect-size measures from the participants' RT. D-measures were computed as the difference between mean RT for blocks 3 and 6 (mean for block 6—mean for block 3) and blocks 4 and 7 (mean for block 7—mean for block 4), for which each resulting difference was divided by the pooled standard deviation of the two corresponding blocks.

A linear mixed model was also computed with RT (log-transformed) from the trials in which the participants responded correctly as the dependent variable, with the within-participants factors of Congruency (congruent associations: low-calorie food + word related to purity, high-calorie food + word related to impurity; incongruent associations: high-calorie food + word related to purity, low-calorie food + word related to impurity) and the Group (control, orthorexic, orthorexic and pathologic, pathologic) as the fixed effects. The participant number and the stimulus number were entered into the model as random effects. The models were constructed by iteratively adding predictive variables to the null model (M0, the intercept and no predictor), using the Akaike Information Criterion [AIC; (45)] as a basis for model selection. The R-squared (R^2) was also computed to determine the proportion of the variance explained by the model.

As cut-off scores are not well established yet, ORTO-12-FR total score was also used as a continuous variable and additional generalized models were computed.

Post-test Analysis

The error rate of stimulus categorization was calculated per person, per group, and per stimulus type, and differences between groups and stimulus type were computed with Fisher's exact test.

All of the statistical analyses above mentioned were also carried out without including men in the analyses (since we did not include them in Study 1). As no differences were found in the results, we decided to keep them in the sample analysis and results presented here.

Results Study 2

Participants' Characteristics

A total of 143 respondents were included in the analysis, aged from 18 to 35 years old (Age: $M = 22.89$, $SD = 3.54$; BMI: $M = 21.92$, $SD = 3.15$). Participants' characteristics are gathered in **Supplementary Table 6**. Results indicate that state of satiety was not different from one group to another [$F(3, 139) = 1.33$, $p = 0.269$]. The Pearson correlation coefficient between state of satiety and RT [$r(141) = -0.03$, $p = 0.727$] ensures that state of satiety is not significantly related to RT.

No correlations were found between the demographic variables. As expected, a significant correlation was found

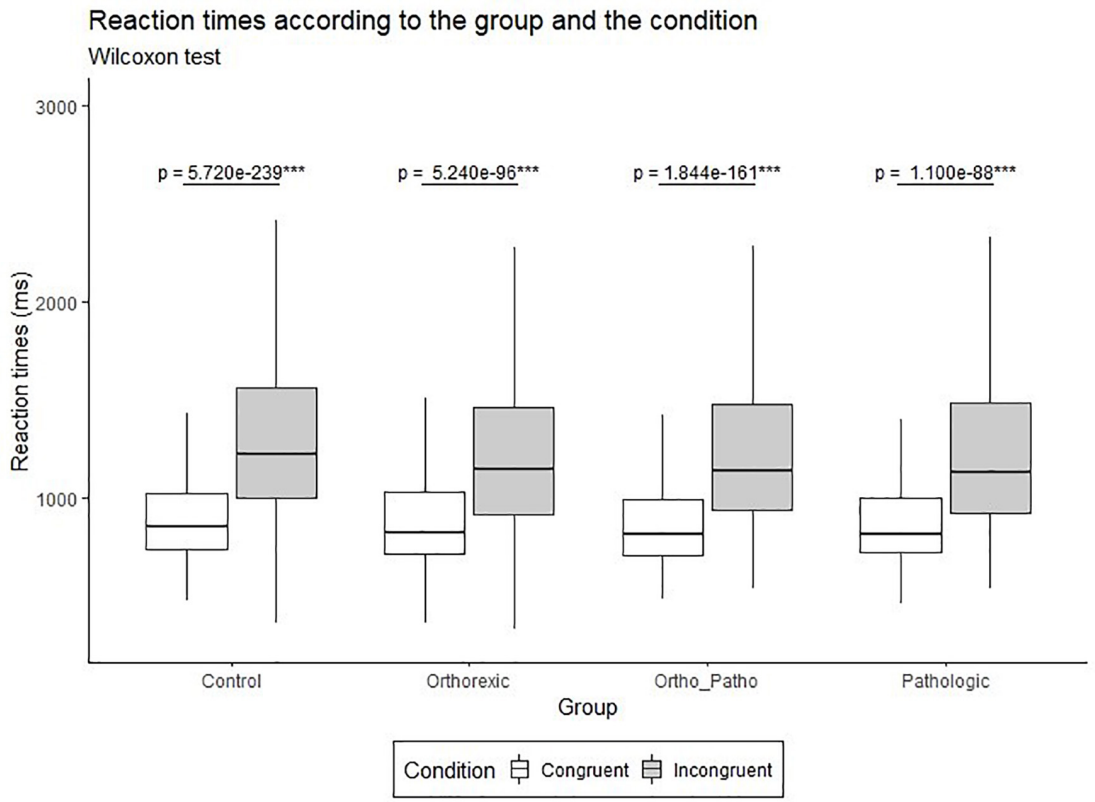

FIGURE 4 | RT (ms) according to the group and the condition with Wilcoxon-test *p*-value results. ***Indicates significant differences between congruent and incongruent conditions.

between the ORTO-12-FR scores and the EDI-II-24 scores [$r(141) = -0.43$, $p < 0.001$].

IAT Results

Results for H1

Overall, mean RT was significantly different between the congruent and incongruent conditions ($U = 2{,}115$, $p < 0.001$). This result was also found in each of the four groups (Control, Orthorexic, Ortho_Patho, Pathologic; see **Figure 4**) with statistical powers of the association of 0.99, 0.97, 0.99, and 0.93 in each group, respectively. Overall, the mean effect size was 0.86, with a standard deviation of 0.4. Detailed results are in **Supplementary Table 7**.

Results for H2

Overall, no significant difference was found between our four groups [$H(3) = 1.68$, $p = 0.642$]. Mann–Whitney-tests between each pair of groups specify that no difference was found between groups. No significant difference between groups has been seen either regarding the effect size [$H(3) = 3.05$, $p = 0.383$].

The mixed model conducted showed a significant effect of the condition [$\chi^2(1{,}143) = 3{,}564.95$, $p < 2e\text{-}16$] with the incongruent condition being significantly and positively different from the congruent condition [*beta* = 14.17, 95% CI (13.88, 15.03), $t(11{,}749) = 38.15$, $p < 0.001$]. The model showed neither an influence of the group [$\chi^2(3{,}143) = 3.17$, $p = 0.366$] on RT, nor an influence of the interaction between the group and the condition [$\chi^2(3{,}143) = 2.94$, $p = 0.401$] on RT. Results are gathered in **Supplementary Table 8**.

The model's total explanatory power was: $R^2_C = 0.37$.

This analysis conducted with the orthorexic score taken instead of the group variable did not show any significant influence [$\chi^2(1{,}143) = 2.50$, $p = 0.114$].

Post-test Results

No significant difference between groups was shown [$F(3{,}282) = 0.46$, $p = 0.708$] regarding the post-test results. Nevertheless, a significant difference regarding the type of stimuli was seen, with stronger error rates for food stimuli [Food stimuli: $M = 0.94$, $SD = 1.4$; Word stimuli: $M = 0.17$, $SD = 0.4$; $F(1{,}284) = 41.2$, $p < 0.001$]. Overall, the mean error rates were really low, therefore stimuli were considered to be sufficiently correctly categorized for the IAT task.

Discussion, Study 2

In this second study, we observed shorter RT in the congruent condition (block 4) than the incongruent condition (block 7) in all groups of participants. In addition, the calculation of the D-measure showed a large effect size in all groups. These findings support our hypothesis that high-calorie foods are implicitly

associated with "impurity" whereas low-calorie foods are implicitly associated with "purity." Moreover, this result extended our findings from Study 1 and suggest that both a subjective cue for energy content such as food transformation and an objective food variable such as calorie content per 100 g trigger moral attributes in healthy controls, subjects exhibiting orthorexia nervosa dispositions, and subjects exhibiting anorexia nervosa.

Stein and Nemeroff's (1995) (63) analysis of a moralization of fat can shed light on the association found between high-calorie food and "impurity". Indeed, in their study, the "fatty-food-eater" (people who eat "steak, hamburgers, French fries, doughnuts, and double-fudge ice cream sundaes" versus those who eat "fruit, especially oranges, salad, homemade wholewheat bread, chicken and potatoes") were considered significantly less "moral" on a morality score composed of evaluations along dimensions such as considerate-inconsiderate, ethical-unethical, and kind-hearted-cruel on 8-point Likert-type scales.

Interestingly, Stein and Nemeroff obtained no evidence of a difference between restrained and unrestrained eaters in their moral inferences based on eating habits. In the same vein, hypothesis H2' was not confirmed by our findings. The strength of the implicit associations was comparable between subjects exhibiting disordered eating behaviors and healthy control subjects: the analysis of the D-measures did not reveal any differences between the groups.

As a limitation, it should be noted that this experiment had to be done online due to the COVID-19 pandemic. Therefore, participants' environments, which could have effects on reaction times, could not be controlled. Moreover, participants were young adults between 18 and 35 years old with high level of education, therefore, no conclusions regarding the general population can be drawn from the results.

GENERAL DISCUSSION

The present studies aimed to determine whether certain food properties might trigger such moral categories in the general population as well as in subjects suffering from eating disorders, without using declarative methods. Our findings revealed for the first time the existence of robust associations between food variables cueing energy value and moral attributes related to purity or impurity at an implicit level, in subjects suffering from eating disorders as well as in subjects exhibiting disordered eating behaviors and dispositions and control subjects. Furthermore, the studies reported here represent a first and successful attempt to capture the moral properties that various populations ascribed to food without relying on declarative data that might be liable to social desirability, declarative data being only used to described the population itself in these studies. In other words, they represent a first body of evidence that implicit methods might be fruitfully deployed to better understand moral categorization of foods in various populations.

In today's Western societies, advertisers and marketers make extensive use of the vocabulary of morality when it comes to selling food products (15). Some foods that are usually highly processed and/or have a high calorie content have become "guilty pleasures" or "irresistible temptations." At the same time, the development of nutrition education programs has contributed to the growth of the classification of foods into good and bad foods. Historically, moral adjectives were attributed to food when referring to people suffering from "holy anorexia," also called "anorexia mirabilis" (i.e., people suffering from eating disorders using their religious beliefs to justify the way they eat and to protect themselves from judgments) (64, 65). Nowadays, the lexicon of morality seems to have pervasively influenced the manner in which the general population characterizes food. For instance, Brennan and colleagues (66) conducted recorded interviews with young adults about healthy eating. The interviews were so laden with moral terms that they decided to classify their participants into religious categories such as "Saint, Sinner, and Person in the Pew". Study 1 and Study 2 revealed that these associations between moral categories and food variables are observable at an implicit level as well, in patients with anorexia nervosa, in subjects with orthorexia nervosa, and in healthy control subjects. Therefore, reasonable doubts about the idea that moralization of food would result only from social desirability or self-presentation concerns might be raised. Indeed, the measurement of robust implicit associations between moral attributes and food variables pave the way for further research on an evaluative system of categories about food that subjects cannot always control but that can still contribute to the expression of food behaviors and attitudes.

Limits and Perspectives

An important limitation of our studies lies in the questionnaires used to categorize our participants into sub-groups. Firstly, the EDI questionnaire is made of different subscales that measure different dimensions of ED (drive for thinness, bulimia, body dissatisfaction, inefficacity, perfectionism, interpersonal distrust, interoceptive awareness, maturity fears). Here, only the EDI overall score was taken, as the sum of the scores for each dimension. Thus, anorexic as well as for instance bulimic symptoms have been taken into account. The inclusion of people with eating disorders other than AN may have reduced the effect size of the association, which may have been larger in only people with AN considering the previously discussed literature on AN. Nevertheless, no literature has been found about subjects with dietary disinhibition or binge eating concerning the association studied here. A promising perspective is thus to pursue the investigation of these associations between moral attributes and food variables in patients suffering from different eating disorders especially those characterized by a deficit of inhibition. Secondly, the ORTO15 was used to detect orthorexic traits. Even though it is the most widely used and translated measurement tool (67), several weaknesses have been raised such as its underlying structure, which was not assessed during its development (21), and its validity has been questioned with an overall accuracy of 0.70 (32). The corrected scoring procedure recommended by Meule et al. (34) showed internal consistencies of the ORTO15 and ORTO-12-EN of 0.56 and 0.76, respectively. These figures suggest that other tools may be more accurate in detecting orthorexia nervosa, but as new detection tools are under development, it seemed safer to use the most

commonly used tool for these studies. Thirdly, it is important to note that these detections of orthorexia nervosa or eating disorder traits as well as the BMI of the participants were done with declarative data, which may present a social desirability bias. Indeed, as traits of eating disorders are not always well-regarded socially and even though the studies were anonymous, participants may have tended to respond in a way that they felt was more socially acceptable than their 'real' response, in order to project a favorable image of themselves, as described by Edwards (68). Thus, the formation of groups in Study 2 is to be put into perspective.

To conclude, these findings revealed that associations between food properties that cue for the energetic value of food triggered moral representations of purity/impurity in the general population, in the population suffering from disordered eating such as orthorexia nervosa, and in patients suffering from eating disorders such as anorexia nervosa. Further studies should try to explore whether such associations are also present at the opposite end of the disordered eating spectrum (i.e., loss of control) and whether such implicit associations have an impact on food behaviors on everyday food behaviors.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: The databases and R code are available at https://osf.io/3eku8/?view_only=cf962fa223b2462ea8e2b9cc6b84d052 and upon request from the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by CPP Ile-de-France; ID-RCB Number: 2015-A01194-45. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JL, SI, VM, LT, and CL contributed to the conception and design of the study. SI, PD, VM, LT, and CL contributed to the acquisition of data. LT and CL organized the database and performed the statistical analysis. CL wrote the first draft of the manuscript. JL and MO wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.884003/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Chapter 8. Exploring the perception of food through the lens of healthiness in Orthorexia Nervosa.

The findings of Chapter 7 raise the question of the distinction between the population suffering from ON and the general population in their perception of food.

This chapter presents the fourth article currently submitted, which compiles three consecutive studies that investigate food perception in orthorexia nervosa.

The studies were conducted in France, then replicated in another French-speaking population, Quebec, to test the robustness of the effects. This replication was made possible thanks to collaboration with Dr. Sylvain Iceta of the Institut Universitaire de Cardiologie et de Pneumologie de Quebec at Université Laval, Canada.

The first study is an initial exploration of food categorization in 228 subjects (N=112 France, N=116 Quebec) according to their orthorexia nervosa tendencies. This study examined subjects' performance and strategy in a categorization task of food stimuli according to healthy/unhealthy categories. The executive functions of cognitive flexibility and inhibition, hypothesized to play a role in orthorexia nervosa, were also tested with general tasks. While the results provided initial clues to a possible correlation between response strategies and orthorexia nervosa tendencies, the rigidity observed in orthorexia nervosa did not seem to be reflected in a cognitive flexibility task in the general domain.

These results prompted us to test cognitive flexibility applied specifically to the eating domain in the second study. A total of 235 subjects (N=149 France, N=86 Quebec) were then tested on their speed in changing categorization instructions at each trial (healthy/unhealthy; to snack/to eat at the table; sweet/salty; dry/juicy). The results again gave us clues to a possible correlation between response strategies and orthorexic tendencies.

The third study was then devoted to exploring in greater depth the categorization strategy according to orthorexia nervosa tendencies. The task consisted of two conditions: in the first, subjects had to detect healthy foods from other foods, in the second, subjects had to detect unhealthy foods from other foods. A total of 255 subjects (N=149 France, N=106 Quebec) performed the experiment. Using Signal Detection Theory, the results showed a difference in categorization strategy according to orthorexic tendencies.

Food categorization performance and strategies in orthorexia nervosa

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Abstract

Orthorexia nervosa (ON) is an obsession with healthy eating. The cognitive mechanisms that underlie this type of food selectivity remain poorly understood. Recent research on anorexia nervosa and food neophobia, which overlap with ON, has revealed specific categorization performance (i.e., accuracy in discriminating between food categories) and strategies (tendencies to avoid one type of error over another) in both anorexic and neophobic subjects. The present study includes three experiments that investigated food categorization performance and strategies in ON. Experiment 1 explored ON subjects' abilities to categorize foods as healthy or unhealthy. Experiment 2 investigated ON subjects' cognitive flexibility in the food domain. Experiment 3 tested ON subjects' strategies using the signal detection theory framework. The three experiments were conducted in France and replicated in Quebec. Results revealed significant effects of ON scores on the subjects' strategies when categorizing food as healthy or unhealthy, reflecting the fear of mistaking unhealthy foods for healthy ones in ON. The findings challenge the standard way to define ON and open doors for future research on emotional distress about food to improve the understanding of orthorexia nervosa.

Keywords: cognition, healthy food, Signal Detection Theory, executive functions, cognitive flexibility, eating disorders.

Introduction

The term “Orthorexia nervosa” (ON) was coined by Steven Bratman (1997) to refer to the obsession with eating healthy foods exhibited by his patients. Subjects suffering from ON are characterized by intrusive thoughts about healthy eating and stereotyped behaviors with rigid and inflexible rules, accompanied by emotional distress (e.g., anxiety) and negative psychosocial (e.g., isolation) consequences (Cena et al., 2019; Donini et al., 2022). The prevalence of ON has been investigated with several self-report questionnaires and it has been shown to occur in 1% to 7% of the general population. However, after two decades of research on ON, the cognitive underpinnings of this “conjectured eating disorder” (Hayatbini & Oberle, 2019, p.1) have yet to be documented.

ON is characterized by self-imposed rigid and inflexible rules in the food domain. For this reason, ON can be reasonably suspected to be negatively associated with executive functions, and with cognitive flexibility (understood as the opposite of rigidity) in particular. Recent empirical evidence might be seen as adding plausibility to this hypothesis. Indeed, executive functions such as inhibitory control and cognitive flexibility have been associated with eating disorders (Tchanturia et al., 2012; Yue et al., 2020). Therefore, given the documented overlaps between ON and eating disorders (Dell’Osso et al., 2016a; Pini et al., 2016) it is reasonable to suspect that executive functions are also involved in the expression of ON.

To our knowledge, only three studies have tested directly, though unsuccessfully, executive functions in subjects suffering from ON. Koven and Senbonmatsu (2013) used two approaches in their study: a self-report questionnaire and neuropsychological tasks. The self-report questionnaire was the Behavior Rating Inventory of Executive Functioning Adult Version (BRIEF-A) (Roth, Isquith, and Gioia, 2005), a 75-item self-report questionnaire that assesses the experience of executive functions in daily life with nine subscales: Working Memory, Ability to Plan, Ability to Task Monitor, Ability to Organize Materials, Ability to Inhibit, Task Initiation, Shifting, Emotional Control, and Self-Monitoring. The neuropsychological tasks included the Wide Range Achievement Test 4th Edition (Wilkinson and Robertson, 2006), the Delis-Kaplan Executive Function System (D-KEFS) (Delis, Kaplan, and Kramer, 2001), and the California Verbal Learning Test 2nd Edition (CVLT-II) (Delis, et al., 2000). The authors used the ORTO-15 (Donini et al., 2005) questionnaire to assess ON dispositions. Results failed to show significant correlations between ORTO-15 score and neuropsychological task

performance. However, they showed that ORTO-15 score was associated with self-reported weaknesses in Shifting, Emotional Control, Self-Monitoring, and Working Memory. Therefore, impairment in executive functions was seen on self-reported measures but not using neuropsychological tasks. Hayatbini and his colleagues looked more specifically at cognitive flexibility (Hayatbini & Oberle, 2019) and inhibition control (Hayatbini et al., 2020), with one study for each. In their first study, they investigated cognitive flexibility in ON using the Wisconsin Card Sorting Test and the Trail Making Test (Hayatbini & Oberle, 2019). In a second study, they investigated inhibitory control (as the inability to suppress an action or thought about healthy eating in ON) using the Go/No-Go Task, the Flanker Task, and the Stroop Task (Hayatbini et al., 2020). They used the Eating Habits Questionnaire (a 21-item self-report questionnaire designed to assess ON; Gleaves et al., 2013) to detect ON traits in both studies. The authors failed to confirm their hypotheses. ON subjects were not different from healthy control subjects with respect to their performance in cognitive flexibility tasks, and ON symptomatology was not correlated with performance of inhibitory control tasks.

Self-imposed rules in ON exclude numerous food categories, similar to what has been observed in patients suffering from anorexia nervosa (AN) (Donini et al., 2022) or from food neophobia (Rioux et al., 2016). Food categorization is an essential mechanism that allows us to classify, partition, and eventually exclude classes of objects in the food domain. It is thus reasonable to expect that the way in which ON subjects classify foods differs from that of subjects who show no ON dispositions. Furthermore, recent studies revealed that populations characterized by hyperselectivity in the food domain (potentially overlapping with ON) exhibited specific behaviours regarding their food categorisation abilities. For instance, in a food categorization task where children were shown pictures of fruit and vegetables and were asked to classify each as fruit or vegetable, children with high neophobic dispositions (characterized by food hyperselectivity regarding novel foods) exhibited poorer performance than children with low neophobic dispositions (Rioux et al., 2016). This was also found for other food categorization tasks, for example when children were asked to discriminate foods from perceptually similar non-foods, children with high neophobic dispositions exhibited poorer performance than children with low neophobic dispositions (Foinant et al., 2021a). Furthermore, patients suffering from AN also demonstrated specific patterns in food categorization tasks. When exploring the implicit associations between food stimuli (low-calorie vs. high-calorie foods) and body stimuli (underweight vs. overweight bodies) in patients suffering from AN and control subjects using a Go/No-Go Association Task (Lakritz et al., under review), results revealed that patients suffering from AN exhibited an implicit association between food and body stimuli that

was not exhibited by control subjects. In addition, the two groups showed different categorization strategies: AN patients tended to categorize fewer stimuli as low-calorie foods and underweight bodies than the control subjects, and they tended to categorize more stimuli as high-calorie foods and overweight bodies than the control subjects. Therefore, it seems that these food-related dispositions, namely food neophobia and anorexia nervosa, resulted in specific categorization performance or strategies. Considering the overlaps (including food hyper-selectivity) between ON, AN, and food neophobia, we could expect ON to also be associated with specific response patterns in food categorization tasks.

It is also worth mentioning an important difference between ON, food neophobia, and AN though. Only AN displays a marked gender bias, with women constituting 90% of those affected (van Eeden et al., 2021), and the literature suggests differences in cognition abilities between women and men in AN (e.g., in central coherence, women present a deficit in AN whereas no evidence for that was seen in men) (Goddard et al., 2014). Conversely, gender does not appear to exert any discernible influence on the manifestation of food neophobia in children or ON, as no empirical evidence of this effect has emerged (Donini et al., 2022; Rioux, 2020). Nonetheless, considering the overlaps mentioned above between anorexia nervosa and orthorexia nervosa, gender differences were investigated in our studies.

To test the hypothesis of specific response patterns in food categorization tasks in ON, it is first important to stress that categorization performance is generally distinguished from categorization strategy. Food categorization performance embeds accuracy, reaction times and consistency. Indeed, for a given food categorization task, for instance categorizing berries as either edible or poisonous, you can 1) be *quick* to decide, or it can take you ages to make the decision (i.e., reaction time); 2) be *consistent*, making the same decision every time the same item is presented or you can change your decision during the task; and 3) be *accurate* when discriminating edible from poisonous berries, or not (i.e., discriminability). Having short reaction times, great consistency or great discriminability are variables that indicate good performance. Applied to our research question, we may hypothesize that the intensity of ON traits (i.e., high scores on an ON rating scale) influence subjects' performance in a healthy/unhealthy food categorization task (hypotheses H1 and H2 below). As there are no objective criteria for determining whether a food is healthy or unhealthy, there are no right or wrong answers, therefore we cannot make any assumptions about the ON subjects' accuracy in a healthy/unhealthy food categorization task. However, as ON subjects are characterized by an obsession with healthy foods, we expect that subjects who exhibit high ON scores will be faster

and more consistent than subjects with a low ON score when categorizing foods as healthy versus unhealthy.

Categorization strategy (sometimes called decision criterion or response bias) is the disposition to avoid a certain type of error, a disposition that might bias your responses to a task. Response strategy is a key aspect of signal detection theory, one of the most ubiquitous models used to capture processes that underlie simple two-choice decisions (Green & Swets, 1966). Interestingly, response strategy is a variable that is especially sensitive to uncertainty or perceived risk. The disposition to avoid a certain type of error depends on the risk associated with this type of error, and the level of risk is also a function of uncertainty. Going back to the example of berry categorization, even if you are very good at discriminating edible from poisonous berries, you might be inclined to categorize edible berries as poisonous to avoid mistaking a poisonous berry for an edible one (an error that might have deadly consequences). If you compare this error to the reverse one, mistaking an edible berry for an inedible one, you realize that the former is far more costly than the latter, which is harmless. Perceiving the risk associated with one type of answer might thus bias your responses, independently from your ability to discriminate between berries. The response strategy, bias, or decision criterion are synonymous expressions that refer to this second component of categorization abilities. This leads to our prediction that ON subjects exhibit specific food categorization strategies when they are asked to reason about food categories under uncertainty and when certain errors appear risky to them (hypotheses H6-H8 below). Choosing whether or not a food is healthy when discrimination is difficult might be perceived as a risky task from ON subjects' perspective. We hypothesize that mistaking an unhealthy food for a healthy one is the type of error that ON subjects will try to avoid.

One measure of the perception of risk associated with a type of response is the breadth of the category (wide/narrow, i.e., the set of category members). The greater the perceived risk of mistaking an unhealthy food for a healthy one, the more likely the subject will classify the food as unhealthy. Consequently, we expect that the set of stimuli categorized as unhealthy will be broader for those with a high ON score than for those with a low ON score (hypotheses H3 and H6 below). Interestingly, it has been shown in the literature on neophobia that children with high levels of food rejection generalized more negative properties to all kinds of food than children with low levels of food rejection (Foinant et al., 2021b). Food neophobia and ON have shown some overlaps: hyper-selectivity for food, being a risk factor for eating disorders (Dell'Osso et al., 2016a; Herle et al., 2020), and intolerance of uncertainty (Giles et al., 2021).

Considering these overlaps, we would again expect that subjects with high ON scores would categorize more foods as unhealthy (consistent with the overgeneralisation of negative properties evidenced by Foinant and colleagues, 2021) compared to their counterparts with low ON scores (hypotheses H3 and H6 below).

We conducted three studies to examine whether subjects with ON traits exhibit specific food categorization behavior (performance and/or strategies). With a healthy/unhealthy two-choice food categorization task, Study 1 was an initial exploration to determine whether categorization performance variables (reaction times, response consistency) and a measure of strategy (category breadth), as well as executive functions (cognitive flexibility, inhibition), were associated with score on an orthorexia nervosa rating scale. Study 2 expanded Study 1 to investigate cognitive flexibility in the food domain according to ON score. The results motivated the further investigation of ON subjects' categorization strategies (i.e., response bias) in Study 3.

All three studies were conducted in France and replicated in a French-speaking population in the province of Quebec, to test the robustness of the effects across different geographical areas.

All three studies were preregistered, and stimuli, anonymized datasets, and statistical scripts can be accessed at OSF https://osf.io/6h5v8/?view_only=e3d180cee71c4588ac0b1817a634c6a7 project. All three studies received approval by the Ethics Committee of University Lyon 1, France (Study 1 and 2: n° 2022-04-14-002; Study 3: n° 2023-04-06-001) and the Sectoral Committee on Ethics in Health Science Research of Laval University, Quebec, Canada (Study 1 and 2: n° 2022-104 A-1 / 09-08-2022; Study 3: n° 2023-4008, 22328 for Study 3). All studies' analyses were conducted using Spyder © software (Raybaut, 2009) and Rstudio 3.6.0 R © software (RStudio Team, 2021).

Study 1

For Study 1 we designed and conducted a food categorization task to investigate ON subjects' categorization performance and strategy. We measured several facets of performance (reactions times, consistency) and strategy (breadth of the unhealthy category, defined as the set of stimuli to which the unhealthy category applies). We tested three hypotheses:

H1: Subjects with high ON scores are faster at classifying foods as healthy/unhealthy than subjects with low ON scores.

H2: For the same food, subjects with high ON scores exhibit greater response consistency (the same item is categorized the same way across trials) than subjects with low ON scores.

H3: The unhealthy food category is broader (i.e., has more members) for subjects with high ON scores than for subjects with low ON scores.

The study's secondary aims were to measure cognitive flexibility to determine whether rigidity of thoughts and behaviors was observed in ON subjects to measure inhibition ability according to ON scores.

Study 1 – Methods

Participant

No previous research directly investigated the categorization of food into healthy and unhealthy categories according to an ON rating scale, so we decided to based our sample size on the existing literature on young adults' perception of food according to health aspects (Bailey & Muldrow, 2019; De Vlieger et al., 2017), using sample sizes around 150 participants.

A total of 228 French-speaking participants from 18 to 35 years old completed the experiment online in June 2022: 112 from France with 83 women, 25 men, and 4 non-binary or others (mean age = 24.6, SD = 4.44; mean BMI = 22.7, SD = 3.39); and 116 from the province of Quebec, Canada with 103 women, 10 men, and 3 non-binary or others (mean age = 26.2, SD = 4.74; mean BMI = 24.8, SD = 5.94). In France, participants were recruited through email databases of French universities and through Facebook. Participants who fully completed the experiment could participate in a drawing for a chance to win a 40€ voucher (4 vouchers were sent). In Quebec, participants were recruited through Laval University email database and Facebook. Data were collected through an anonymous self-report questionnaire.

Materials

The study was developed with PsychoPy © software (Peirce et al., 2019) and was administered online to the participants through the Pavlovia platform (pavlovia.org).

Demographic Questionnaire. The demographic questionnaire comprised questions to document gender, age, height, weight (body mass index, BMI, was calculated), socio-professional category, food-related pathology, and level of hunger.

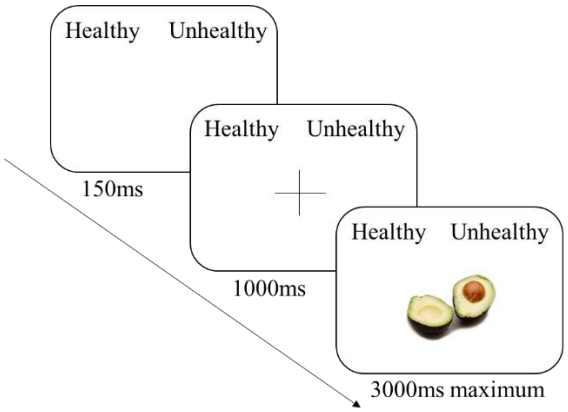
Eating Habits Questionnaire (EHQ). Participants completed the French version (Godefroy et al., 2021) of the Eating Habits Questionnaire (Gleaves et al., 2013), a 16-item validated questionnaire for detecting orthorexic traits. Each item includes a sentence followed by a response on a 4-point Likert-type scale ranging from "False, Not at All True" to "Very True". A high score on this scale portrays greater ON tendencies. The French version includes three subscales: rigid eating behaviour (REB) (e.g., "I follow a diet with many rules.", "I only eat what my diet allows."); positive feeling of control (PFC) (e.g., "I feel in control when I eat healthily", "I feel great when I eat healthily"); and problems of attention control and social relationships (PACSR) (e.g., "My healthy eating is a significant source of stress in my relationships", "I go out less since I began eating healthily."). In the present study, in the French sample, global Cronbach's $\alpha = 0.79$ and Cronbach's $\alpha = 0.73$, 0.63, and 0.81 for REB, PFC and PACSR respectively. In the Quebec sample, global Cronbach's $\alpha = 0.85$, and Cronbach's $\alpha = 0.82$, 0.67, and 0.76 for REB, PFC and PACSR respectively. Thus, internal consistency was quite good in both sample.

Eating Disorder Examination – Questionnaire (EDE-Q). We used the French version (Carrard et al., 2015) of the EDE-Q (Fairburn & Beglin, 1994) to assess eating disorder-related attitudes and behaviours. The French version has 28 items. Of those, 22 items make up four subscales that specifically address the core features of eating disorders: restraint (5 items, e.g., "Have you tried to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?"), eating concern (5 items, e.g., "Have you had a definite fear of losing control over eating?"), shape concern (8 items, e.g., "Have you had a definite desire to have a totally flat stomach?"), and weight concern (5 items, e.g., "Have you had a strong desire to lose weight?"). One item belongs to both shape concern and weight concern subscales. In addition, 6 items assess the frequency of binge eating episodes and inappropriate compensatory behaviours and are analyzed separately. The whole assessment refers to the previous 28 days. Items are rated with a Likert-type scale from 0 (no days) to 6 (every day); the mean of the four subscale scores constitutes a global score. In our French sample, global Cronbach's $\alpha = 0.95$ and Cronbach's α of the subscales were between 0.79 and 0.92. In the

Quebec sample, global Cronbach's α = 0.96 and Cronbach's α of the subscales were between 0.79 and 0.93, which showed good internal consistency.

Food stimuli. A set of 32 stimuli were selected from the FoodPics database (Blechert et al., 2014), according to the two variables that most explain the perception of healthiness in the food domain: energy density and food processing (Coricelli et al., 2019; Foroni et al., 2022). Stimuli ranged from 69 to 145 Kcal per image and have a gradient from 15 to 654 Kcal per 100g (mean Kcal per 100g = 197.5, SD = 188.1; mean Kcal per image = 98.9, SD = 20.0) as per the data and recommendations of Foroni and colleagues (2013, 2022). We selected 17 natural-perceived foods and 15 processed-perceived foods following Blechert and colleagues' classification. No food stimuli containing animal protein were included to avoid bias related to religious or ethical beliefs.

Forced-choice task. The forced-choice task assessed the performance of classifying food stimuli into the healthy or unhealthy category. Each stimulus was repeated 4 times per participant. Thus, each participant had 128 trials. The stimulus sequences can be seen Figure 4. The keyboard keys used for the healthy/unhealthy categories (E and I) were randomly assigned between participants. Each response and reaction time was recorded.



Note. Interstimulus Interval (ISI): 1150ms. For the purpose of this paper, this figure is an English translation of the task, whereas it was administered in French.

Figure 4. Stimulus sequences

Trail Making Test (TMT). We used a computerized version of the Trail Making Test (Reitan, 1958) to assess cognitive set-shifting abilities. In part A, subjects connected in ascending order a series of 25 numbered circles randomly placed on the screen. In part B, subjects connected 25 circles alternating between ascending numbers and letters (e.g., 1-A-2-B, etc.). The difference

between mean reaction time (RT) in part B and part A (part B RT – part A RT) was used to assess set-shifting abilities.

The Stroop Task. A computerized version of the Stroop Task (Stroop, 1935) assessed attention and inhibition processes. Two types of items were presented: congruent items (i.e., when color words were presented in their ink color), and incongruent (i.e., when color words were presented in another color). Mean RTs were determined for congruent and incongruent categories. From these mean RTs, an interference index was calculated: mean RT incongruent items − mean RT congruent items.

Procedure

First, participants were asked to complete the demographic questionnaire and to rate their state of hunger on a 7-point visual scale ranging from "not at all" to "extremely". Then, participants proceeded following these instructions: "Please classify the food that appears on your screen as quickly as possible, either in the healthy category (key E) or in the unhealthy category (key I). In this study, we consider the healthy criterion equivalent to the following examples: it is commonly considered that smoking is unhealthy, or that practicing 30 minutes of physical activity per day is healthy. In the same way, we ask you to classify foods according to whether they are healthy or unhealthy." The task was followed by an evaluation of each food stimulus on familiarity and liking with 5-point visual scales ranging respectively from "Not known at all" to "Perfectly known" and from "Not liked at all" to "Liked very much". Then, participants completed computerized versions of the Stroop Task and the TMT. Last, they completed the EHQ and EDE-Q. The entire procedure took about 30 minutes.

Data recording and analyses

Reaction times and response types were recorded. Effects were considered significant when $p < .05$.

Confirmatory analyses. As Greenwald and colleagues recommended (1998), RT distributions were examined and values below 300ms were excluded (246 trials out of 28362). The number of unhealthy food classifications per participant was computed and an exact binomial test was performed. After examination, no participant was excluded from the analyses. RT distributions were first assessed for normality using a Shapiro-Wilk test (France: $W(112) = 0.971$, $p = .014$; Quebec: $W(116) = 0.973$, $p = .018$), revealing non-normal distributions.

In order to test H1, according to which subjects exhibiting high ON scores classify foods as healthy/unhealthy faster than subjects exhibiting low ON scores, Pearson correlations between RT means and EHQ score were computed.

To test H2, according to which subjects with high ON scores exhibit greater response consistency (the same item is categorized the same way across trials) than subjects with low ON scores, a 3-level variable named "consistency variable" was created: 0 indicated that the stimulus was classified twice in one category and twice in the other category, 1 indicated that the stimulus was classified once in one category and three times in the other category, and 2 indicated that the stimulus was classified four times in the same category. The differences in mean EHQ scores between the 3 levels were tested with Mann-Whitney-U tests.

To test H3, according to which the category of unhealthy foods is broader when subjects have high ON scores than when subjects have low ON scores, proportion of food stimuli classified as unhealthy for each participant was computed and Pearson correlations with EHQ score were computed. As our data are repeated measures, generalized mixed models were conducted to explain the probability that a food was classified as unhealthy. Models were constructed by iteratively adding predictive variables to the null model (M0, the intercept and no predictor), using the Akaike Information Criterion (AIC; Hu, 2007) as a basis for model selection. EHQ global score was included as fixed effect. Item and subject were included in all models as random effects. The R-squared conditional (R^2_C) and marginal (R^2_M) were computed to determine the proportion of the variance explained by the model.
All analyses were controlled for age, gender, and BMI.

Exploratory analyses. The properties of the food stimuli (degree of processing and energy density) were considered in the analyses. The degree of processing variable had two modalities (natural/processed) according to Blechert's classification (2014), and the energy density variable had two modalities (low/high) according to Foroni and colleagues (2022) who considered food pictures below 150 Kcal per 100g as having a low energy density, and food pictures above 150 Kcal per 100g as having a high energy density.

Post-test analyses. Regarding the TMT, which assessed cognitive flexibility, Pearson correlations were computed between the difference in completion times (mean RTs part B – mean RTs part A) and the EHQ score and subscales scores. Regarding the Stroop Task, which assessed inhibition ability, Pearson correlations were computed between the interference index

(mean RTs for incongruent items − mean RTs for congruent items) and the EHQ score and subscales scores.

Study 1 – Results

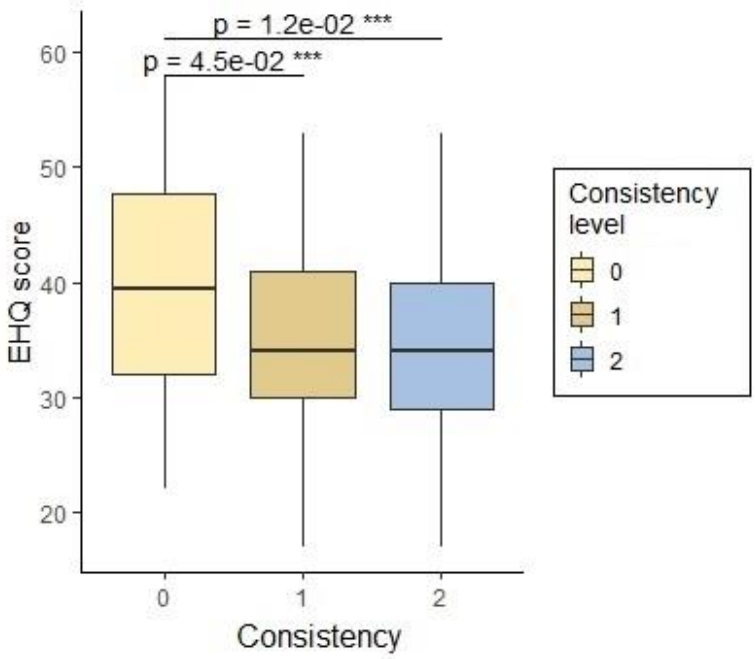
Participants' Characteristics

Participants' characteristics, questionnaire scores, and their response indices (reaction time, proportion of foods classified as unhealthy, and response consistency) are available in Supplementary Materials 1a, 1b, 2a and 2b.

Results of confirmatory analyses

Regarding H1, we failed to find significant correlations between the mean RT and EHQ score in France as well as when the task was replicated in Quebec [France: $r(110) = -0.11$, $p = .260$; Quebec: $r(114) = -0.05$, $p = .630$].

Regarding H2, a significant difference in EHQ means was shown between levels of response consistency: participants with a consistency score of 0 (indicating that the same item presented four times was classified as healthy twice and as unhealthy twice) exhibited a significantly higher EHQ score than those with consistency scores of 1 or 2, in the Quebec sample [difference between level 0 and level 1: U = 6236, $p = .045$; difference between level 0 and level 2: U = 82194, $p = .012$] (see Figure 2). We did not observe any significant effect in the French sample.



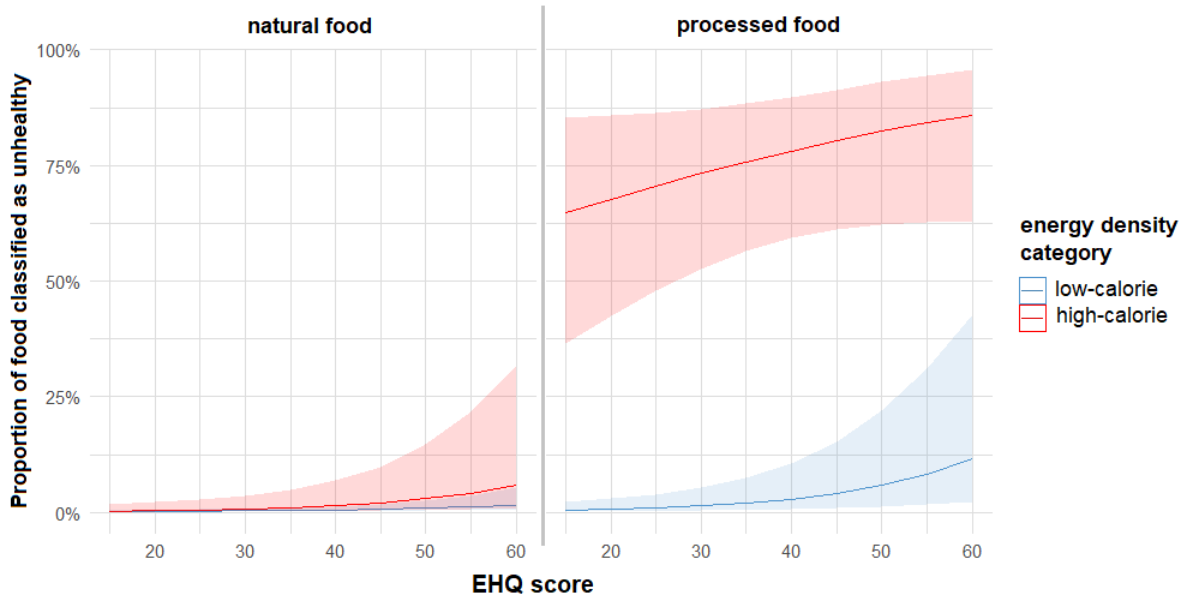
Note. EHQ = Eating Habits Questionnaire; Consistency of responses level 0 = stimuli classified twice in one category and twice in the other category; level 1 = stimuli classified once in one category and three times in the other category; level 2 = stimuli classified four times in the same category;
* $p < .05$; ** $p < .01$; *** $p < .001$.

Figure 5. EHQ score according to levels of response consistency in the Quebec sample.

Regarding H3, results showed a positive correlation between the proportion of food items classified as unhealthy and EHQ score only in the Quebec sample [$r(114) = 0.20$, $p = .032$]. Results of a mixed models test confirmed an effect of the EHQ global score on the probability of food items being classified as unhealthy in the Quebec sample [$\beta = 0.06$, $F(1,114) = 4.44$, $p = .035$]. Details of the mixed models can be found in Supplementary Materials 3a, 3b and 4.

Exploratory analyses

Regarding food properties, a positive correlation was found between the proportion of food classified as unhealthy and EHQ score (H2) only for processed, low-calorie foods [$r(114) = 0.25$, $p = .007$] and only in the Quebec sample. Results of a mixed models test showed a three-way interaction between EHQ score, energy density, and food processing [$\chi 2(1,114) = 6.33$, $p = .012$] that affected the probability of food items being classified as unhealthy in the Quebec sample (see Figure 3).



Note. EHQ = Eating Habits Questionnaire

Figure 6. Study 1 – Three-way interaction effect of EHQ score, energy density, and food processing on the proportion of food classified as unhealthy in the Quebec sample.

Cognitive flexibility and inhibition

Regarding cognitive flexibility performance on the Trail Making Test, a negative correlation was found between the difference in completion times and the EHQ score only for women in the French sample [$r(81)= -0.22$, $p = .047$]. No significant correlation was found in the Quebec sample.

Regarding inhibition ability with the Stroop Task, no significant correlation was found between the interference index and EHQ score, either in France [$r(110) = -0.16$, $p = .089$] or in the Quebec sample [$r(114) = -0.07$, $p = .459$].

Study 1 – Discussion

Study 1 was a first attempt to determine whether categorization performance and strategy in a healthy/unhealthy food categorisation task were associated with ON score. Regarding H1, we found that subjects with high ON scores were not significantly faster to classify foods as healthy/unhealthy than subjects with low ON scores. Interestingly, and contrary to what was expected with H2, response consistency was lower for subjects with high ON scores than for subjects with low ON scores in the Quebec sample. One interpretation might be that subjects with high ON scores were more uncertain than subjects with low ON scores when they were asked to classify food as healthy or unhealthy. Finally, considering H3, we partly confirmed

that the category of unhealthy foods was broader for subjects with high ON scores than for subjects with low ON scores in the Quebec sample, but only regarding processed, low-calorie food. Therefore, both ON dispositions and food properties influenced the proportion of food classified as unhealthy. For H2 and H3, we failed to observe these effects in the French sample.

When looking at cognitive flexibility abilities, in line with the literature, the Trail Making Test did not show poorer cognitive flexibility performance among subjects with high ON scores than subjects with low ON scores. Surprisingly, a negative correlation coefficient was found between the difference in completion times and EHQ score in the French sample among women, suggesting better flexibility performance when exhibiting high ON scores than when exhibiting low ON scores. A potential gender effect seen here might question the literature, as existing research is for now inconclusive as to an influence of gender in ON (L. M. Donini et al., 2022). Nevertheless, sample sizes for each gender were small, and these results were not replicated in the Quebec sample.

Significant results of confirmatory analyses were found in the Quebec sample only, and significant exploratory results were found in the French sample. The French and Quebec samples differed in terms of age, body mass index, gender ratio, EHQ score, and proportion of food classified as unhealthy, therefore they should be compared with caution.

Results of the confirmatory analyses suggested that subjects' performance was influenced by ON score, as shown by less response consistency in subjects with high ON scores than subjects with low ON scores when classifying food as healthy or unhealthy. But this inconsistency can also be seen in terms of a greater perception of uncertainty: in a context with high uncertainty, subjects can be at loss when detecting healthy versus unhealthy, which lead them to be less consistent. In addition, subjects with high ON scores showed a larger unhealthy category than subjects with low scores, indicating a greater perceived risk of mistaking an unhealthy food for a healthy one. These results are in favour of an influence of ON score on subjects' food categorization *strategies*, which we explore further in Study 3.

Furthermore, in line with Hayatbini and colleagues' findings (Hayatbini & Oberle, 2019), we did not find poorer cognitive flexibility in subjects with high ON scores than subjects with low ON scores. Surprisingly, we even observed the opposite pattern among women in the French sample. Therefore, the rigidity of thoughts and behaviours seen in ON does not seem to be reflected in cognitive flexibility performance measured with a standard task. We further investigate the flexibility aspect in Study 2 by relying on a distinction that has been made

between cognitive flexibility understood as a domain general capacity (what we measured in Study 1 using the Trail Making Test) versus conceptual flexibility, which is the ability to activate different features for the same object or concept depending on the context (Hoenig et al., 2008) and potentially the domain of knowledge. Because Study 1 highlighted cues (category breadth and consistency) sensitive to ON, it led us to hypothesize that the rigidity of thoughts and behaviours seen in ON could reflect flexibility impairments only in the food domain.

Study 2

The food domain is extremely liable to cross-classification (Nguyen & Murphy, 2003). Foods can be categorized in various ways, such as an apple and a banana being both fruits and snacks. This ability to cross-classify is a matter of conceptual flexibility, according to which relies on the hypothesis developed by Hoenig and colleagues (2008) that "concepts are flexibly tailored to the current contextual constraints" (p. 1799). Therefore, the ability to access concepts in different contexts is a matter of conceptual flexibility. Conceptual flexibility, which we investigate in Study 2, differs from cognitive flexibility as tested by standard domain-general tests in Study 1.

The criteria on which categorisation (i.e., classification) is based are sensitive to an individual's characteristics such as BMI or eating disorders. Indeed, using an electroencephalography (EEG) task, Pergola and colleagues (2017) presented participants of different body mass index (BMI) with a sentence (prime) and a picture of a food item, then asked them to asked to judge whether or not the sentence was congruent with the food item. The primes described either a sensory characteristic ("It tastes sweet") or a functional characteristic ("It's suitable for a wedding party") of the food, while the pictures depicted a natural (e.g., cherry) or processed (e.g., pizza) food. Using the amplitude and latency of the N400 event-related potentials, the authors found that food categorization was modulated by food type (here natural vs. processed) and prime type (sensory vs. functional), and that these processes were modulated by the participants' BMI. The results revealed modulations of N400 amplitude and latency by sensory-functional primes only for processed foods (e.g., lasagna) in obese participants, but only for natural foods (e.g., an apple) in underweight participants. This interaction between individuals' characteristics and food categorization has also been investigated in behavioral tasks (Coricelli et al., 2019) and with qualitative methods (Urdapilleta et al., 2005), revealing that individuals with dietary restrictions relied more on functional attributes to categorize foods. Because subjects suffering from ON are obsessed with healthy eating, we hypothesize that they are used to reasoning about food in terms of its effect on health (functional property) and that they are not used to recruiting

other features of foods. We hypothesized that subjects with high ON scores have more difficulty regarding conceptual flexibility in the food domain than subjects with low ON scores. To date, however, no studies have measured conceptual flexibility in the food domain in subjects suffering from ON.

Based on this literature, Study 2 investigated conceptual flexibility in the food domain in ON. We tested subjects' ability to change their way of categorizing food according to four different pairs of attributes: healthy/unhealthy, snack/side dish, sweet/salty, and dry/juicy. Two pairs constituted the functional condition (healthy/unhealthy, snack/side dish), and two constituted the sensory condition (sweet/salty and dry/juicy). We tested two hypotheses:

H4: Subjects with high ON scores exhibit longer reaction times than subjects with low ON scores when they are asked to change from one condition to another.

H5: Subjects with high ON scores are faster at categorizing food in functional conditions than in sensory conditions, a difference that is not expected in subjects with low ON scores.

Study 2 – Method

Participants

The sample size was calculated on the basis of Hayatbini and Oberle's study in which subjects with and without orthorexic traits completed the cognitive flexibility tasks Wisconsin Card Sorting Test (Berg, 1948) and Trail Making Test (Reitan, 1958). A priori, we had based our calculations in OSF on the results of the Wisconsin Card Sorting Test results the authors obtained, but which were results on error types. In our study, however, we were interested in reaction times. The authors obtained an effect size d=0.3 by comparing the reaction times of subjects with orthorexic traits with those without (Hayatbini & Oberle, 2019). Considering that we studied the correlation between reaction times and orthorexia scale score, with the same effect size and an expected power of 0.8, a sample size calculation with the Sample size Calculator site (Ristl, 2022 Version 1.058) indicated that a sample size of 85 participants was sufficient. Looking at the existing literature on young adults' perception of food according to health aspects, this sample size was slightly smaller to what the studies presented (N = 124 and N=115, respectively Bailey & Muldrow, 2019; De Vlieger et al., 2017), therefore we slightly overrecruited.

A total of 235 French-speaking participants from 18 to years old completed the experiment online between June and October 2022. Of these, 149 were from France with 69 women, 73 men, 4 non-binary or others, and 3 who did not want to respond (mean age = 25.7, SD = 4.4; mean BMI = 23.7, SD BMI = 5.7), and 86 were from the province of Quebec, Canada with 74 women, 9 men, and 3 non-binary or others (mean age = 25.4, SD = 5.7; mean BMI = 24.0, SD BMI = 5.4). In France, participants were recruited through the Prolific platform, where participants were paid 10 euros. In Quebec, participants were recruited through Laval University email database and Facebook, and participants who fully completed the experiment could participate in a drawing for a chance to win a 40 Canadian dollar voucher (4 vouchers were sent). Data were collected through an anonymous self-report questionnaire.

Materials

The study was developed with PsychoPy © software (Peirce et al., 2019) and was administered online to the participants through the Pavlovia platform.

The questionnaires and stimuli for Study 2 were identical to those of Study 1.

Eating Habits Questionnaire. In Study 2, in the French sample global Cronbach's α = 0.85 and Cronbach's α = 0.82, 0.77, and 0.80 for REB, PFC, and PACSR subscales respectively. In the Quebec sample, global Cronbach's α = 0.90 and Cronbach's α = 0.91, 0.70, and 0.87 for REB, PFC, and PACSR subscales respectively, which showed quite good internal consistency.

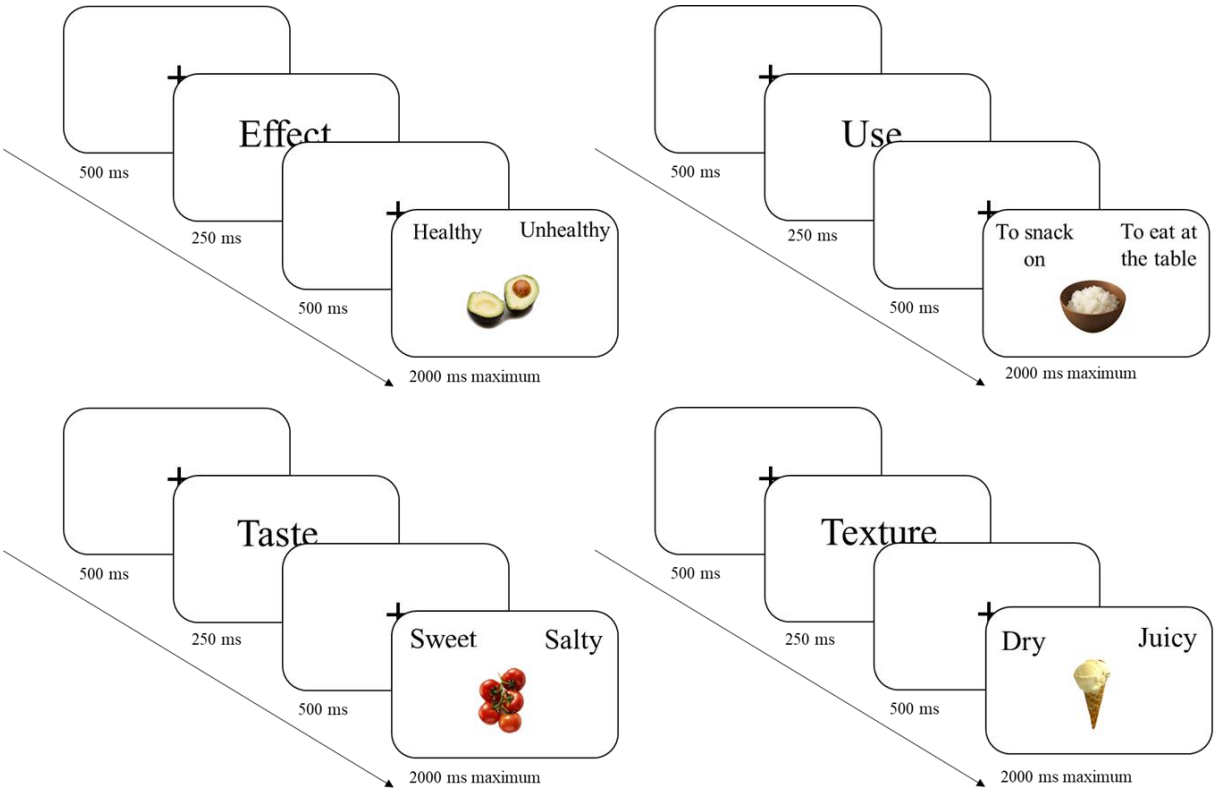
Eating Disorder Examination – Questionnaire. As in Study 1, we used the French version of the Eating Disorder Examination Questionnaire (EDE-Q) that includes 28 items (Carrard et al., 2015). In Study 2, in the French sample global Cronbach's α = 0.95 and Cronbach's α of the subscales were between 0.85 and 0.91. In the Quebec sample, global Cronbach's α = 0.95 and Cronbach's α of the subscales were between 0.82 and 0.92, which also showed quite good internal consistency.

Forced-choice task. The forced-choice task consisted of trials in which a word was first shown and then followed by a food stimulus accompanied by two semantic categories presented at the top left and right of the screen. Each word referred to the dimension according to which the subjects had to categorize the food. For instance, the word "effect" indicated to categorize the food according to its effect on health (i.e., healthy versus unhealthy). The semantic words

were either functional ("effect" or "use") or sensory ("taste" or "texture"). The two semantic categories presented corresponded to the word, for example, when "taste" appeared, the categories "sweet" and "salty" followed. After seeing the word, the subject classified the stimulus into one of the two categories. The list of words and associated categories can be seen Table 1.

Table 1. Study 2 – List of semantic words and associated categories presented to the participant, and corresponding type of condition.

Words	Categories in which the stimuli were categorized	Type of Condition
Effect	Healthy / Unhealthy	Functional
Use	Snack / Side dish	Functional
Taste	Sweet / Salty	Sensory
Texture	Dry / Juicy	Sensory



Note. Interstimulus Interval (ISI): 1250ms. This figure is an English translation of the task, whereas it was administered in French.

Figure 7. Stimulus sequences

Stimulus sequences can be seen Figure 4. We followed the recommendations of Wentura and Degner (2010) and Roque and colleagues (2020) concerning the duration of each frame. The task consisted of a training phase with 12 trials and a test phase with 128 trials. The order of word-stimulus pairs and category-key assignments were randomized between participants.

Procedure

First, participants were asked to complete the demographic questionnaire and to rate their state of hunger on a 7-point visual scale ranging from “not at all” to “extremely”. Then, participants proceeded with the forced-choice task following these instructions: "In the following task, you will have to reason about different food groups, e.g., healthy and unhealthy foods, or hard and soft foods. Choose as quickly as possible which group the food presented on your screen belongs to, by pressing the E (for the group at the top left of the screen) and I (for the group at the top right of the screen) keys, depending on which group you want to select." The task was followed by an evaluation of each food stimulus on familiarity and liking with 5-point visual scales. Last, they completed the EHQ and EDE-Q. The entire procedure took about 20 minutes.

Data recording and analyses

Reaction times and response types were recorded. Effects were considered significant when $p < .05$.

A total of 140 (out of 29648) trials had a response time value below 300ms and were excluded, as well as one participant in the French sample who exhibited 113 reaction time values (88%) below 300ms. In order to test H4, according to which subjects with high ON scores would be slower to change from one instruction to another, we computed Pearson correlations between RT means and EHQ scores. In order to test H5, according to which subjects with high ON scores would be faster to categorize food in the functional condition than in the sensory condition, we computed Pearson correlations between RT means and EHQ scores in the functional and sensory conditions and we compared correlation coefficients. All analyses were controlled for age, gender, and BMI and were conducted on the overall population and independently in men and women. Exploratory analyses were done using EHQ subscales instead of global EHQ score to determine whether one or several subscales could reveal any effect.

Study 2 – Results

Participants' Characteristics

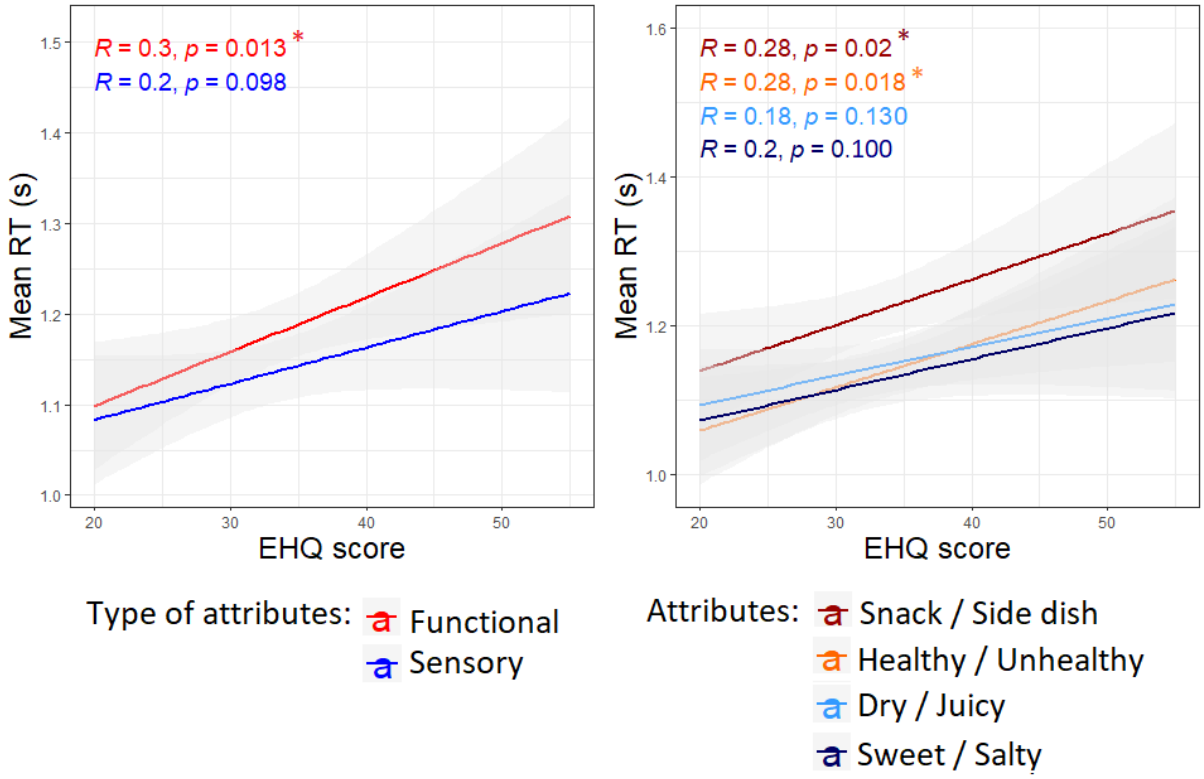
Participants' characteristics, scores on the questionnaires, and their response indices (reaction time, proportion of foods classified as unhealthy, and response consistency) are available in Supplementary Materials 5a, 5b, 6a and 6b.

Results

Regarding H4, results showed a positive correlation between the global mean RT and EHQ score in the French sample only among women [$r(67) = 0.26$, $p = .031$]. No significant correlation was found when the task was replicated in the Quebec sample.

Regarding H5, when looking at the functional and sensory conditions as seen Figure 5a, only the correlation coefficient in the functional condition between the global mean RT and EHQ score was significant [$r(67) = 0.30$, $p = .013$] in the French sample when considering only women.

More precisely when looking at each word (see Figure 5b), use (snack/side dish) and effect (healthy/unhealthy) both showed positive correlations between the global mean RT and EHQ score [use: $r(67) = 0.28$, $p = .020$; effect: $r(67) = 0.28$, $p = .018$] whereas texture (dry/juicy) and taste (sweet/salty) did not show significant correlations.



Note. EHQ = Eating Habits Questionnaire; RT = Reaction times; * $p < .05$; ** $p < .01$; *** $p < .001$

Figure 8. RT means (s) according to EHQ score by word type (a.) and by word (b.) in the French sample.

Study 2 – Discussion

Study 2 investigated participants' conceptual flexibility in the food domain according to ON score. As expected, subjects with high ON scores were slower to change from one condition to another (functional vs. sensory) than subjects with low ON scores (H4).

We found no evidence to support our second hypothesis (H5) that subjects with high ON scores would be faster at categorizing food in the functional condition than the sensory condition, unlike subjects with low ON scores. On the contrary, only the functional condition showed positive correlations between EHQ score and reaction times, meaning that subjects with high ON scores were slower to categorize food in the functional condition than subjects with low ON scores. No significant correlation was found regarding the sensory condition.

Results of H4 and H5 were found only among women in the French sample, and results were not significant when the task was replicated in Quebec. As in Study 1, the influence of gender on the results questions the influence of gender in ON. Moreover, the French and Quebec

samples differed in terms of gender ratio, EDE-Q score, and mean reaction times, and therefore, they should be compared with caution.

A first possible interpretation of longer reaction times found for subjects with high ON scores compared to subjects with low ON scores when changing from one condition to another (H4) could be that subjects with high ON scores exhibit poorer conceptual flexibility in the food domain than subjects with low ON scores. However, these results were only found in part of the sample (only among women in the French sample), and they were found only in the functional condition, as seen in the results of H5, which led us to another possible interpretation. Longer reaction times in the functional condition for subjects with high ON scores than for subjects with low ON scores could be interpreted as greater perceived uncertainty and risk, when classifying foods according to their effect on health or the context of consumption, for subjects with high ON scores. Indeed, the risk of mistaking an unhealthy food as a healthy one might be perceived as higher from an ON subjects' perspective, then it could take longer to decide when classifying food as healthy or unhealthy. As for the context of consumption, snacks are considered unhealthy by the majority of consumers whereas eating a proper meal is considered much healthier (Saint Pol & Hébel, 2021), therefore, the same reasoning can be applied to the context of consumption. A greater perception of risk and uncertainty in subjects with a high ON score therefore suggests that the subject's categorization strategy could be influenced by the ON score.

These findings echoed the results of Study 1, which gave clues (less consistency and a broader unhealthy category) that subjects with high ON scores might be more uncertain than subjects with low ON scores when asked to classify food as healthy or unhealthy. In Study 3, we investigated further food categorization's strategy under risk and uncertainty in ON subjects using the signal detection theory framework.

Study 3

Perception of uncertainty and risk can affect a categorization task via the subject's strategy, also called the response bias or decision criterion. Study 3 investigated further subjects' strategies in food categorization according to ON scores. In the signal detection theory framework, if subjects tend to avoid risks, they exhibit a more *conservative* strategy with a higher decision criterion. If subjects tend to take risks, they exhibit a more *liberal* strategy with a lower criterion of decision (Stanislaw & Todorov, 1999). Considering that mistaking an unhealthy food for a healthy food represents a harmful error while mistaking a healthy food for an unhealthy food

represents a harmless error for subjects suffering from ON, they would exhibit different strategies depending on the categorization asked. Three hypotheses were tested in Study 3:

H6: The breadth of the unhealthy category (i.e., proportion of food categorized as unhealthy) is influenced by both food energy density and ON score (in line with the results of Study 1).

H7: Subjects with high ON scores exhibit a more liberal response bias when detecting unhealthy food than subjects with low ON scores.

H8: Subjects with high ON scores exhibit a more conservative response bias when detecting healthy food than subjects with low ON scores.

Study 3 – Method

Participants

The calculation of sample sizes was similar to that of Study 2. A total of 255 participants completed the experiment online from 18 to 35 years old. Of those, 149 were from France with 61 women, 82 men, and 6 non-binary or others (mean age = 26.9, SD = 4.4, mean BMI = 23.8, SD BMI = 4.7) and 106 were from the province of Quebec, Canada with 64 women, 39 men, and 3 non-binary or others (mean age = 26.3, SD = 4.6, mean BMI = 24.7, SD BMI = 5.8). In both samples, French-speaking participants between 18 and 35 years old were recruited through Labvanced crowdsourcing panel. Participants who fully completed the experiment received financial compensation of 10 Canadian dollars or the equivalent in euros.

Materials

The study was developed and administered online through the Labvanced © software and platform (Finger et al., 2017).

Demographic questionnaire. The demographic questionnaire comprised questions to document gender, age, body mass index (BMI), socio-professional category, food-related pathology, hunger level, current state of mind, and physical condition.

Eating Habits Questionnaire. As in Studies 1 and 2, we used the French version of the EHQ including 16 items (Godefroy et al., 2021). In Study 3, in the French sample global Cronbach's $\alpha = 0.87$ and Cronbach's $\alpha = 0.82$, 0.73, and 0.81 for REB, PFC, and PACSR subscales respectively. In the Quebec sample, global Cronbach's $\alpha = 0.88$ and Cronbach's $\alpha = 0.87$, 0.80,

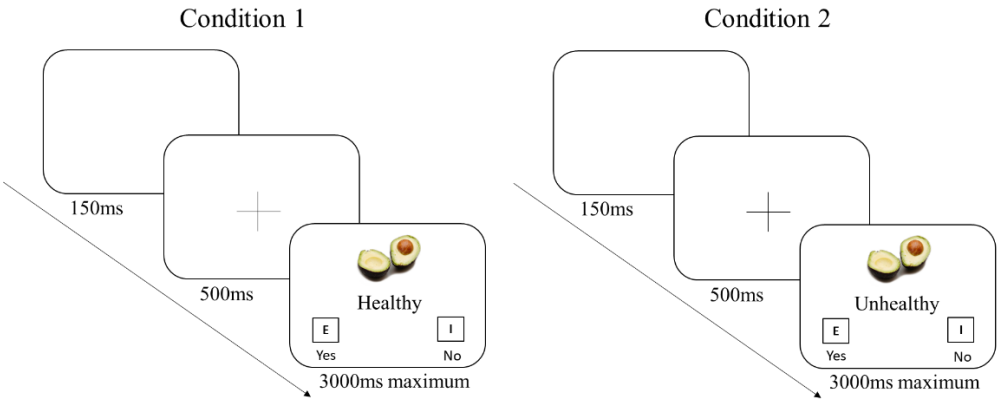
and 0.78 for REB, PFC, and PACSR subscales respectively, which shows good internal consistency.

Eating Disorder Examination – Questionnaire. As in Studies 1 and 2, we used the French version of the EDE-Q including 28 items (Carrard et al., 2015). In Study 3, in the French sample global Cronbach's α = 0.96 and Cronbach's α of the subscales were between 0.84 and 0.94. In the Quebec sample, global Cronbach's α = 0.96 and Cronbach's α of the subscales were between 0.85 and 0.94, which shows good internal consistency.

Food stimuli. A set of 32 food stimuli was selected from the FoodPics database (Blechert et al., 2014) and was based on Bonin and colleagues' (2022) article and on the results of Study 1. First, in Bonin and colleagues' research (2022) each stimulus was rated on its perceived effect on health (healthiness score) from 1 (unhealthy) to 10 (healthy). We included 16 healthy and 16 unhealthy stimuli. Second, Study 1 indicated that significant correlations between proportion of food classified as unhealthy and EHQ score were shown only when it comes to *processed* food. Based on these results, we chose to select only stimuli perceived as processed, ranging from 10 to 600 Kcal per 100g (mean Kcal per 100g = 224.8, SD = 130.0; mean Kcal per image = 229.8, SD = 145.4). Following Foroni and colleagues' (2022) recommendations, food items with an energy density above 150 Kcal per 100g were considered high-calorie, and those below were considered low-calorie. Thus, two sets of processed food stimuli were created: one containing 16 stimuli considered healthy (8 low-calorie, 8 high-calorie), and one containing 16 stimuli considered unhealthy (8 low-calorie, 8 high-calorie). The stimuli are available in the OSF directory https://osf.io/6h5v8/?view_only=e3d180cee71c4588ac0b1817a634c6a7.

Forced-choice task. The forced-choice task included two conditions: the first consisted of two similar blocks in which food stimuli were presented with a statement: "Healthy". For each food, participants were asked whether they considered the statement to be in agreement with the food (yes or no answer). The second condition consisted of two similar blocks in which participants were asked to respond to the statement "Unhealthy", with the same food stimuli presented. Therefore, there were two conditions, and each condition contained two identical blocks. The four blocks were randomly presented between participants. Each stimulus was repeated 4 times per condition (2 times per block), so 8 times per participant. Thus, with 32 stimuli, each participant had 256 observations. The stimulus sequences can be seen Figure 6. The keys of the

keyboard used to assess the healthy/unhealthy categories (E and I) were randomly assigned between participants. Each response and reaction time was recorded.



Note. Interstimulus Interval (ISI): 650ms. This figure is an English translation of the task, whereas it was administered in French.

Figure 9. Study 2 stimulus sequences in each condition.

Procedure

First, participants were asked to complete the demographic questionnaire and to rate their current hunger level, their current state of mind, and their current physical condition on 7-point visual scales ranging respectively from “not hungry at all” to “extremely hungry”, from “very bad” to “very good”, and from “very bad” to “very good”. Then, participants proceeded with the forced-choice task following these instructions: “You will see food scrolling across the screen and a sentence will be presented underneath. For example, the phrase might be "*this is healthy*". For each food, use the keyboard to indicate whether you think the food is in agreement with the sentence ("*Yes*") or not ("*No*"). The aim is to answer as quickly and accurately as possible”. Then, participants were asked to evaluate each food stimulus on familiarity and liking with 7-point Likert scales ranging respectively from “Not known at all” to “Perfectly known” and from “Not liked at all” to “Liked very much”. Last, participants completed EHQ and EDE-Q. The entire procedure took about 20 minutes.

Data recording and analyses

Reaction times and response types were recorded. Effects were considered significant when $p < .05$.

Confirmatory analyses

A total of 784 (out of 65536) trials had a reaction time below 300ms and were excluded, as well as six participants from the Quebec sample for whom at least 10% of trials had RT values below 300ms. Therefore, 246 participants (146 French sample, 100 Quebec sample) were included in the analyses.

In order to test H6, according to which the proportion of food classified as unhealthy is influenced by both energy density and orthorexic score (in line of the results of Study 1), the proportion of food stimuli classified as unhealthy in Condition 2 was computed according to energy density (low-calorie and high-calorie), and we calculated Pearson correlations between these proportions of unhealthy food and EHQ score.

In order to test H7 and H8, response types were analyzed in each condition: each participant was assigned a score for hits (i.e., saying yes when stimuli were in the target category, e.g., when detecting healthy stimuli, pressing the yes button for healthy stimuli) and a score for false alarms (i.e., saying yes when stimuli were not in the target category). Based on signal detection theory (Green & Swets, 1966; Stanislaw & Todorov, 1999), we computed participants' response bias (β''). β'' ranged from -1 to +1: -1 indicates a liberal criterion, meaning the participant exhibited a tendency to say that the signal is present; +1 indicates a conservative criterion, meaning the participant exhibited a tendency to not say that the signal is present. In other words, β'' captures the personal response strategy in the presence of risk and/or uncertainty. To test H7, according to which subjects with high ON scores would exhibit a more liberal response bias when detecting unhealthy food than subjects with low ON scores, we computed the response bias criterion in Condition 2, and computed Pearson correlations with EHQ score.

To test hypothesis H8, according to which subjects with high ON scores exhibit a more conservative response bias when detecting healthy food than subjects with low ON scores, we computed the response bias criterion in Condition 1, and computed Pearson correlations with EHQ score.

All analyses were controlled for age, gender, and BMI and were conducted on the overall population and independently in men and women.

Exploratory analyses

Exploratory analyses were conducted using EHQ subscales in addition to EHQ score to see if one or several subscales could reveal any effect when EHQ score did not show any significant effect.

In addition, the ability to discriminate (i.e., discriminability) was tested according to EHQ scores, using the discriminability index from signal detection theory. The discriminability index (A') ranges from 0 to 1. An index of .5 indicates responses at chance level, and 1 indicates maximum discriminability.

Study 3 – Results

Participants' Characteristics

Participants' characteristics, scores on the questionnaires, and response indices (proportion of foods classified as healthy and unhealthy and response bias indices) are available in Supplementary Materials 7a, 7b, 8a and 8b.

Results of confirmatory and exploratory analyses

Considering H6, according to which the proportion of food categorized as unhealthy is influenced by both energy density and ON score (in line with the results of Study 1), results revealed that only women in the French sample showed positive correlations between the proportion of processed high-calorie foods classified as unhealthy and EHQ score [$r(59) = 0.27$, $p = .034$].

In the Quebec sample, results showed positive correlations between the proportion of foods classified as unhealthy and EHQ score for processed low-calorie foods [$r(98) = 0.28$, $p = .005$] and for processed high-calorie foods [$r(98) = 0.23$, $p = .023$]. When analyzing the results by gender, correlations only remain significant for women.

Regarding H7, according to which subjects with high ON scores would exhibit a more liberal response bias when detecting unhealthy food than subjects with low ON scores, we did not find significant correlations between the response bias and EHQ score in the French sample. When exploring by gender and by EHQ subscales, women in the French sample showed a negative correlation between the response bias and the EHQ problems of attention, control and social relationships subscale score [$r(59) = -0.29$, $p = .021$].

In the Quebec sample, results showed negative correlations between the response bias and EHQ score when detecting unhealthy food [$r(98) = -0.28$, $p = .005$]. When considering results by gender, only women showed negative correlations between the response bias and EHQ score [$r(60) = -0.28$, $p = .027$].

Considering the discriminability index A', results revealed negative correlations in the Quebec sample between the A' and EHQ score among men only, when detecting healthy food [$r(33) = -.44$, $p = .008$].

Regarding H8, according to which subjects with high ON scores would exhibit a more conservative response bias when detecting healthy food than subjects with low ON scores, we did not find significant correlations between the response bias and EHQ score when detecting healthy food in the French sample [$r(148) = -0.004$, $p = .959$]. We also analysed by gender and EHQ subscales and did not find significant correlations.

In the Quebec sample, results revealed positive correlations between the response bias and EHQ score [$r(98) = 0.24$, $p = .014$]. When considering results by gender, only women showed positive correlations between the response bias and EHQ score [$r(60) = 0.26$, $p = .039$].

Considering the discriminability index A', results revealed negative correlations in the Quebec sample between the A' and EHQ score among men only, when detecting unhealthy food [$r(33) = 0.41$, $p = -.015$].

Study 3 – Discussion

Study 3 built upon the findings from Studies 1 and 2 and investigated subjects' food categorization strategies according to ON score. In the Quebec sample, we replicated Study 1 results that indicated that the proportion of foods classified as unhealthy was positively influenced by the ON score. In addition, in the Quebec sample we found that subjects with high ON scores exhibited a more liberal strategy (i.e., classifying more items) when detecting unhealthy food stimuli than subjects with low ON scores. Moreover, in the Quebec sample we found that subjects with high ON scores exhibited a more conservative strategy (i.e., classifying fewer items) when detecting healthy food stimuli than subjects with low ON scores. When we analysed the results by gender, we found significant correlation coefficients only for women. These results obtained in the Quebec sample are consistent with the gender effect observed in the French sample. This gender effect could explain the results from the Quebec sample, which contains more women than men. Overall, these findings suggested that some subjects with high ON scores exhibited a specific response strategy that prevent them from mistaking an unhealthy food for a healthy food that was not observed in subjects with low ON scores. In addition, in the Quebec sample, results of exploratory analyses revealed than men with high ON scores exhibited lower discriminability than subjects with low ON scores, when detecting both healthy food and unhealthy food.

Results obtained in the French sample also showed the gender effect observed in the Quebec sample. In addition, we found that subjects with higher ON scores were more liberal when detecting unhealthy stimuli only among women, and when considering the EHQ problems of attention, control and social relationships subscale, instead of the global ON score. However, contrary to the Quebec sample, we failed to confirm H8 (that subjects with high ON scores would exhibit a more conservative strategy when detecting healthy food stimuli than subjects with low ON scores) in the French sample. Results of discriminability index were also not replicated in the French sample.

Both the French and the Quebec samples differed in terms of gender ratio, EHQ global score, and response bias in Condition 2 (when detecting unhealthy food), and therefore, samples should be compared with caution.

General Discussion and Perspectives

These studies investigated for the first time ON subjects' food categorization performance and strategies.

Regarding food categorization performance, we found a significant difference between subjects with high and low ON scores with respect to response consistency: subjects with high ON scores were less consistent. We interpreted this pattern of response as a sign of a greater state of uncertainty in subjects with a high ON score. Considering the discriminability index, results revealed that subjects with high ON scores had lower performance than subjects with low ON scores, only among men in the Quebec sample. Also, we found no significant effect of ON scores on reaction times. Taken altogether, it is therefore difficult to draw firm conclusions about any association between ON scores and food categorization performance.

Regarding food categorization strategies, which is influenced by both perceived risk and uncertainty, we evidenced that ON influenced strategies. Our results revealed a broader unhealthy category (i.e., a larger set of category members), longer reaction times when categorizing food according to functional attributes (healthy/unhealthy and snack/side dish), and less response consistency in subjects with high ON scores compared to subjects with low ON scores. These results suggested that subjects with high ON scores are in greater state of *uncertainty* when asked to categorize food as healthy or unhealthy, and that they perceived higher *risk* of mistaking an unhealthy food for a healthy one than subjects with low ON scores.

These suggestions were confirmed by the investigation of the response bias as an index of participants' strategy: subjects with high ON scores showed a more liberal strategy when detecting unhealthy food than subjects with low ON scores, suggesting that they were more inclined to mistake a healthy food for an unhealthy food than to do the opposite. Reciprocally, subjects with high ON scores showed a more conservative strategy when detecting healthy food than subjects with low ON scores. To understand whether this response pattern is a matter of uncertainty or risk, it is worth noting that these results were found only among women, and that in women no correlation was found between ON scores and discriminability. Discriminability is influenced by uncertainty: in situations of perceived uncertainty (e.g., when silhouettes need to be detected in fog), the ability to detect is much poorer than in situations without uncertainty (e.g., when silhouettes need to be detected in clear visibility). Therefore, if it was a matter of uncertainty, we would observe correlations between ON scores and discriminability, which is not the case. Taking together our three studies led us to hypothesize a greater perception of risk in ON when choosing whether a food is healthy or unhealthy. Another way to put it is to say that our findings challenge the standard view of ON defined as the obsession with healthy food and healthy eating. Instead, we assume that ON could be more accurately characterized by the fear of unhealthy food. Our seminal experiments speak in favor of the later view of fear as an emotional response to risk (Crane et al., 2020).

This interpretation echoes recent research on a food-related disposition that seems to overlap with ON: food neophobia. Recent studies revealed that high levels of food neophobia in children were significantly associated with food categorization strategies (Foinant et al., 2021a). When children were asked to discriminate between edible and non-edible foods, probably because of the perceived risk, neophobic children compensated with very conservative strategies to avoid mistaking an inedible food for an edible one. Thus, the food categorization strategy has been associated with genuine food phobias in children. Applied to our population of interest, the risk for a subject with a high ON score is to mistake an unhealthy food for a healthy one, and that is what we observed when subjects were asked to categorize food as healthy and unhealthy. Although this remains debated, it has been reported that anorexia nervosa is associated with fear of food and fear of fat, leading medical staff to target anxiety-related therapies (Cardi et al., 2019). Considering the overlap between ON, anorexia nervosa, and food neophobia, we may legitimately wonder whether subjects suffering from ON are characterised by a fear of eating unhealthy foods. One might indeed wonder whether, along with the obsession with eating healthily, the fear of eating unhealthy food is not also a feature

of orthorexia nervosa. This hypothesis could be empirically tested in future studies focusing on the influence of emotions, particularly fear, in orthorexia nervosa. The identification of fear as a potential driving force behind the rigidity and obsession with healthy eating in orthorexia nervosa paves the way for deeper investigations into the emotional dimensions of this phenomenon. For further exploration, the use of a dimensional framework such as the Research Domain Criteria matrix (Cuthbert & Insel, 2013) would be of interest, especially because it enables us to explore the different sub-constructs of the negative valence system (e.g., acute, potential, and sustained threat) and the positive valence system (e.g., reward responsiveness and learning) (Cuthbert & Insel, 2013).

The implications of this research extend to early detection and intervention. By understanding the cognitive factors associated with orthorexic behaviors, clinicians and researchers can work towards developing more precise diagnostic tools and effective interventions that target both the cognitive and emotional aspects of orthorexia nervosa. As orthorexia nervosa has been shown to be a risk factor for developing eating disorders (Dell'Osso et al., 2016a), future research could lead to earlier detection and may prevent the development of severe eating disorders.

Moreover, while the literature on gender differences in ON remains inconclusive (Donini et al., 2022), our results suggested a gender effect on the interaction between categorization strategies and ON. Indeed, the interaction seems to be more pronounced in women. Given the well-established gender bias in anorexia nervosa (van Eeden et al., 2021) and that ON is a possible risk factor for anorexia nervosa (Dell'Osso et al., 2016a), it is worth considering in future research whether a greater vulnerability to food-related risk in women with ON tendencies could trigger anorexia nervosa. Further research is needed to fully understand the gender dynamics of ON.

The insights gained from these studies provide a foundation for continued exploration into the complexities of orthorexia nervosa, offering a comprehensive perspective that integrates cognitive processes, emotional factors, and the potential for early identification and intervention. In addition, further investigation on the gender dynamics is needed for a deeper and better understanding of orthorexia nervosa.

Limitations

In the three studies, the French and the Quebec samples differed in demographic variables as well as in dependant variable means, therefore these two samples could not be compared.

Significant effects in Studies 1 and 3 were mainly seen in Quebec samples, whereas significant effects in Study 2 were seen in the French sample, therefore one may wonder which variables were implicated in this difference of results between samples. One possible variable could be the gender: the samples differed in their gender ratio in all three studies, with much more women in the Quebec samples. Significant effects were seen in French samples when considering only women. Moreover, the findings seemed to suggest that there is a gender effect on the interaction between categorization strategies and ON, something that we had not anticipated and therefore we had small sample sizes for each gender. In further research, a potentially rewarding strategy would be to increase the sample sizes in each gender category.

In addition, while the EHQ has good psychometric properties and is widely used to investigate orthorexia nervosa, some authors have identified limitations in the scale's ability to capture certain aspects of the disorder, such as negative emotions and compulsive behavior (Koven & Abry, 2015). As such, additional tools are needed to fully investigate this phenomenon; future studies could even consider adding a clinical diagnosis to the methodology.

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Part C – General Discussion and Perspectives

Chapter 9. General Discussion

9.1. Research findings

This thesis explores how the willing to control one's food intake could result in a loss of control. We identified factors involved in this paradox of control, using two case studies: anorexia nervosa, which is the oldest, most prominent, and extensively researched model; and orthorexia nervosa, an emerging phenomenon that blurs the line between the desire for control and the loss of control over food intake hyperselectivity.

A first type of factor that we found, involved in the paradox of control, is the individual's environment, which can be associated with higher risk of development of eating disorders and orthorexia nervosa. Indeed, results of Chapter 5 revealed that culinary arts students exhibited more eating disorders and orthorexia nervosa at-risk behaviors compared to their counterparts in dietetics and nutrition and compared to the general population of students. It appears that this environment, which is closely linked to food, was more susceptible to welcome subjects suffering from eating disorders and orthorexia nervosa. While our cross-sectional study rules out any causal interpretation of the data, the difference prompts inquiries into potential causes. While there are numerous possible factors and causes, we chose to discuss one as particularly relevant in the context of this thesis. Environmental factors within the culinary arts and gastronomy field may contribute to the development of eating disorders and ON tendencies. For instance, the curriculum in culinary arts and gastronomy includes internships with direct applications in restaurants. This industry is known for its very high demands and its stressful environment. Research has consistently identified such stressors as potential risk factors for the onset of eating disorders (Lin et al., 2023). In contrast, the nutrition and dietetics field may offer a comparatively less stressful educational and professional environment, which could account for the disparities observed in our results. Longitudinal study is needed to test this hypothesis. Such investigations could shed light on the interplay of individual predispositions, environmental stressors, and academic choices in the development of eating disorders and ON tendencies among students in these distinct academic domains.

A second type of factor involved in the paradox of control is the relationship to the body underlying food categorization. Indeed, the results of the second study (Chapter 6) indicated that individuals with anorexia nervosa had a stronger association between body stimuli and food stimuli compared to control subjects. Individuals with anorexia nervosa (AN) have a constant preoccupation with their body image, which is disturbed with over-evaluation of weight and height (American Psychiatric Association, 2013a), leading to higher body dissatisfaction (Hagman et al., 2015). This body dissatisfaction is a known risk factor for the onset of eating disorders (Stice et al., 2011). Our study has shown an association between food and body stimuli in AN, raising the question of whether disturbances in body image affect food perception in AN, or vice-versa. These results pave the way for future studies investigating the functional and causal relationship between body and food perception in AN. Furthermore, if this factor is indeed underlying food choices in the paradox of control, these results should be found also in subjects with high tendencies of orthorexia nervosa. Indeed, even if ON tendencies was not correlated with body dissatisfaction (Donini et al., 2022), it was correlated with drive for thinness and the desire for a healthy body (Atchison & Zickgraf, 2022). Therefore, our results also pave the way for studies on food-body relationships in orthorexia nervosa. One first step will be to duplicate the study design we used to compare a population with high orthorexia nervosa score or clinically diagnosed orthorexia nervosa to a control population.

A third type of factor implicated in the paradox of control is a high perception of risk when making food choices. Both Chapter 6 and 8 studies found that individuals with anorexia nervosa and high traits of orthorexia nervosa used specific food categorization strategies, which suggested a higher perception of risk when making food choices within these populations compared to control populations. The specific food categorization strategies in high ON tendencies were found in two populations from different cultures, demonstrating the robustness of the effect found. Therefore, the results suggest that this heightened perception of risk towards food is an essential factor of the paradox of control. Further research is needed to explore this hypothesis, including studying if this perception of risk is present in individuals with other forms of paradoxical control over their food intake, such as ARFID or atypical AN, and if different levels of severity should be considered.

Interestingly, this heightened perception of risk focuses on the risk of not achieving the set goal (i.e. losing weight in anorexia nervosa, eating healthily, or having a healthy body in orthorexia nervosa), to the detriment of the risk of malnutrition or physical or mental problems caused by these disorders. Indeed, in AN it is frequent to observe an ever-increasing desire to lose weight,

despite an already very low weight. In such case, the risk of harm to the body, or even death, is therefore very much minimized. It has also been pointed out in orthorexia nervosa that individuals are not always aware of the negative impacts of their eating behaviours, with poor insight into illness (Donini et al., 2022). The perception of risk is therefore not the same depending on what it relates to. Therefore, it would be interesting to better understand the impairments and distress specifically related to each type of perceived risk (e.g. food and body perception), to ultimately develop new prevention or therapeutic targets.

9.2. Research perspectives and implications of the results

Overall, this thesis provides a better understanding of the categorization processes involved in anorexia and orthorexia nervosa, and provides several types of factors of the paradox of control: the individual's environment, the underlying relationship to the body in food choice, and the heightened perception of risk in food choice. Our work suggests avenues for future research.

It is important to consider whether the tasks used in the study were sensitive enough to identify differences between individuals with anorexia nervosa and those without, as well as those with orthorexia nervosa traits in the general population. Regarding the tasks performed in patients with anorexia nervosa, while the Go/No-Go Association Task testing the connection between food and moral traits did not show any differences between the groups, the Go/No-Go Association Task testing the connection between food and body stimuli did show differences with a moderate effect size. This suggests that the latter task was sensitive enough to detect differences between the two groups, and the discrepancies between the two tasks were due to the concepts tested rather than the nature of the task itself. The food categorization tasks related to orthorexia nervosa in Chapter 8 did not have a significant effect on all variables measured, but for the variables that were significantly correlated with the orthorexia nervosa score (consistency, proportion of food items classified as unhealthy, reaction times when changing instructions, and response bias), there were moderate effect sizes. This could indicate that the tasks were sufficiently sensitive to capture orthorexia nervosa traits. Based on the results obtained, we can therefore envisage various clinical applications for this method, which could rapidly enable practitioners to detect risk factors in sub-clinical populations or prevent relapse in patients with anorexia nervosa.

In addition, in several studies, we have realized that we underestimated the impact of gender. In the study comparing dietetics students and culinary arts students (Chapter 5), women in

culinary arts exhibited higher prevalence of eating disorders and orthorexia nervosa tendencies than men. This suggested that studying the gender issue in the culinary arts field is crucial. Additionally, we also underestimated the effect of gender in the study of orthorexia nervosa (Chapter 8). Although previous literature has established a clear correlation between sex and gender and eating disorders, studies on orthorexia nervosa have not reached a consensus on the impact of gender (Donini et al., 2022). Therefore, we were not expecting this variable to have as much effect. However, it is important to consider that our results consistently showed symptoms in women, in both the French and Quebec populations. Therefore, further investigation into the relationship between gender and orthorexia nervosa is necessary.

Finally, in this thesis, the questionnaire used to detect orthorexia nervosa tendencies was found to be moderately to highly correlated with eating disorder scales, in line with existing literature. However, this makes it difficult to determine whether variables correlated with orthorexia scores are actually related to eating disorders rather than orthorexia nervosa. This is made all the more difficult by the fact that orthorexia nervosa is not considered to be an eating disorder or a separate entity, which is supported by research showing that it can coexist with other eating disorders, serve as a risk factor for their development, or be a transitional stage in recovery from them (Costanzo et al., 2022; Dell'Osso et al., 2016b). Nevertheless, a 49-author consortium has advocated for orthorexia nervosa to be recognized as a distinct eating disorder in its own, separate from other eating disorders due to the absence of preoccupation with body weight, and shape (Donini et al., 2022). Understanding whether or not orthorexia nervosa is a distinct eating disorders would help to develop diagnostic or detection tools. The definition of orthorexia nervosa built by the consortium of authors is indeed useful if we consider a categorical approach, but research suggests that considering specific traits in a dimensional approach can be more useful in detection and identifying risk factors. Research suggests that a dimensional approach may be more effective in detecting and identifying risk factors associated with eating disorders (Wildes & Marcus, 2015). It may be beneficial to apply this approach to orthorexia nervosa as well, in order to better identify and address eating disorders.

Indeed, in our research we considered anorexia nervosa as an eating disorder through its DSM-5 definition. Yet, the categorical approach (the one used in DSM-5 classification) has been questioned for more than a decade now (Cuthbert, 2014; Insel et al., 2010). While this approach has been reliable in diagnosing based on signs and symptoms, it may not accurately represent valid pathological entities. The National Institute of Mental Health advocated for a more holistic approach that incorporates genetics, neuroimaging, and cognitive science into diagnostic schemes. The Research Domain Criteria (RDoC) was created to encourage research into psychopathologies that validate neurobiological dimensions and behavioral measures (Insel et al., 2010). The RDoC matrix aims to identify biological and cognitive factors associated with observable behavioral dimensions (organized into 6 domains such as Positive Valence Systems, Negative Valence System, Cognitive Systems or Social Processes). Moreover, the dimensions are studied along a continuum from normal to pathological and using subjective and objective measurements. It is believed that a dimensional approach to eating disorders would enable to identify varying degrees of severity and provide more accurate diagnoses that address individual variability observed clinically (Wildes & Marcus, 2015). This approach would allow each patient to receive treatment tailored to their specific needs. In line with this dimensional approach, our findings on heightened risk perception in relation to food could lead to the consideration of studying orthorexia nervosa and anorexia nervosa through a dimensional prism. A particularly relevant domain would be the Negative Valence System, and future studies would benefit from focusing on the different constructs of this domain, such as acute, potential, and lasting risk perception. These constructs of the negative valence system, and in particular their degree of severity, could also help to better target necessary interventions. Indeed, a greater perception of risk has been shown to lead to emotional responses of fear and anxiety in individuals, which are typical targets in cognitive-behavioural therapies. Thus, cognitive-behavioural intervention could help the patient better assess risk and eliminate distortions in this perception of risk over food (and / or over body perception). It would then be necessary to evaluate the effectiveness of these therapies, particularly in the case of orthorexia nervosa tendencies, which has never been done to date.

Moreover, our results invite us to take a critical step back from the various public health initiatives aimed at promoting healthy eating among the general population. Over the past decades, the implementation of nutritional guidelines and rating systems on food products has increased considerably, as illustrated by initiatives such as the Nutri-score in France. The primary goal behind these efforts was to reduce uncertainty in food choices by providing

consumers with clearer information to make healthier food choices. However, this increased emphasis on nutritional information can also increase the perceived risk of consuming foods deemed unhealthy foods or high in calories. This raises concerns regarding the potential for nutritional advice to contribute to the development of eating disorders and to the paradoxical control over one's food intake. This concern is particularly relevant for populations already at elevated risk, such as culinary arts students. To gain a comprehensive understanding of this issue, future studies should delve into the precise impact of nutritional guidance within at-risk populations, shedding light on potential interventions and strategies for promoting healthier relationships to food.

Finally, this work also opens up new perspectives on the study of certain populations that are exposed to strong constraints on their diet and have shown a greater prevalence of orthorexia nervosa tendencies and eating disorders. This is particularly true of the population living with type 1 diabetes (T1DM) who, due to the need for frequent monitoring of blood glucose concentrations before and after each meal and the required adherence to a healthy diet in T1DM, often report feeling excessively preoccupied with their diet (Rodin et al., 2002; Young-Hyman & Davis, 2010). These concerns can become overwhelming and lead to orthorexia nervosa or eating disorders (Grammatikopoulou et al., 2021; Rodin et al., 2002). However, data and studies remain limited in the context of T1DM, and the mechanisms that may explain these associations are not clearly established (Grammatikopoulou et al., 2021). In these populations with strict dietary constraints and where consuming certain foods can put the individual at risk, it would be valuable to explore the perception of risk, particularly to see whether this perception is very high towards foods and related to the presence of eating disorders symptoms and orthorexia nervosa tendencies. It would also be valuable to explore whether this perception of risk is heightened only in foods that present a risk associated with the pathology, or whether it has spread to all foods, and with what degree of intensity. In fact, we have been working on the implementation of such a study, which is currently under recruitment in Quebec. This study, and others to come, will serve as the basis for continuing my scientific involvement in this field through a post-doctoral internship in Québec beginning in January 2024.

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LIST OF APPENDICES

Appendix 1: Chapter 5 - Supplementary Materials

Chapter 5 - Supplementary Materials 1

SM Table 1. Comparison of EHQ subscale means between culinary arts students and the general population (Godefroy et al., 2021) in women and in men

Women		Culinary arts (N=51)		General population (N=416)		t	p
		Mean	SD	Mean	SD		
	EHQ Global score	36.0	8.45	30.9	8.33	4.12	<.001***
	EHQ REB	8.10	2.69	8.04	3.50	0.21	.609
	EHQ PFC	17.8	3.67	15.9	3.75	1.98	.120
	EHQ PACSR	10.1	3.40	6.96	2.37	6.22	.005**
Men		Culinary arts (n = 92)		General population (n = 1645)			
		Mean	SD	Mean	SD		
	EHQ Global score	31.2	6.88	33.5	7.87	-2.75	.006**
	EHQ REB	7.22	2.41	8.97	3.80	-4.37	<.001***
	EHQ PFC	16.3	3.84	16.7	3.76	-0.99	.321
	EHQ PACSR	7.72	2.59	7.84	3.03	-0.37	.710

Note. SD = standard deviation; EHQ = Eating Habit Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problem of Attention, Control and Social Relationship; t = statistic test for Student's test; p = p-value adjusted with the Bonferroni correction. * <.05, ** <.01, ***<.001

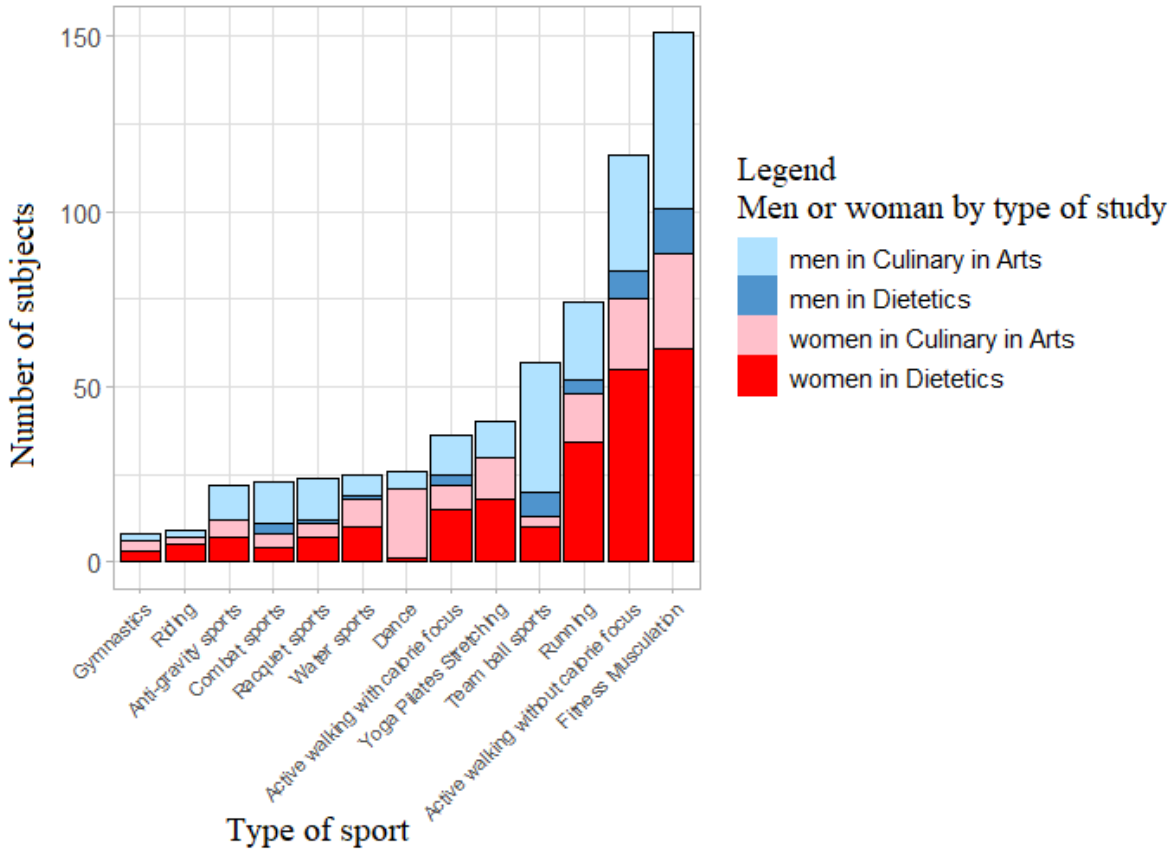
Chapter 5 - Supplementary Material 2

SM Table 2. Comparison of mean scores of scales between culinary arts students and dietetics students, women and men

Women		Culinary Arts (n = 51)		Dietetics (n = 106)		U	p
		Mean	SD	Mean	SD		
	EDEQ Global score	3.04	1.59	1.90	1.41	3842	<.001***
	EDEQ subscales:						
	EDEQ Restraint	2.31	1.71	0.96	1.24	4100	<.001***
	EDEQ Eating concern	2.15	1.48	1.28	1.29	3723	<.001***
	EDEQ Weight concern	3.92	1.87	2.59	1.77	3787	<.001***
	EDEQ Shape Concern	3.78	1.91	2.76	1.87	3592	.002**
	EDEQ13 Excessive meals	4.08	5.05	3.47	6.92	3013	.452
	EDEQ14 Loss of control	8.12	8.74	4.21	7.70	3630	<.001***
	EDEQ15 Binge eating days	4.43	5.84	3.24	6.19	3314	.028*
	EDEQ16 Self-induced vomiting	1.49	3.75	0.76	5.97	3434	<.001***
	EDEQ17 Laxative misuse	0.59	2.57	0.29	2.91	2864	.142
	EDEQ18 Excessive exercise	5.71	7.22	2.83	5.44	3349	.017*
	EHQ Global score	36.0	8.45	30.9	8.33	3310	.046*
	EHQ subscales						
	EHQ REB	8.10	2.69	8.04	3.50	3042	.392
	EHQ PFC	17.8	3.67	15.9	3.75	3091	.290
	EHQ PACSR	10.10	3.40	6.96	2.37	3640	<.001***
	EDI BD	11.49	7.27	7.83	6.93	3514	.005**
Men		Culinary arts (n = 92)		Dietetics (n = 15)			
		Mean	SD	Mean	SD		
	EDEQ Global score	1.50	1.15	1.20	0.71	762	.524
	EDEQ subscales:						
	EDEQ Restraint	0.97	1.24	0.69	0.76	741	.647
	EDEQ Eating concern	0.92	1.01	0.76	0.54	690	.999
	EDEQ Weight concern	1.92	1.39	1.48	0.96	806	.298
	EDEQ Shape Concern	2.20	1.58	1.87	1.27	750	.593
	EDEQ13 Excessive meals	9.16	11.06	6.67	9.96	848	.308
	EDEQ14 Loss of control	3.27	5.44	4.47	9.13	702	.913
	EDEQ15 Binge eating days	2.93	5.45	3.27	7.40	723	.739
	EDEQ16 Self-induced vomiting	0.90	3.30	0	0	758	.424
	EDEQ17 Laxative misuse	0.39	1.86	0	0	728	.728
	EDEQ18 Excessive exercise	5.33	7.59	2.73	6.26	892	.103
	EHQ Global score	31.2	6.88	33.5	5.69	540	.358
	EHQ subscales:						
	EHQ REB	7.22	2.41	7.13	1.88	663	.808
	EHQ PFC	16.3	3.84	18.3	2.52	494	.157
	EHQ PACSR	7.72	2.59	8.07	2.37	608	.922
	EDI BD	6.03	6.13	5.2	4.6	712	.842

Note. M = mean; SD = standard deviation; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problem of Attention, Control and Social Relationship; EDEQ = Eating Disorder Examination Questionnaire; EDI BD: Eating Disorder Inventory Body Dissatisfaction subscale; U = statistic test value for U-Mann-Whitney test; p = p-value adjusted with the Bonferroni correction. * <.05, ** <.01, ***<.001

Chapter 5 - Supplementary Materials 3



SM Figure. Number of subjects in each type of sports according to the type of study and gender.

SM Table 3. Number of sports practice according to the type of study and gender.

	Culinary Arts				Dietetics			
	Women		Men		Women		Men	
	M	SD	M	SD	M	SD	M	SD
Number of sports played	2.86	2.43	2.74	2.41	2.96	1.77	3.13	1.64
Total hours of physical activity per week	11.08	20.85	6.86	8.39	6.53	5.68	9.17	5.88
Number of hours of physical activity per week, excluding hours of walking	3.84	4.10	4.54	5.27	3.48	3.54	6.53	3.62
Number of hours of walking	7.25	19.84	2.32	4.80	3.05	3.62	2.63	3.71

Note. M = Mean; SD = Standard Deviation.

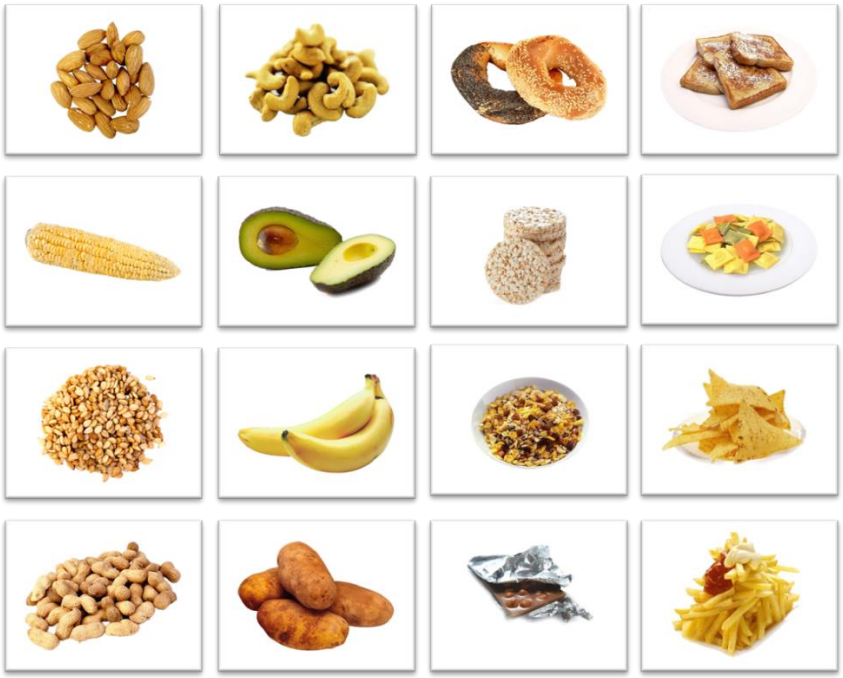
Appendix 2: Chapter 6 - Supplementary Materials

Chapter 6 – Stimuli Sets

Food stimuli from Food-pics database (Blechert et al., 2014):

Low-calorie foods

High-calorie foods :



Properties of food stimuli in Chapter 6 from the database of Blechert and colleagues (2014)

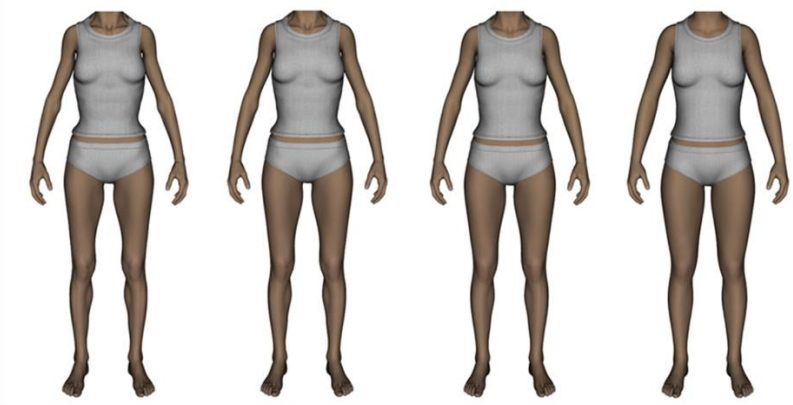
Ref. FoodPics	Item description	Calorie-content group*	Degree of Transformation	Kcal per 100g	Kcal total per image
192	apple	Low-calorie	Natural	52	78
254	kiwi	Low-calorie	Natural	53	26,5
261	soybean sprouts	Low-calorie	Natural	52	41,6
281	grapes	Low-calorie	Natural	71	71
398	cherries	Low-calorie	Natural	63	50,4
402	pear	Low-calorie	Natural	52	78
263	mushrooms (brown)	Low-calorie	Natural	12	14,16
274	spinach	Low-calorie	Natural	17	17
229	salad plate	Low-calorie	Transformed	24,6	31,98
303	cauliflower	Low-calorie	Transformed	23	11,5
362	beans and carrots, cooked	Low-calorie	Transformed	25	30
369	sushi roll with cucumber	Low-calorie	Transformed	100	40
447	mixed vegetables	Low-calorie	Transformed	56,62	73,606
502	mixed vegetables, cooked	Low-calorie	Transformed	44,3	15,505
558	asparagus with bechamel sauce	Low-calorie	Transformed	20,5	114,8
567	tomato and mozzarella	Low-calorie	Transformed	86,7	104,04
110	Nuts (cashews)	High-calorie	Natural	621	310,5
283	avocado	High-calorie	Natural	217	542,5
341	banana	High-calorie	Natural	95	376,2
346	potatoes	High-calorie	Natural	71	426
410	peanuts	High-calorie	Natural	561	1683
457	sesame seeds	High-calorie	Natural	559	335,4
459	corn / maize	High-calorie	Natural	211,2	528
539	almonds	High-calorie	Natural	598	478,4
022	french fries	High-calorie	Transformed	295	649
104	tortilla chips	High-calorie	Transformed	478	119,5
112	opened bar of chocolate with nuts	High-calorie	Transformed	555	555

181	bowl of muesli (granola)	High-calorie	Transformed	343	857,5
244	rice waffles	High-calorie	Transformed	380	253,46
366	bagels with sesame and poppy seed	High-calorie	Transformed	276,1	496,98
378	ravioli	High-calorie	Transformed	189	945
471	French Toast	High-calorie	Transformed	235	958,8

Note. * group assigned by the authors.

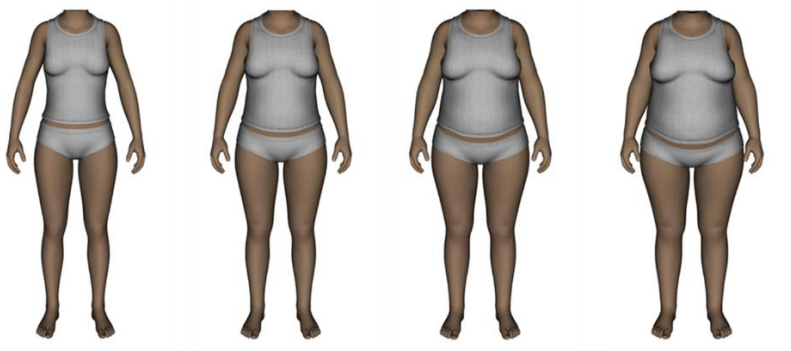
Body stimuli from the database of Moussally et al. (2017)

Body stimuli perceived as underweight



Identification name UW15 UW16 UW17 UW19

Body stimuli perceived as overweight



Identification name OW21 OW27 OW31 OW36

Chapter 6 – List of body stimuli from the database of Moussally and colleagues (2017).

Identification name	Stimulus BMI	BMI range	WHO Categories	Subscale set
UW15	15.67	15 – 15.99	Severe underweight	Underweight
UW16	16.64	16 – 16.99	Moderate underweight	Underweight
UW17	17.56	17 – 18.5	Mild underweight	Underweight
UW19	19.61	18.5 – 24.9	Normal	Underweight
OW21	21.55	18.5 – 24.9	Normal	Overweight
OW27	27.37	25 – 29.9	Overweight	Overweight
OW31	31.84	30 – 34.99	Moderate obesity	Overweight
OW36	36.58	35 – 39.99	Severe obesity	Overweight

Note. WHO: World Wide Organization; BMI: Body Mass Index.

Chapter 6 - Supplementary Materials Table 1

SM Table 1 List of body stimuli from the database of Moussally and colleagues (2017).

Identification name	Stimulus BMI	BMI range	WHO Categories	Subscale set
UW15	15.67	15 – 15.99	Severe underweight	Underweight
UW16	16.64	16 – 16.99	Moderate underweight	Underweight
UW17	17.56	17 – 18.5	Mild underweight	Underweight
UW19	19.61	18.5 – 24.9	Normal	Underweight
OW21	21.55	18.5 – 24.9	Normal	Overweight
OW27	27.37	25 – 29.9	Overweight	Overweight
OW31	31.84	30 – 34.99	Moderate obesity	Overweight
OW36	36.58	35 – 39.99	Severe obesity	Overweight

Note. WHO: World Wide Organization; BMI: Body Mass Index.

Chapter 6 - Supplementary Materials Table 2

SM Table 2 Summary of the design for the Go/No-Go Association Task (GNAT) blocks.

N° of Block	Type of block	Task	Target categories	Number of trials
	Practice	Single task	Low-caloric food	8
	Practice	Single task	Underweight silhouettes	8
	Practice	Single task	High-caloric food	8
	Practice	Single task	Overweight silhouettes	8
	Practice	Combined task	Low-caloric food + Underweight silhouettes	16
1	Critical	Critical combined task	Low-caloric food + Underweight silhouettes	128
	Practice	Combined task	High-caloric food + Overweight silhouettes	16
2	Critical	Critical combined task	High-caloric food + Overweight silhouettes	128
	Practice	Combined task	Low-caloric food + Overweight silhouettes	16
3	Critical	Critical combined task	Low-caloric food + Overweight silhouettes	128
	Practice	Combined task	High-caloric food + Underweight silhouettes	16
4	Critical	Critical combined task	High-caloric food + Underweight silhouettes	128

Note. Practice blocks were presented in a randomly assigned order between participants. Then, combined blocks were presented also in a randomly assigned order between participants. Only results of critical blocks were analyzed and presented in the results section. The number of the blocks in the present paper refers to the first column (N° of the blocks).

Chapter 6 - Supplementary Materials Table 3

SM Table 3 Participants' characteristics (N=55) by group and comparison of scores between groups.

Sample characteristics		AN group		HC group		*t*	*p*
		M	SD	M	SD		
Whole sample	Age	25.1	5.92	23.6	2.69	1.18	.244
	BMI	16.5	1.46	21.6	2.52	-9.23	< .001***
	Satiety level	1.59	1.08	2.22	1.53	-1.75	.087
1st recruitment (June 2019)	Age	23.1	4.65	23.1	2.80	-0.05	0.962
	BMI	16.7	1.52	22.0	2.66	-6.70	< .001***
	EDI-II-24	65.08	16.50	39.43	11.77	4.62	< .001***
	ORTO-15	29.62	6.14	37.79	5.28	-3.69	.001***
2nd recruitment (December 2022)	Age	27.6	6.56	24.2	2.55	1.68	.228
	BMI	16.1	1.37	21.2	2.36	-6.38	< .001***
	SCOFF	3.50	1.78	1.88	1.45	2.58	.018*
	EDE-Q	4.04	2.00	2.58	1.56	2.39	.025*
	EHQ	50.3	7.58	35.3	9.66	4.61	<.001***

Note. M = mean; SD = standard deviation; BMI, Body mass index; EDI-II, Eating Disorder Inventory – 24 items; t, test statistic for the comparison test of each variable between the two groups; p, pvalue of each test. * <.05, ** <.01, ***<.001

Chapter 6 - Supplementary Materials Table 4

SM Table 4 Mean and standard deviation of reaction times (ms) and discriminability indices by group and condition, with comparison between conditions.

	Condition				*U or t*	*p*
	Congruent		Incongruent			
	M	SD	M	SD		
Discriminability	0.90	0.03	0.88	0.04	*542*	*.014***
RT (ms)	538.49	49.21	564.63	50.66	*-2.74*	*.004***
For AN group only	(N = 28)					
Discriminability	0.914	0.02	0.894	0.03	*542*	*.014***
RT (ms)	555.65	44.53	586.21	45.00	*-2.55*	*.013***
For HC group only	(N = 27)					
Discriminability	0.895	0.04	0.888	0.03	*449*	*.146*
RT (ms)	520.70	48.22	542.25	46.97	*-1.66*	*.102*

Note. M = mean; SD = standard deviation; U, test statistic for the Mann-Withney test of discriminability index between conditions; t, test statistic for the Student's test of mean RT between conditions; p, pvalue of each test. ns = nonsignificant at $\alpha = .05$; * $p < .05$; ** $p < .01$.

Chapter 6 - Supplementary Materials Table 5

SM Table 5 Percentages of responses by group, block and type of responses

Type of responses		Hit		False Alarm		Correct Rejection		Miss		A’		β’’	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Congruent blocks													
	Block 1												
AN		22.67%	6.50	2.04%	2.35	29.96%	2.35	9.34%	6.50	0.900	0.03	0.564	0.30
HC		26.74%	4.28	5.78%	4.68	26.22%	4.68	5.26%	4.28	0.896	0.04	-0.838	0.36
	Block 2												
AN		26.91%	4.03	3.41%	3.94	28.57%	3.94	5.09%	4.03	0.927	0.02	0.195	0.53
HC		23.13%	5.42	1.96%	2.11	30.04%	2.11	8.87%	5.42	0.906	0.04	0.538	0.35
Incongruent blocks													
	Block 3												
AN		26.30%	6.65	4.54%	4.74	28.61%	6.58	6.84%	4.25	0.900	0.04	0.239	0.47
HC		25.78%	5.06	5.85%	6.17	26.15%	6.17	6.22%	5.06	0.880	0.08	0.031	0.25
	Block 4												
AN		22.00%	9.20	3.05%	4.49	30.09%	7.34	11.07%	7.09	0.864	0.11	0.454	0.33
HC		22.50%	5.48	2.61%	2.39	29.39%	2.39	9.50%	5.48	0.892	0.03	0.466	0.37

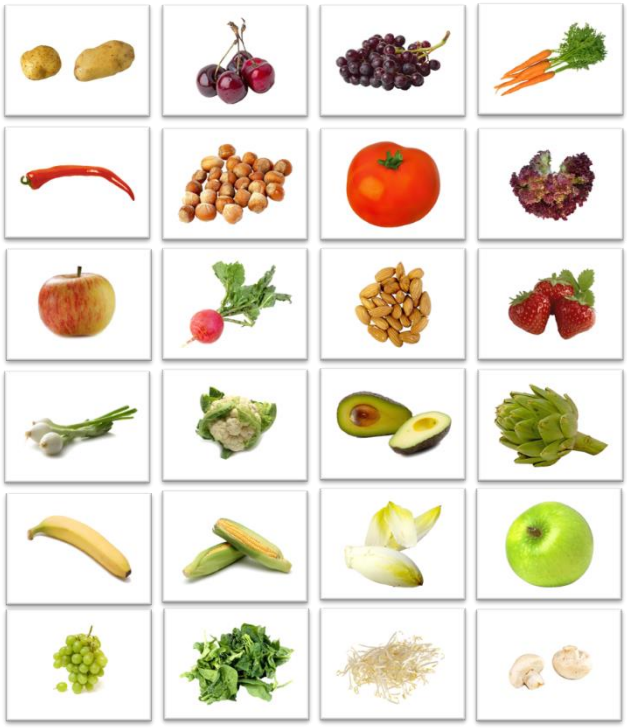
Note. M = mean; SD = standard deviation; AN group = 28 patients suffering from Anorexia Nervosa; HC group = 27 control subjects; A’ = discriminability index; β’’ = decision criterion

Appendix 3: Chapter 7 - Supplementary Materials

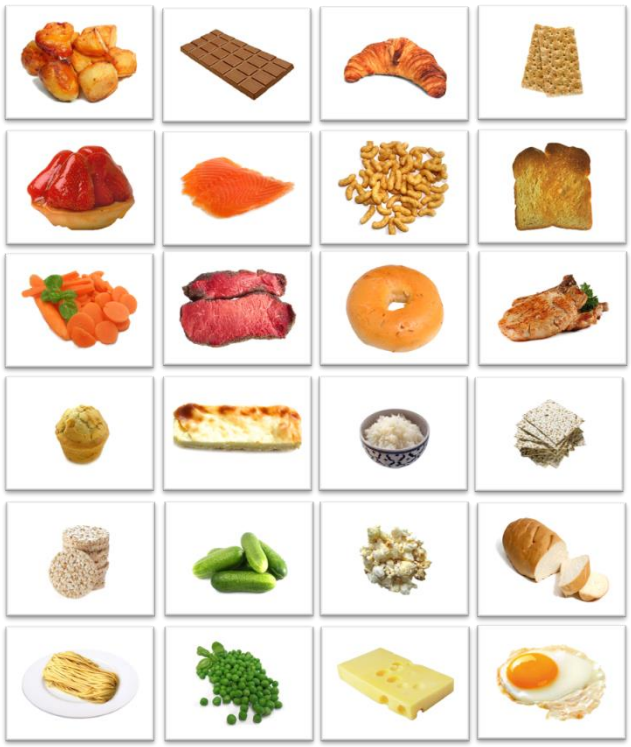
Chapter 7 – Stimuli Sets

Chapter 7 Study 1 Food stimuli from the database of Blechert and colleagues (2014)

Food stimuli perceived as Natural



Food stimuli perceived as Processed



Properties of food stimuli in Chapter 7 – Study 1 from the database of Blechert and colleagues (2014)

Ref. FoodPics	Name	Kcal per 100g	Kcal total	Red	Green	Degree of Transformation
449	garden radish	15	4.5	0.40848	0.37694	Natural
460	tomato	17	13.6	0.75434	0.20539	Natural
257	lettuce (lollo rosso)	21	63	0.51129	0.25054	Natural
334	carrots	26	104	0.44464	0.42032	Natural
234	strawberries	31	9.3	0.59543	0.24827	Natural
401	red chili	40	4	0.65761	0.21229	Natural
192	apple	52	78	0.52422	0.31193	Natural
398	cherries	63	50.4	0.51320	0.21970	Natural
397	grapes, red	71	142	0.46819	0.24860	Natural
412	potatoes	71	142	0.47822	0.36872	Natural
539	almonds	598	478.4	0.53929	0.33371	Natural
450	hazelnuts	636	1157.5	0.53172	0.30414	Natural
264	mushrooms (white)	12	4.00	0.37022	0.33793	Natural

249	cauliflower	14	266	0.38006	0.40304	Natural
368	chiccory	15	105	0.38336	0.37402	Natural
455	spinach	17	13.6	0.33142	0.48762	Natural
360	artichoke	22	55	0.44306	0.45971	Natural
266	green onion (shallot)	42	44.1	0.36552	0.39099	Natural
466	green apple	52	114.4	0.39647	0.46946	Natural
261	soybean sprouts	52	41.6	0.37507	0.34690	Natural
282	banana	64	128	0.42835	0.36503	Natural
270	corn (on a cob)	67	388.6	0.39555	0.39551	Natural
281	grapes	71	71	0.42432	0.45206	Natural
283	avocado	217	542.5	0.46381	0.40153	Natural
253	pickles	16	36	0.35905	0.47814	Transformed
424	peas cooked	84	109.2	0.31149	0.50497	Transformed
385	tagliatelle	170	425	0.38425	0.34370	Transformed
560	fried egg	195	117	0.42245	0.34632	Transformed
300	loaf of bread	253	1265	0.44973	0.33740	Transformed
146	cheese cake	255	255	0.43560	0.34599	Transformed
182	bowl of rice	349	349	0.35472	0.32387	Transformed
226	crisp bread	350	700	0.37964	0.34406	Transformed
244	rice waffles	380	253.5	0.38688	0.33531	Transformed
515	Emmentaler cheese	383	766	0.40726	0.37653	Transformed
14	muffin	404	359.6	0.48600	0.36589	Transformed
294	popcorn	424	21.2	0.39837	0.35271	Transformed
361	carrots, cooked	26	39	0.57997	0.30674	Transformed
353	strawberry tartlet	104	111.3	0.66040	0.21426	Transformed
540	beefsteak, raw	111	333	0.55984	0.21914	Transformed
306	roast potatoes	117	269.1	0.57530	0.30807	Transformed
562	cutlet	133	399	0.52524	0.31806	Transformed
329	salmon	193	96.5	0.62898	0.26315	Transformed
549	bagel	233	186.4	0.52594	0.33257	Transformed
187	croissant	333	233.1	0.55322	0.28491	Transformed
348	rusk	365	36.5	0.52290	0.35202	Transformed
193	crisp bread	372	96.7	0.46632	0.35054	Transformed
152	peanut puffs	500	100	0.50156	0.34384	Transformed
286	bar of chocolate	530	530	0.51583	0.31211	Transformed

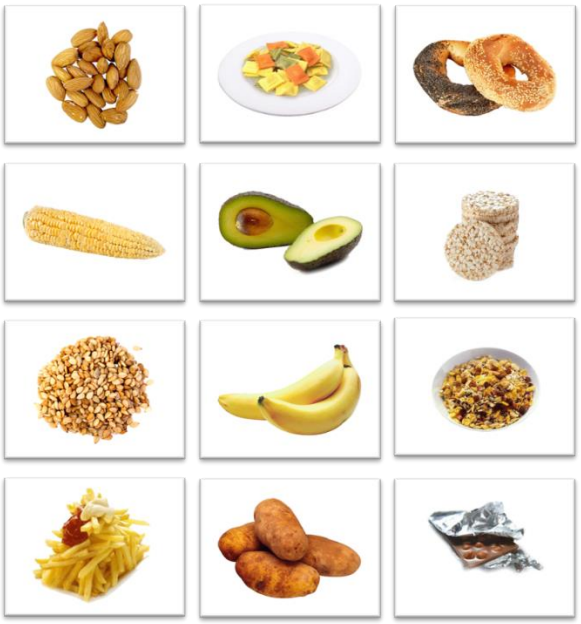
Chapter 7 - List of word stimuli from the word bank of Graham and colleagues (2009).

Pure (12 words)		**Impure (12 words)**	
English	**French**	**English**	**French**
Clean	Propre	Lax	Laxiste
Innocent	Innocent	Sick	Malade
Pristine	Intact	Defile	Souillé
Wholesome	Sain	Gross	Dégoutant
Abstemious	Sobre	Wanton	Dévergondé
Saint	Saint	Contagious	Contagieux
Virgin	Vierge	Sinful	Honteux
Sterile	Stérile	Sins	Fautes
Refined	Epuré	Repulse	Répugné
Pure	Pur	Debase	Dégradé
Limpid	Limpide	Sinful	Coupable
Virtuous	Vertueux	Indecent	Indécent

Chapter 7 Study 2 Food stimuli from the database of Blechert and colleagues (2014)

Low-calorie foods

High-calorie foods



Properties of food stimuli in Chapter 7 – Study 2 from the database of Blechert and colleagues (2014)

Ref. FoodPics	Name	Kcal per 100g	Kcal total	Group Calorie content*	Degree of Transformation
274	spinach	17	17	Low-caloric	Natural
402	pear	52	78	Low-caloric	Natural
263	mushrooms	12	14.16	Low-caloric	Natural
280	cherries	63	37.8	Low-caloric	Natural
194	kiwi	53	26.5	Low-caloric	Natural
281	grapes	71	71	Low-caloric	Natural
369	sushi roll	100	40	Low-caloric	Transformed
558	asparagus cooked	20.5	114.8	Low-caloric	Transformed
567	tomato and mozzarella	86.7	104.04	Low-caloric	Transformed
362	beans cooked	25	30	Low-caloric	Transformed
249	cauliflower	14	266	Low-caloric	Transformed
196	salad plate	25	37.5	Low-caloric	Transformed
346	potatoes	71	426	High-caloric	Natural
459	corn / maize	211.2	528	High-caloric	Natural
283	avocado	217	542.5	High-caloric	Natural
457	pine nuts	559	335.4	High-caloric	Natural
539	almonds	598	478.4	High-caloric	Natural
282	banana	64	128	High-caloric	Natural
244	rice waffles	380	253.46	High-caloric	Transformed
181	bowl of muesli	343	857.5	High-caloric	Transformed
112	opened bar of chocolate	555	555	High-caloric	Transformed
366	bagels	276.1	496.98	High-caloric	Transformed
26	chips	539	183.26	High-caloric	Transformed
867	pasta	350	350	High-caloric	Transformed

Note. * group assigned by the authors.

Chapter 7 - Supplementary Materials Table S1

Table S1. List of food stimuli in Study 1 from the database of Blechert and colleagues (2014).

Ref. FoodPics	Name	Kcal per 100g	Kcal total	Red	Green	Degree of Transformation
449	garden radish	15	4.5	0.40848	0.37694	Natural
460	tomato	17	13.6	0.75434	0.20539	Natural
257	lettuce (lollo rosso)	21	63	0.51129	0.25054	Natural
334	carrots	26	104	0.44464	0.42032	Natural
234	strawberries	31	9.3	0.59543	0.24827	Natural
401	red chili	40	4	0.65761	0.21229	Natural
192	apple	52	78	0.52422	0.31193	Natural
398	cherries	63	50.4	0.51320	0.21970	Natural
397	grapes, red	71	142	0.46819	0.24860	Natural
412	potatoes	71	142	0.47822	0.36872	Natural
539	almonds	598	478.4	0.53929	0.33371	Natural
450	hazelnuts	636	1157.5	0.53172	0.30414	Natural
264	mushrooms (white)	12	4.00	0.37022	0.33793	Natural
249	cauliflower	14	266	0.38006	0.40304	Natural
368	chiccory	15	105	0.38336	0.37402	Natural
455	spinach	17	13.6	0.33142	0.48762	Natural
360	artichoke	22	55	0.44306	0.45971	Natural
266	green onion (shallot)	42	44.1	0.36552	0.39099	Natural
466	green apple	52	114.4	0.39647	0.46946	Natural
261	soybean sprouts	52	41.6	0.37507	0.34690	Natural
282	banana	64	128	0.42835	0.36503	Natural
270	corn (on a cob)	67	388.6	0.39555	0.39551	Natural
281	grapes	71	71	0.42432	0.45206	Natural
283	avocado	217	542.5	0.46381	0.40153	Natural
253	pickles	16	36	0.35905	0.47814	Transformed
424	peas cooked	84	109.2	0.31149	0.50497	Transformed
385	tagliatelle	170	425	0.38425	0.34370	Transformed
560	fried egg	195	117	0.42245	0.34632	Transformed
300	loaf of bread	253	1265	0.44973	0.33740	Transformed
146	cheese cake	255	255	0.43560	0.34599	Transformed
182	bowl of rice	349	349	0.35472	0.32387	Transformed
226	crisp bread	350	700	0.37964	0.34406	Transformed
244	rice waffles	380	253.5	0.38688	0.33531	Transformed
515	Emmentaler cheese	383	766	0.40726	0.37653	Transformed
14	muffin	404	359.6	0.48600	0.36589	Transformed

294	popcorn	424	21.2	0.39837	0.35271	Transformed
361	carrots, cooked	26	39	0.57997	0.30674	Transformed
353	strawberry tartlet	104	111.3	0.66040	0.21426	Transformed
540	beefsteak, raw	111	333	0.55984	0.21914	Transformed
306	roast potatoes	117	269.1	0.57530	0.30807	Transformed
562	cutlet	133	399	0.52524	0.31806	Transformed
329	salmon	193	96.5	0.62898	0.26315	Transformed
549	bagel	233	186.4	0.52594	0.33257	Transformed
187	croissant	333	233.1	0.55322	0.28491	Transformed
348	rusk	365	36.5	0.52290	0.35202	Transformed
193	crisp bread	372	96.7	0.46632	0.35054	Transformed
152	peanut puffs	500	100	0.50156	0.34384	Transformed
286	bar of chocolate	530	530	0.51583	0.31211	Transformed

Chapter 7 - Supplementary Materials Table S1'

Table S1'. List of word stimuli from the word bank of Graham and colleagues (2009).

Pure (12 words)		**Impure (12 words)**	
English	**French**	**English**	**French**
Clean	Propre	Lax	Laxiste
Innocent	Innocent	Sick	Malade
Pristine	Intact	Defile	Souillé
Wholesome	Sain	Gross	Dégoutant
Abstemious	Sobre	Wanton	Dévergondé
Saint	Saint	Contagious	Contagieux
Virgin	Vierge	Sinful	Honteux
Sterile	Stérile	Sins	Fautes
Refined	Epuré	Repulse	Répugné
Pure	Pur	Debase	Dégradé
Limpid	Limpide	Sinful	Coupable
Virtuous	Vertueux	Indecent	Indécent

Chapter 7 - Supplementary Materials Table S2

Table S2. Means and standard deviation of RT (ms) in each block in each group and comparisons between conditions within-group.

Group	**Block1** Natural food + Impure word		**Block2** Natural food + Pure word		***t***	***p***	***D-measure***
	M	***SD***	***M***	***SD***			
AN group	582.7	101.6	544.3	93.3	-3.45	0.012*	0.35
HC group	567.7	101.7	525.9	99.9	-4.26	0.001*	0.38
	Block3 Processed food + Impure word		**Block4** Processed food + Pure word				
	M	***SD***	***M***	***SD***			
AN group	559.0	85.1	606.0	99.7	-4.54	0.000*	0.45
HC group	555.6	86.8	589.2	104.5	-3.82	0.004*	0.35

Note. AN, AN group; HC, HC group; t, test statistic; p, p-value of the Student test computed here between the two blocks and adjusted by the Bonferroni correction, D-measure, coefficient of the effect size. As guideline, a D-measure between 0.50 and 0.80 indicated 'moderate' effect; a strong effect is above 0.80 (Cohen, 1988; Nosek & Banaji, 2001).

** p-value < 0.05

Chapter 7 - Supplementary Materials Table S3

Table S3. Summary of the generalized mixed model conducted on RT with the group and the condition (congruent/incongruent) as fixed effect, and with the subject and the stimulus as random effects in Study 1.

Effect	**Parameter name**	***Estimate***	**95% CI**		***SD***	***p***
			LL	***UL***		
fixed	(Intercept)	1445.32	1433.29	1464.26	0.59	<0.001
fixed	GroupHC	-1.10	-2.96	0.00	0.72	0.123
fixed	ConditionIncongruent	3.23	3.05	4.08	0.20	<0.001
fixed	Interaction GroupHC: ConditionIncongruent	-0.16	-1.00	0.00	0.28	0.572
random	Stimulus	-	-	-	2.91	-
random	Subject	-	-	-	2.80	-
random	Residual	-	-	-	7.33	-

Note. Number of observations: 10488; Number of subjects: 64. CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Chapter 7 - Supplementary Materials Table S4

Table S4. D-measure (effect size) for each group according to the blocks and conditions.

Group	D-measure	
	Blocks	Condition
AN group		0.39
NatImpur – NatPur	0.35	
TransPur – TransImpur	0.45	
HC group		0.36
NatImpur – NatPur	0.38	
TransPur – TransImpur	0.35	

Note. AN, AN group; HC, HC group; NatImpur, Block 1; NatPur, Block 2; TransImpur, Block 3; TransPur, Block 4. According to Cohen's d scale, a d of 0.2 corresponds to a small effect size, a d of 0.5 corresponds to a medium effect size, and a d of 0.8 corresponds to a large effect size.

Chapter 7 - Supplementary Materials Table S5

Table S5. List of food stimuli in Study 2 from the database of Blechert and colleagues (2014).

Ref. FoodPics	Name	Kcal per 100g	Kcal total	Group Calorie content*	Degree of Transformation
274	spinach	17	17	Low-caloric	Natural
402	pear	52	78	Low-caloric	Natural
263	mushrooms	12	14.16	Low-caloric	Natural
280	cherries	63	37.8	Low-caloric	Natural
194	kiwi	53	26.5	Low-caloric	Natural
281	grapes	71	71	Low-caloric	Natural
369	sushi roll	100	40	Low-caloric	Transformed
558	asparagus cooked	20.5	114.8	Low-caloric	Transformed
567	tomato and mozzarella	86.7	104.04	Low-caloric	Transformed
362	beans cooked	25	30	Low-caloric	Transformed
249	cauliflower	14	266	Low-caloric	Transformed
196	salad plate	25	37.5	Low-caloric	Transformed
346	potatoes	71	426	High-caloric	Natural
459	corn / maize	211.2	528	High-caloric	Natural
283	avocado	217	542.5	High-caloric	Natural
457	pine nuts	559	335.4	High-caloric	Natural
539	almonds	598	478.4	High-caloric	Natural
282	banana	64	128	High-caloric	Natural
244	rice waffles	380	253.46	High-caloric	Transformed
181	bowl of muesli	343	857.5	High-caloric	Transformed
112	opened bar of chocolate	555	555	High-caloric	Transformed
366	bagels	276.1	496.98	High-caloric	Transformed
26	chips	539	183.26	High-caloric	Transformed
867	pasta	350	350	High-caloric	Transformed

Note. * group assigned by the authors.

Chapter 7 - Supplementary Materials Table S6

Table S6. Study 2 Participants' characteristics (number by gender, age, and BMI by groups, ORTO-12-FR, EDI-II-24, and Satiety scores with mean and standard deviation).

Baseline characteristics	Control		Orthorexic		Orthorexic & Pathologic		Pathologic	
	n	%	n	%	n	%	n	%
Number	62		21		43		17	
Gender								
Female	45	73	14	67	41	95	16	94
Male	17	27	7	33	2	5	1	6
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age [1]	23.19	3.80	22.30	2.31	22.37	3.20	23.82	4.53
BMI [2]	21.66	2.59	21.02	3.03	22.14	3.08	23.44	4.71
ORTO-12-FR [3]	34.73	2.89	27.38	2.29	25.77	3.58	33.41	1.94
EDI-II-24 [4]	38.18	8.98	43.38	9.07	65.95	9.56	57.65	5.33
Satiety score [1]	2.16	1.20	2.62	1.29	2.44	1.44	2.88	1.50

Notes. BMI, Body mass index; EDI-II-24, Eating Disorder Inventory – 24 items

[1] For Age and Satiety score, no significant difference between groups.

[2] For BMI, only one significant difference between the Control group and the Pathologic group (T = -2.33, p = 0.028).

[3] For ORTO-12-FR, the average score of each group is significantly different from that of the other groups.

[4] For EDI-II-24, the average score of each group is significantly different from that of the other groups except for the control and the orthorexic, where the difference is not significant between them (T = -1.29, p = 0.204).

Chapter 7 - Supplementary Materials Table S7

Table S7. RT (ms) according to the group and the condition (means and standard errors), and Student-test results between RT of each condition in each group.

Group	Conditions	RT (ms)		Comparison between conditions		
		M	*SD*	*t*	*p*	*D-measure*
Control						
	Congruent	959.74	266.95	-8.72	< 0.001	0.84
	Incongruent	1305.69	458.46			
Orthorexic						
	Congruent	926.12	349.43	-6.66	< 0.001	0.85
	Incongruent	1276.88	448.57			
Ortho_Patho						
	Congruent	908.63	325.92	-8.87	< 0.001	0.92
	Incongruent	1249.29	460.86			
Pathologic						
	Congruent	933.36	335.52	-5.44	< 0.001	0.85
	Incongruent	1316.09	491.83			

Note. M, means; SD, standard error; t, test statistic; p, p-value of the Student test computed here between the two conditions and adjusted by the Bonferroni correction; D-measure, coefficient of the effect size. As guideline, a D-measure between 0.2 and 0.50 indicated a 'small' effect; a D-measure between 0.50 and 0.80 indicated a 'moderate' effect; a strong effect is above 0.80 (Project Implicit, 2017).

Chapter 7 - Supplementary Materials Table S8

Table S8. Summary of the mixed model conducted on log-transformed RT with the group and the condition (congruent/incongruent) as fixed effect, and with the subject and the stimulus as random effects in Study 2.

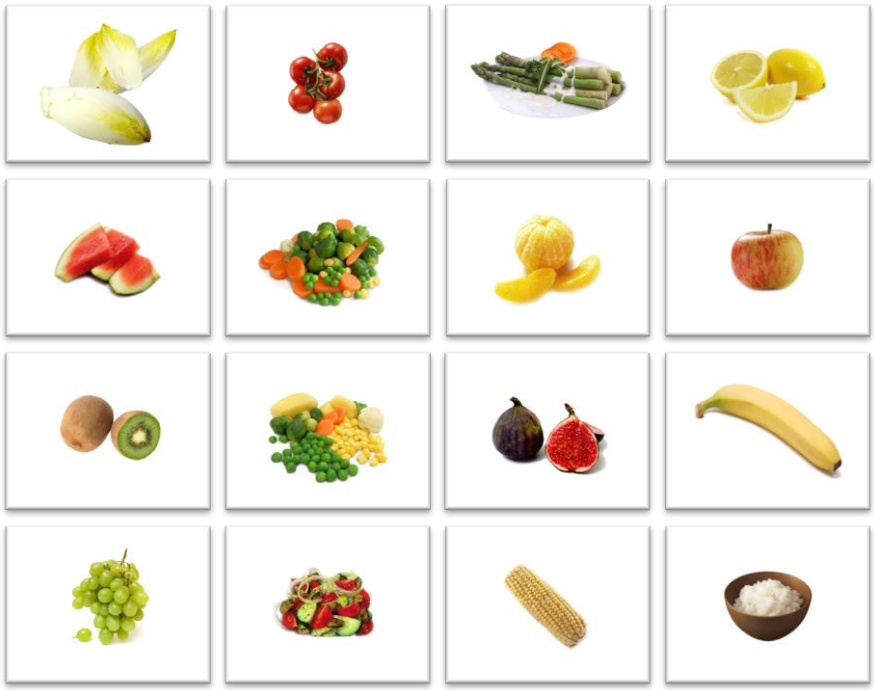
Effect	**Parameter name**	***Estimate***	**% CI**		***SD***	***p***
			LL	*UL*		
fixed	(Intercept)	1832.21	1791.58	1868.78	0.86	<0.001
fixed	ConditionIncongruent	14.17	13.88	15.03	0.35	<0.001
fixed	GroupOrtho_Patho	-1.58	-4.88	1.01	1.58	0.310
fixed	GroupOrthorexic	-2.17	-4.88	0.00	1.24	0.075
fixed	GroupPathologic	-1.00	-3.92	2.02	1.72	0.555
fixed	ConditionIncongruent: GroupOrthorexic	0.75	-1.00	2.02	0.69	0.276
fixed	ConditionIncongruent: GroupOrtho_Patho	0.22	-1.00	1.01	0.54	0.685
fixed	ConditionIncongruent: GroupPathologic	1.13	0.00	3.05	0.74	0.129
random	Id	-	-	-	6.10	-
random	Stimulus	-	-	-	2.26	-
random	Residual	-	-	-	13.06	-

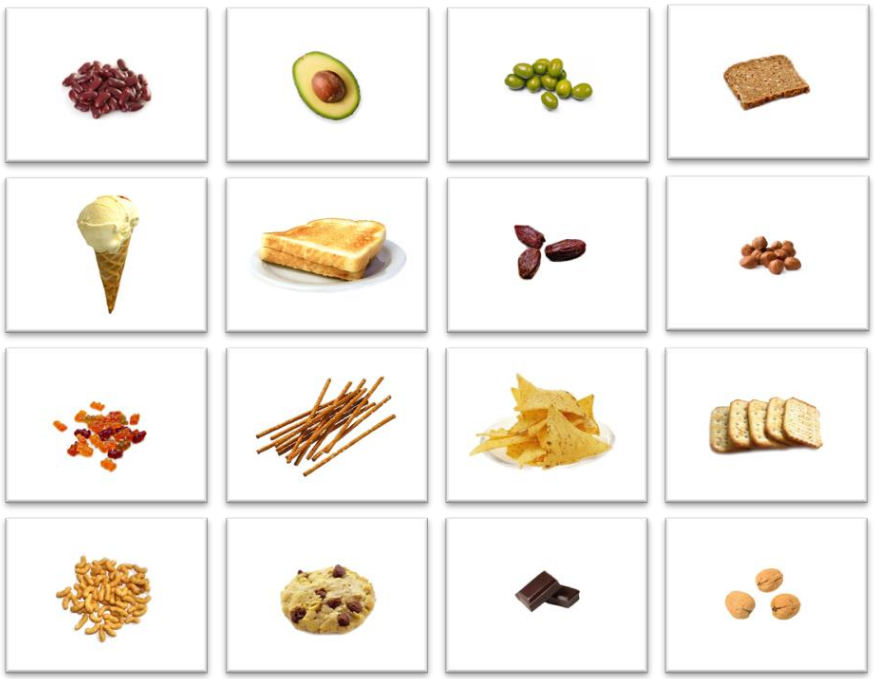
Note. Number of observations: 11760; Number of subjects: 143. CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Appendix 4: Chapter 8 - Supplementary Materials

Chapter 8 – Stimuli Sets

Food stimuli from Food-pics database (Blechert et al., 2014):





Properties of food stimuli in Chapter 8 – Studies 1 and 2 from the database of Blechert and colleagues (2014)

Item description	Kcal per 100g	Kcal total per image	Degree of Transformation
chiccory	15	105	Natural
tomatoes	16	104	Natural
asparagus with bechamel sauce	20,5	114,8	Transformed
lemons	36	94,5	Natural
water melon	39	69	Natural
mixed vegetables	43	129	Transformed
oranges	47	94	Natural
apple	52	78	Natural
kiwis	53	103,35	Natural
mixed vegetables	56,62	73,606	Transformed
figs	62	74,4	Natural
banana	64	128	Natural
grapes	71	71	Natural
greek salad	80	120	Natural
corn	80	100	Natural
rice	110	120	Transformed
red beans	111	120	Natural
avocado	138	113,5	Natural
olive	145	75	Natural
wheat bread	200	110	Transformed
vanilla ice cream	211	135,04	Transformed
toast	253	126,5	Transformed
dates	266	119,5	Natural
hazelnuts	300	88	Natural
gummy bears	334	100	Transformed
pretzel sticks	347	97,16	Transformed
tortilla chips	478	119,5	Transformed
crackers	486	121,5	Transformed
peanut puffs	500	100	Transformed
chocolate cookie	510	96,9	Transformed
chocolate two pieces	543	145	Transformed
walnuts	654	98,1	Natural

Chapter 8 Study 3 – Food stimuli from the database of Bonin and colleagues (2021), extract from the Foodpics database (Blechert et al., 2014)

Food stimuli perceived as healthy according to Bonin and colleagues (2021):

Food stimuli perceived as unhealthy according to Bonin and colleagues (2021) :

Properties of food stimuli in Chapter 8 – Study 3 (Bonin and colleagues, 2021; extract from the FoodPics database; Blechert et al., 2014):

N° Stimuli	Image description	Energy Density	Degree of Processing	Healthiness mean	Healthy/ Unhealthy category	Kcal per 100g	Kcal total per picture
502	mixed vegetables, cooked	Low	Processed	9,61	Unhealthy	44,3	15,505
567	tomato and mozzarella	Low	Processed	7,68	Unhealthy	86,7	104,04
244	rice waffles	High	Processed	7,42	Unhealthy	380	253,46
329	salmon	High	Processed	7,03	Unhealthy	193	96,5
236	bowl of rice	High	Processed	6,84	Unhealthy	349	174,5
560	fried egg	High	Processed	6,61	Unhealthy	195	117
327	mashed potatoes	Low	Processed	6,61	Unhealthy	78	175,5
337	meat fillets and vegetables, grilled	Low	Processed	6,61	Unhealthy	106,86	320,58
537	beefsteak, raw	Low	Processed	5,71	Unhealthy	111	222
292	bread roll	High	Processed	5,5	Unhealthy	253	151,8
180	muesli bar (oatmeal)	High	Processed	5,35	Unhealthy	345	86,25
10	Spaghetti with tomato sauce	Low	Processed	5,32	Unhealthy	139	347,5
564	sushi rolls	Low	Processed	5,23	Unhealthy	106,7	80,025
347	toast with jam	High	Processed	5,2	Unhealthy	248,5	124,25
301	roasted chicken	Low	Processed	5,13	Unhealthy	140	420
527	tuna sandwiches	High	Processed	5	Unhealthy	231	415,8
536	cooked ham cut	Low	Processed	4,9	Healthy	111	188,7
348	rusk	High	Processed	4,87	Healthy	365	36,5
145	lasagna	Low	Processed	4,57	Healthy	123	430,5
O_1	greek_yogurt	Low	Processed		Healthy	100	220
483	pancake with fruits	Low	Processed	4,42	Healthy	148	503,2
353	strawberry tartlet	Low	Processed	4,03	Healthy	104	111,28
193	crisp bread	High	Processed	4	Healthy	372	96,72
58	ham sandwich	Low	Processed	4	Healthy	155	359,6
4	chocolate cookie	High	Processed	3,87	Healthy	510	96,9
150	popcorn	High	Processed	3,68	Healthy	397	238,2
535	sausages	High	Processed	3,53	Healthy	200	200
507	waffle	High	Processed	3,16	Healthy	400	460

137	chocolate muffin	High	Processed	2,97	Healthy	398	298,5
155	crackers	High	Processed	2,83	Healthy	486	121,5
O_2	fish and chips	High	Processed	NA	Healthy	167	588
741	salmon and spinach	Low	Processed	NA	Healthy	150	300

Note. O_1, O_2: stimuli selected stimuli from Internet royalty-free pictures databases

Chapter 8 – Study 1

Supplementary Materials Table 1a. Study 1 – Participants' demographic characteristics in the French sample (N=112)

French sample	N	Mean	SD	Min	Max
Gender					
Woman	83 (74%)				
Men	25 (22%)				
other	4 (4%)				
Age	112	24.1	4.4	18	35
BMI	112	22.7	3.4	15.8	32.9
Socio-Professional Categories :					
Students	61 (54%)				
Executives	30 (27%)				
Employees	14 (12%)				
Others	4 (4%)				
Intermediate professions	1 (1%)				
Craftsmen, shopkeepers and company managers	2 (2%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 1b. Study 1 – Participants' demographic characteristics in the Quebec sample (N=116)

Quebec sample	N	Mean	SD	Min	Max
Gender					
Woman	103 (89%)				
Men	10 (8%)				
other	3 (3%)				
Age	116	26.2	4.7	18.0	35.0
BMI	116	24.9	5.9	15.8	42.1
Socio-Professional Categories :					
Students	77 (66%)				
Executives	10 (9%)				
Employees	23 (20%)				
Others	2 (2%)				
Intermediate professions	4 (3%)				
Craftsmen, shopkeepers and company managers	0 (0%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 2a. Study 1 –Participants' questionnaire scores and responses indices (reaction times, proportion of food classified as unhealthy and stability of responses) in the French sample

	M	SD	Min	Max
EHQ Global score	33.18	6.04	22.00	52.00
EHQ subscales :				
EHQ REB	7.70	2.57	5.00	17.00
EHQ PFC	17.71	2.85	8.00	24.00
EHQ PACSR	7.78	2.91	5.00	20.00
EDEQ Global score	2.39	1.18	0.60	5.49
EDEQ subscales :				
EDEQ Eating Concern	1.84	1.08	0.40	5.60
EDEQ Restraint	1.95	1.15	1.00	6.00
EDEQ Shape Concern	3.23	1.70	0.63	6.88
EDEQ Weight Concern	2.55	1.42	0.20	5.60
Reaction times	0.82	0.12	0.59	1.24
Proportion of food classified as unhealthy	0.26	0.05	0.03	0.41
Stability of responses:				
level 0	0.28	0.54	0.00	2.00
level 1	2.21	1.64	0.00	8.00
level 2	25.5	1.78	20.0	28.0

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship; Stability of responses level 0: stimuli classified twice in one category and twice in the other category; level 1= stimuli classified once in one category and three times in the other category; level 2: stimuli classified four times in the same category

Moreover, the EHQ and EDEQ scales were moderately correlated in the French sample [$r(110)=0.52$, $p<.001$].

Supplementary Materials Table 2b. Study 1 –Participants' questionnaire scores and responses indices (reaction times, proportion of food classified as unhealthy and stability of responses) in the Quebec sample

	M	SD	Min	Max
EHQ Global score	35.21	7.51	17.00	58.00
EHQ subscales :				
EHQ REB	8.70	3.53	5.00	19.00
EHQ PFC	18.12	3.03	7.00	24.00
EHQ PACSR	8.39	2.94	5.00	17.00
EDEQ Global score	2.33	1.29	0.65	6.20
EDEQ subscales :				
EDEQ Eating Concern	1.81	1.25	0.40	6.80
EDEQ Restraint	2.01	1.27	1.00	6.00
EDEQ Shape Concern	3.06	1.75	0.50	7.00
EDEQ Weight Concern	2.45	1.51	0.20	5.60
Reaction times	0.81	0.13	0.40	1.33
Proportion of food classified as unhealthy	0.23	0.08	0.00	0.46
Stability of responses:				
level 0	0.29	0.59	0.00	3.00
level 1	1.74	1.40	0.00	6.00
level 2	25.91	1.55	22.00	28.00

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship; Stability of responses level 0: stimuli classified twice in one category and twice in the other category; level 1= stimuli classified once in one category and three times in the other category; level 2: stimuli classified four times in the same category

Moreover, the EHQ and EDEQ scales were moderately correlated in the Quebec sample [$r(114)=0.41$, $p<.001$].

Supplementary Materials Table 3a. Mixed model predicting the probability of food items classified as unhealthy food in Canadian sample – Estimates of Fixed Effects

	Beta		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	-7.66	-9.29 – -6.03	<.001***
EHQ Global score	0.06	0.021 – 0.10	.002**
Energy density [High calorie]	2.12	0.20 – 4.04	.030*
Food processing [Processed]	1.63	0.08 – 3.19	.039*
EHQ Global score * Energy density[High calorie]	-0.03	-0.05 – -0.01	.005**
EHQ Global score * Food processing [Processed]	0.02	-0.01 – 0.06	.162
Energy density[High calorie] * Food processing[Processed]	3.98	1.60 – 6.35	.001**
EHQ Global score * Energy density[High calorie] * Food processing [Processed]	-0.07	-0.12 – -0.02	.012*
Random Effects			
σ^2	3.29		
$\tau_{00\ Id}$	2.11		
$\tau_{00\ Stim}$	1.82		
ICC	0.54		
Marginal R^2 / Conditional R^2	0.546 / 0.793		

Note. CI: Confidence Interval; p, pvalue of each test. ns = nonsignificant at α = .05; * p < .05; ** p < .01.

Supplementary Materials Table 3b Mixed model predicting decision criterion - Type III Tests of Fixed effects.

Source	Df	Chisq	p
EHQ Global score	1	4.44	.035*
Energy density	1	26.86	<.001***
Food processing	1	31.38	<.001***
EHQ Global score * Energy density	1	8.03	.005**
EHQ Global score * Food processing	1	0.011	.916
Energy density * Food processing	1	10.77	.001**
EHQ Global score * Energy density * Food processing	1	6.33	.012*

Note. Df = degrees of freedom; p, pvalue of each test. ns = nonsignificant at α = .05;
* p < .05; ** p < .01.

Supplementary Materials Table 4. Comparison of mixed model predicting the probability of food items classified as unhealthy food in Canadian sample – Estimates of variables, Multilevel Model Results

	Unconditional	Level-1variable	Level-3variables with food properties	Final model
(Intercept)	-3.141***	-4.527***	-4.485***	-7.66***
EHQ Global score	–	0.061*	–	0.060*
Energy density [High calorie]	–	–	0.968*	2.124*
Food processing [Processed]	–	–	5.637***	5.618***
EHQ Global score * Food processing [Processed]	–	–	–	0.02
Energy density[High calorie] * Food processing[Processed]	–	–	4.006***	3.980**
EHQ Global score * Energy density[High calorie] * Food processing [Processed]	–	–	–	-0.07*
R^2_M	–	0.01	0.54	0.55
R^2_C	0.80	0.80	0.79	0.79
AIC	5848.9	5846.5	5800.7	5790.6
AIC pvalue	–	.036*	<.001***	.001**

Note. R^2_M: percentage of variance explained by the fixed effects only; R^2_C : percentage explained by the fixed and random effects. AIC pvalue: p value of the AIC difference test between this model and the unconditional model test. α = .05; * p < .05; ** p < .01; *** p < .001;

The majority of the variance explained by model's fixed effects (R^2_M) is explained by food properties, but the addition of the EHQ score and its interactions significantly decreased the AIC of the model, therefore we kept it in the final model.

Chapter 8 – Study 2

Supplementary Materials Table 5a. Study 2 – Participants' demographic characteristics in the French sample (N=149)

French sample	N	Mean	SD	Min	Max
Gender					
Woman	69 (46%)				
Men	73 (49%)				
other	7 (5%)				
Age	149	25.7	4.4	18.9	35
BMI	149	23.7	5.7	15.2	53.9
Socio-Professional Categories :					
Students	61 (41%)				
Executives	33 (22%)				
Employees	25 (17%)				
Others	11 (8%)				
Intermediate professions	8 (5%)				
Craftsmen, shopkeepers and company managers	11 (7%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 5b. Study 2 – Participants' demographic characteristics in the Quebec sample (N=86)

Quebec sample	N	Mean	SD	Min	Max
Gender					
Woman	74 (86%)				
Men	9 (10%)				
other	3 (4%)				
Age	86	25.4	5.7	18.9	35
BMI	86	24.0	5.4	15.2	46.8
Socio-Professional Categories :					
Students	61 (71%)				
Executives	5 (6%)				
Employees	15 (17%)				
Others	2 (2.3%)				
Intermediate professions	2 (2.3%)				
Craftsmen, shopkeepers and company managers	1 (1.4%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 6a. Study 2 – Participants' questionnaire scores and responses indices (reaction times by type of primes) in the French sample (N=149)

	M	SD	Min	Max
EHQ Global score	33.75	7.22	20	56
EHQ subscales :				
EHQ REB	8.28	3.35	5	19
EHQ PFC	17.5	3.05	8	24
EHQ PACSR	7.89	3.04	5	19
EDEQ Global score	2.52	1.29	0.95	6.47
EDEQ subscales :				
EDEQ Eating Concern	1.91	1.33	1	7
EDEQ Restraint	2.37	1.51	1	7
EDEQ Shape Concern	3.25	1.64	1	7
EDEQ Weight Concern	2.57	1.41	0.8	5.6
RT means (s)	1.18	0.15	0.81	1.65
RT means functional primes	1.20	0.16	0.81	1.68
RT means sensory primes	1.17	0.15	0.81	1.62

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship.

Moreover, the EHQ and EDEQ scales were moderately correlated in the French sample [$r(147)=0.43$, $p<.001$].

Supplementary Materials Table 6b. Study 2 – Participants' questionnaire scores and responses indices (reaction times by type of primes) in the Quebec sample (N=86)

	M	SD	Min	Max
EHQ Global score	35.00	8.73	22	61
EHQ subscales :				
EHQ REB	8.15	3.97	5	20
EHQ PFC	18.37	2.99	11	23
EHQ PACSR	8.47	3.53	5	20
EDEQ Global score	2.21	1.26	0.53	6.08
EDEQ subscales :				
EDEQ Eating Concern	1.48	1.25	0,4	5.8
EDEQ Restraint	2.16	1.45	1	7
EDEQ Shape Concern	2.97	1.66	0.5	6.5
EDEQ Weight Concern	2.21	1.39	0.2	5
RT means (s)	1.27	0.13	0.92	1.65
RT means functional primes	1.29	0.14	0.91	1.64
RT means sensory primes	1.24	0.13	0.92	1.65

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship.

Moreover, the EHQ and EDEQ scales were moderately correlated in the Quebec sample [$r(84)=0.61$, $p<.001$].

Chapter 8 – Study 3

Supplementary Materials Table 7a. Study 3 – Participants' demographic characteristics in the French sample (N=149)

French sample	N	Mean	SD	Min	Max
Gender					
Woman	61 (41%)				
Men	82 (55%)				
other	6 (4%)				
Age	149	26.9	4.4	19	35
BMI	149	23.8	4.7	17.2	44.6
Socio-Professional Categories :					
Students	43 (29%)				
Executives	37 (25%)				
Employees	43 (29%)				
Others	14 (9%)				
Intermediate professions	6 (4%)				
Craftsmen, shopkeepers and company managers	6 (4%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 7b. Study 3 – Participants' demographic characteristics in the Quebec sample (N=100)

Quebec sample	N	Mean	SD	Min	Max
Gender					
Woman	62 (63%)				
Men	35 (35%)				
other	3 (2%)				
Age	100	26.3	4.6	18	35
BMI	100	24.7	5.8	15.8	52.6
Socio-Professional Categories :					
Students	37 (37%)				
Education, law and social, community and government services	14 (14%)				
Business, finance and administration	15 (15%)				
Natural and applied sciences and related fields	7 (7%)				
Health sector	8 (8%)				
Others	19 (19%)				

Note. SD = standard deviation; BMI = Body Mass Index.

Supplementary Materials Table 8a. Study 3 – Participants' questionnaire scores and responses indices (proportion of food classified as unhealthy, responses bias indices in condition 1 and 2) in the French sample

	M	SD	Min	Max
EHQ Global score	**32.61**	7.84	18	52
EHQ subscales :				
EHQ REB	**7.71**	3.22	5	19
EHQ PFC	**16.77**	3.35	7	24
EHQ PACSR	**8.12**	3.22	5	18
EDEQ Global score	**2.54**	1.33	1	5.95
EDEQ subscales :				
EDEQ Eating Concern	**2.29**	1.46	1	7
EDEQ Restraint	**1.82**	1.10	1	5.8
EDEQ Shape Concern	**2.85**	1.64	1	7
EDEQ Weight Concern	**3.20**	1.74	1	7
Proportion of food classified as unhealthy	**0.46**	0.12	0.16	0.80
Condition healthy				
Response bias	**-0.03**	0.14	-0.74	0.41
Discriminability A'	**0.79**	0.06	0.59	0.91
Condition unhealthy				
Response bias	**0.06**	0.17	-0.35	1.00
Discriminability A'	**0.80**	0.07	0.57	0.91

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship.

Moreover, the EHQ and EDEQ scales were moderately correlated in the French sample [$r(148)=0.53$, $p<.001$].

Supplementary Materials Table 8b. Study 3 – Participants' questionnaire scores and responses indices (proportion of food classified as unhealthy, responses bias indices in condition 1 and 2) in the Quebec sample

	M	SD	Min	Max
EHQ Global score	**34.72**	8.29	16	53
EHQ subscales :				
EHQ REB	**8.32**	3.45	5	18
EHQ PFC	**17.34**	3.39	6	24
EHQ PACSR	**9.06**	3.26	5	19
EDEQ Global score	**2.88**	1.43	1	5.97
EDEQ subscales :				
EDEQ Eating Concern	**2.17**	1.33	1	6.2
EDEQ Restraint	**2.74**	1.72	1	7
EDEQ Shape Concern	**3.43**	1.71	1	7
EDEQ Weight Concern	**3.2**	1.60	1	6.6
Proportion of food classified as unhealthy	**0.44**	0.14	0.10	0.77
Condition healthy				
Response bias	**-0.09**	0.30	-1	0.71
Discriminability A'	**0.76**	0.08	0.45	0.88
Condition unhealthy				
Response bias	**0.14**	0.31	-0.55	1
Discriminability A'	**0.75**	0.09	0.36	0.87

Note. M = Mean; SD = standard deviation; EDEQ = Eating Disorder Examination Questionnaire; EHQ = Eating Habits Questionnaire; REB = Rigid Eating Behaviour; PFC = Positive Feeling of Control; PACSR = Problems of Attention, Control and Social Relationship.

Moreover, the EHQ and EDEQ scales were moderately correlated in the Quebec sample [$r(98)=0.66$, $p<.001$].

RESUME

Le contrôle de son alimentation est devenu une préoccupation majeure, mais qui peut parfois amener à l'individu à perdre le contrôle sur son alimentation et amener jusqu'aux troubles du comportement alimentaire (TCA). Cette thèse s'est intéressée à comprendre comment la volonté de contrôler son alimentation peut mener à la perte de contrôle, en s'appuyant sur deux modèles : l'anorexie mentale et l'orthorexie mentale.
Nous avons identifié trois types de facteurs impliqués : 1) l'environnement de l'individu : nous avons observé des plus grands risques de développement de TCA chez les étudiants en arts culinaires par rapport aux étudiants en diététique et à la population générale ; 2) le rapport au corps qui sous-tend la catégorisation des aliments : nous avons trouvé une association plus forte entre les stimuli alimentaires et corporels chez les sujets souffrant d'anorexie mentale par rapport aux sujets témoins ; 3) une perception élevée du risque lors des choix alimentaires : les individus souffrant d'anorexie mentale et d'orthorexie mentale utilisaient des stratégies spécifiques de catégorisation des aliments, suggérant une perception du risque plus élevée lors des choix alimentaires au sein de ces populations par rapport aux populations témoins.
Cette thèse permet de mieux comprendre les processus de catégorisation impliqués dans l'anorexie et l'orthorexie mentale. Elle ouvre la voie pour de nouvelles études sur la perception du risque et des réactions émotionnelles qui peuvent en découler telles que la peur et l'anxiété, et ainsi cibler les interventions de types cognitivo-comportementales dans l'anorexie et l'orthorexie mentale.

Mots clés : Troubles du comportement alimentaire ; catégorisation alimentaire ; restriction alimentaire ; contrôle ; image du corps ; perception du risque.

ABSTRACT

While it is common for individuals to monitor their food intake, doing so excessively can lead to a loss of control and potentially result in the development of an eating disorder. The objective of this thesis was to explore how the desire to control one's food intake can lead to a loss of control. To achieve this, two models were examined: anorexia nervosa and orthorexia nervosa.
We identified three types of factors involved: 1) the individual's environment, which can be associated with higher risks of developing eating disorders and orthorexia nervosa: we found greater risks in culinary arts students compared with dietetics students and the general population; 2) the relationship to the body underlying food categorization: we found a stronger association between food and bodily stimuli in subjects suffering from anorexia nervosa compared with control subjects ; 3) a high perception of risk when making food choices: we found that individuals with anorexia nervosa and high traits of orthorexia nervosa used specific food categorization strategies, which suggested a higher perception of risk when making food choices within these populations compared to control populations..
This thesis provides a better understanding of the categorization processes involved in anorexia and orthorexia nervosa. It paves the way for further studies on risk perception and the accompanying emotional responses, such as fear and anxiety. Additionally, the findings can be used to develop cognitive-behavioral interventions for individuals struggling with anorexia and orthorexia nervosa.

Keywords: Eating disorders; food categorization; food restriction; control; body image; risk perception.

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