UNIVERSITÀ DEGLI STUDI DI PADOVA
Dipartimento Territorio e Sistemi Agro-forestali
Department of Land, Environment Agriculture and Forestry

Corso di laurea magistrale/Second Cycle Degree (MSc)
in Food and health

Psychoemotional Dependence on Sugar: How to Break the Cycle Without Coercion

Relatore/Supervisor
Prof. Roberta Sellaro

Laureanda/o /Submitted by
Irina Voloshina
Matricola n./Student n.
2087188

ANNO ACCADEMICO/ACADEMIC YEAR 2023-2024

UNIVERSITÀ DEGLI STUDI DI PADOVA
Department of Land, Environment Agriculture and Forestry

Second Cycle Degree (MSc)
in Food and Health

Psychoemotional Dependence on Sugar: How to Break the Cycle Without Coercion

Supervisor
Prof. Roberta Sellaro

Submitted by
Irina Voloshina
Student n. 2087188

ACADEMIC YEAR 2023-2024

Acknowledgement 4
Summary 5
Introduction 7
Chapter 1: The Sweetness Paradox: Sugar's Dual Role in Health and Disease 9
1.1 The Dual Impact of Sugar on Health: Essential Nutrient or Hidden Risk? 9
1.2 The Sweetness Paradox: Innate Desires vs. Modern Diets 11
1.3 Factors Influencing Sweetness Preference and Liking in Humans 14
Chapter 2: Exploring the Controversial Concept of "Food Addiction" 18
2.1 Exploring the Concept and Controversies of Food Addiction 18
2.2 Understanding Sugar Addiction: Evidence and Debates 19
2.3 The Role of Fat and Sugar in Food Reward Mechanisms 22
Chapter 3 25
Neural Mechanisms of Sugar Cravings and Satisfaction: Implications for Eating Behavior and Clinical Practice 25
3.1 Exploring 'Wanting' and 'Liking': Distinct Psychological Processes in Food Reward 25
3.2 The Overlap of Homeostatic and Hedonic Mechanisms in Food Reward: Implications for Sugar Addiction 30
3.3 Hedonic Hunger and Its Role in Sugar Addiction and Obesity 31
Chapter 4: Strategies to Overcome Sugar Addiction 33
4.1 Psychological Support 33
4.1.1 Cognitive Behavioral Therapy (CBT) and Dialectical Behavior Therapy (DBT): 33
4.1.2 Reward Re-Training (RRT): 34
4.2 Nutritional Strategies 34
4.3 Self-Realization and Fulfillment 37
Conclusion 39
References: 41

Acknowledgement

I would like to express my heartfelt gratitude to everyone who supported me throughout the completion of this thesis. This topic arises from my personal lifelong battle with sugar addiction. It has been six months since I last consumed chocolates, ice creams, and confectionery, and I can’t believe this success!

First and foremost, I extend my sincere thanks to my family, who have always stood by me with unwavering support. I am also thankful to all my teachers at medical school in Russia, at Monash University in Australia, and at UNIPD for their guidance and encouragement.

Special appreciation goes to Mara Thiene, the Programme coordinator of "Food and Health," and Professor Roberta Sellaro, my thesis coordinator, whose invaluable assistance was instrumental in shaping this work.

Summary

The prevalence of psychoemotional dependence on sugar has reached alarming levels globally, posing significant challenges to public health and individual well-being. This thesis delves into the intricate web of factors contributing to sugar addiction and proposes a compassionate approach to breaking free from its grasp. By analyzing the roots of sugar dependency, deeply ingrained in childhood experiences and societal norms, this study highlights the multifaceted nature of the problem. Through comprehensive exploration, it elucidates the detrimental effects of sugar on physical health while also delving into its profound impact on emotional well-being. Drawing from insights in psychology, nutrition, and behavioral science, this thesis advocates for a paradigm shift towards mindful eating and emotional intelligence. By fostering a deeper understanding of the underlying drivers of sugar cravings, individuals can develop strategies to differentiate between physical and emotional hunger, thereby empowering themselves to make healthier dietary choices. Furthermore, this research underscores the pivotal role of self-confidence and success in shaping one's relationship with food, shedding light on the interconnectedness between self-esteem and sugar consumption. In navigating the path towards liberation from sugar addiction, this thesis proposes a holistic approach that transcends mere dietary restrictions. By encouraging individuals to explore alternative sources of pleasure and sweetness in life, such as pursuing personal passions and cultivating self-love, this study offers a roadmap for reclaiming agency over one's health and happiness. Moreover, it advocates for the abandonment of punitive measures and self-rejection in favor of a compassionate and nurturing stance towards oneself. Through its exploration of the harmful effects of sugar, the cultivation of mindful eating practices, the cultivation of self-confidence, and the promotion of self-love, this thesis endeavors to offer a comprehensive framework for breaking the cycle of psychoemotional dependence on sugar. By embracing a philosophy of love and self-compassion, individuals can embark on a journey towards holistic well-being, free from the shackles of sugar addiction.

Riassunto

La diffusione della dipendenza psico-emotiva dallo zucchero ha raggiunto livelli allarmanti a livello globale, ponendo significativi sfide alla salute pubblica e al benessere individuale. Questa tesi esplora la intricata rete di fattori che contribuiscono alla dipendenza da zucchero e propone un approccio compassionevole per liberarsi dalla sua presa. Analizzando le radici della dipendenza dallo zucchero, profondamente radicate nelle esperienze infantili e nelle norme sociali, lo studio evidenzia la natura sfaccettata del problema. Attraverso una esplorazione completa, chiarisce gli effetti dannosi dello zucchero sulla salute fisica, approfondendo anche il suo impatto profondo sul benessere emotivo. Attingendo a intuizioni dalla psicologia, dalla nutrizione e dalle scienze comportamentali, questa tesi sostiene un cambio di paradigma verso un'alimentazione consapevole e un'intelligenza emotiva. Favorire una comprensione più profonda dei motori sottostanti dei desideri di zucchero consente alle persone di sviluppare strategie per differenziare tra fame fisica ed emotiva, permettendo così loro di compiere scelte dietetiche più salutari. Inoltre, questa ricerca sottolinea il ruolo cruciale della fiducia in sé stessi e del successo nel plasmare il rapporto con il cibo, gettando luce sull'interconnessione tra autostima e consumo di zucchero. Nell'orientarsi verso la liberazione dalla dipendenza dallo zucchero, questa tesi propone un approccio olistico che va oltre le semplici restrizioni dietetiche. Incoraggiando le persone a esplorare fonti alternative di piacere e dolcezza nella vita, come perseguire passioni personali e coltivare l'amore per sé stesse, lo studio offre una guida per riconquistare il controllo sulla propria salute e felicità. Inoltre, si propone di abbandonare misure punitive e auto-rigetto a favore di una posizione compassionevole e nutritiva verso sé stessi. Attraverso l'esplorazione degli effetti dannosi dello zucchero, la coltivazione di pratiche alimentari consapevoli, il rafforzamento della fiducia in sé stessi e la promozione dell'amore per sé, questa tesi si impegna a offrire un quadro completo per spezzare il ciclo della dipendenza psico-emotiva dallo zucchero. Abbracciando una filosofia di amore e compassione verso sé stessi, le persone possono intraprendere un viaggio verso il benessere olistico, liberandosi dalle catene della dipendenza dallo zucchero.

Introduction

In today's world, sweetness goes beyond mere taste satisfaction, influencing various aspects of human life and psychology. The widespread dependency on sweets globally sparks curiosity about its prevalence and the psychological effects when these treats are unavailable. This thesis aims to delve into the complex connection individuals have with sweets, exploring how this dependency develops, the discomfort felt in its absence, strategies to break free from it, and the importance of fostering healthier relationships with food and emotions.

From early childhood, we learn to associate sweetness with rewards. Achieving academically often results in receiving sweets, reinforcing the idea that success and indulgence go hand in hand. Similarly, celebrations of victories and milestones frequently include cakes and chocolates, further cementing the symbolic role of sweets in marking significant achievements.
These cultural practices embed sugar not just as a symbol but as a tangible reward. Successfully overcoming challenges triggers subconscious cravings for sweets, linking these treats with feelings of success and accomplishment. On the other hand, the absence of sweets can lead to feelings of stagnation and dissatisfaction, suggesting a lack of progress and personal growth. This emotional relationship highlights the deep impact of sweets on our psychological well-being and how they shape our self-perception.

The psychological dependency on sweets is further compounded by their role in stimulating dopamine release—a neurotransmitter associated with pleasure and reward. This instinctual response is deeply rooted in societal norms perpetuated by familial practices and cultural customs, where the consumption of sweets serves not only as a sensory delight but also as a means of emotional gratification and comfort. The quest for dopamine reinforcement through sugary delights thus becomes intertwined with broader socio-cultural narratives of happiness and fulfillment.

To address the challenges posed by sugar dependency, breaking free from its detrimental cycle requires deliberate and thoughtful intervention. It is essential to grasp the psychological roots and societal factors fueling this dependency to develop effective strategies promoting healthier eating habits and emotional resilience.

These interventions extend beyond mere dietary restrictions, advocating compassionate methods that empower individuals to overcome dependency. By fostering self-awareness, teaching healthier coping mechanisms, and creating supportive environments, these strategies aim to foster sustainable behavior change and enhance overall well-being.

Through this systematic approach, the thesis aims to significantly contribute to the understanding of sugar addiction and endorse holistic approaches that prioritize individual well-being. By delving into the complexities of psychoemotional dependency, this study seeks to empower individuals to make informed choices and cultivate healthier lifestyles.

Chapter 1: The Sweetness Paradox: Sugar's Dual Role in Health and Disease

1.1 The Dual Impact of Sugar on Health: Essential Nutrient or Hidden Risk?

Sugar is a vital nutrient for the human body, serving as the primary energy source to fuel its functions. Similar to how machines require specific types of fuel to operate—such as gasoline for cars or electricity for appliances—our bodies, often referred to as our "organic motors," rely on sugar for energy. Sugars provide the body with ATP, facilitating several beneficial physiological processes. Carbohydrates, including sugars, are essential for bodily functions and physical activities, using glucose as their primary source. Therefore, sugar intake promptly satisfies the body's need for instant energy (Misra et al., 2016).

Despite its importance, sugar is often associated with negative effects. It erodes tooth enamel, contributes to weight gain, and is linked to conditions like diabetes (Bachmanov et al., 2011). This apparent contradiction raises the question: How can a substance essential for bodily function also have harmful consequences?

Throughout human history, people have consumed sugars provided by nature for hundreds of thousands of years. However, in the last two centuries, there has been a significant shift towards the consumption of refined white sugar produced by humans themselves. Interestingly, this manufactured sugar is associated with many of the health issues prevalent in contemporary society (Steinert et al., 2011). Its difficulty in being metabolized properly, especially when consumed in large amounts as is common today, is attributed to its lack of compatibility with human physiology. Nature did not anticipate that our bodies would encounter sugar of this kind.

Refined white sugar may appear to be real food, but it lacks essential nutrients, classifying it as a "fake food." These human-made items offer minimal nutritional value and are typically manufactured using concentrated food extracts like sugar from sugar beets and refined flour from grains. Common examples include candy, soft drinks, and pastries. Despite their calorie content, they lack vital vitamins and minerals, making them unsuitable for a healthy diet (Larsson et al., 2006). Relying on fake foods can be harmful to health as they fail to provide the necessary nutrients found in natural foods.

Despite the myriad applications of sugar, its overall impact on health remains unresolved. While some regard sugar as an adversary, its total omission from our diets could significantly impact our well-being. This analysis underscores the dual impact of sugar consumption on human health.

Sugar is essential for the proper functioning of the body; without it, our bodily processes would falter. Naturally occurring sugars, such as those in fruits and lactose in milk, provide significant dietary benefits. In contrast, added sugars, incorporated during food and beverage processing, pose health risks. Essential sugars are carbohydrates necessary for the body to efficiently absorb nutrients (Drewnowski, Krahn, Demitrack, Nairn, & Gosnell, 1992).

Consuming sugars from fruits does not harm the body because, in addition to fructose, fruits also contain fibers and various nutrients. Fructose provides quick energy, while fibers help counterbalance its effects, resulting in sustained energy for the body (Misra et al., 2016). Similarly, sugars in dairy products are beneficial as they provide additional nutrients. Additionally, certain complex carbohydrates found in whole grains and starchy vegetables contain healthy sugars along with nutrient-rich fibers.

Upon sugar consumption, its primary function is to supply energy to our brain and nervous system, crucial for regulating daily activities (Westenhoefer, 2006). Moreover, there are several other vital reasons for incorporating sugar into our diet, including:

Metabolizing Fats: Sugar aids in metabolizing fats, thereby preventing the utilization of proteins for energy, which are otherwise essential as structural constituents.

Reservoir of Energy: Glucose can be stored in the liver as glycogen, serving as a reservoir of energy. This stored energy is utilized by the body during physical exertion or when glucose isn't readily available as an energy source, thereby maintaining stable blood sugar levels (Backer, 1991).

Energy Source for Brain and Muscles: The adult brain consumes approximately 140 grams of glucose per day, representing half of the total dietary carbohydrate intake necessary for its proper functioning. Research indicates that sugar-sweetened beverages or carbohydrate-rich meals are associated with cognitive enhancements such as improved memory, reaction times, attention span, and arithmetic abilities. Additionally, sugar encourages cognitive effects and reduces fatigue (Sunram-Lea, Foster, Durlach, & Perez, 2001;Keul & Jakob, 1990). Moreover, sugar intake triggers the release of two brain hormones/neurotransmitters: serotonin, known as the "feel-good hormone," and beta-endorphin, which act as pain relievers and help alleviate anxiety (Misra et al., 2016).

Insufficient sugar intake in the diet results in low blood sugar levels, leading to various issues such as restlessness, distraction, hunger, and weakness. Additional symptoms may include chills, lack of coordination, sweating, and clammy skin. Prolonged adherence to a low-sugar diet can also result in blurred vision, headaches, confusion, and difficulty in performing even basic tasks. Furthermore, individuals may experience nightmares and crying during sleep (Misra et al., 2016).

It's widely recognized that excessive consumption of anything, including sugars, can have negative consequences. Elevated sugar intake can contribute to various health issues and potentially exacerbate or lead to numerous diseases.

A higher intake of dietary sugars is associated with a multitude of significant health challenges. These include compromised immune function, impaired ability to fend off bacterial infections due to diminished white blood cell activity, disruption of essential mineral and vitamin balances such as chromium deficiency and disturbances in calcium and magnesium roles within the body. Moreover, sugar consumption is linked to macular degeneration, accelerated aging through the production of harmful AGEs, inflammation, and irregular insulin activity. Sucrose intolerance may manifest with symptoms like abdominal discomfort and diarrhea, particularly prevalent in certain populations such as the people of Alaska. Allergic reactions to sucrose and sugar sensitivity, characterized by unstable blood sugar levels and reduced serotonin and beta-endorphin, further underscore the risks associated with excessive sugar consumption (Reas, 2014). Elevated triglyceride and cholesterol levels, DNA damage, and increased uric acid levels leading to hypertension and cardiovascular diseases highlight the comprehensive impact of sugar on overall health, emphasizing the need for moderation in sugar consumption (Misra et al., 2016).

1.2 The Sweetness Paradox: Innate Desires vs. Modern Diets

Human beings have an innate preference for sweet tastes, a trait present even before birth and observed universally across different ages and cultures. Nevertheless, the food landscape has dramatically transformed in recent years, now offering an abundance of convenient, high-calorie foods that are often rich in both fat and sugar.

Our food choices and consumption habits are significantly shaped by taste (de Graaf and Boesveldt, 2017). Working alongside other sensory systems, taste plays a crucial role in our decisions to accept or reject foods, ensuring we consume the necessary nutrients. This phenomenon is evident not only in humans but also in many animal species, where taste enhances the satisfaction and pleasure derived from eating and drinking (Drewnowski, 1997; Steiner et al., 2001).

Sweetness has always been a central element of the human diet. The emotional response to sweetness is reflected in the common use of the term "sweet" to describe both this essential taste and something pleasurable, as seen in expressions like "la dolce vita" (the sweet life) (Reed and McDaniel, 2006). While most adults enjoy sweet flavors, there are considerable individual differences in the preferred level of sweetness.
The reasons behind varying hedonic responses to sweet tastes are not yet fully understood (Armitage et al., 2021). Some studies suggest that humans can be classified into three phenotypic categories based on their response to sweetness: those who increasingly enjoy higher sweetness levels (sweet likers), those who dislike sweetness as it intensifies (sweet dislikers), and those who prefer moderate sweetness (Latreille et al., 2019).

The pleasure derived from tasting sweet substances is rooted in innate mechanisms. Experts believe that the natural preference for sweet flavors and aversion to bitter ones have evolved through natural selection. This evolutionary trait likely offers an adaptive advantage, encouraging newborns to seek out energy-rich foods while avoiding potentially harmful bitter substances (Mennella and Bobowski, 2015).

Sweetness is detected by specific receptors in the mouth. These receptors, which can sense sugars, polyols, and low-calorie sweeteners (LNCS), are part of a group of G-protein coupled transmembrane proteins known as T1R2 and T1R3. When these proteins form the sweet taste receptor and a sweet molecule binds to them, it triggers the release of alpha-gustducin, a G-protein linked to the sweet taste receptor. This event initiates intracellular signaling pathways, resulting in the release of calcium ions (Ca^{2+}) within the cells. The activation of the T1R2 and T1R3 receptors then stimulates gustatory nerves that convey sensory information to the brain via gustatory pathways (Renwick and Molinary, 2010). Similar receptors have also been identified in different parts of the digestive system, including the stomach, pancreas, colon, and enteroendocrine cells (Mehat and Corpe, 2018).

Infants' preference for sweetness aids in the acceptance of breast milk, which is sweet due to the presence of lactose, a sugar found in maternal milk. This implies that the liking for sweetness is rooted in basic biology (Drewnowski et al., 2012). "Liking" and "wanting" are two distinct components of food reward (Morales & Berridge, 2020). "Liking" refers to the pleasure derived from eating a particular food, while "wanting" is the desire or craving to consume that food (Berridge, 1996; Blundell et al., 2010). In contrast, "preference" involves a comparative assessment between different stimuli, leading to the choice of one over the others and establishing a hierarchy of attractiveness (Zellner, 2007). Differences in "liking" or "wanting" levels can shape preferences among various stimuli.

The tendency towards sweetness and aversion to bitterness are inherent traits (Mennella & Bobowski, 2015). This is evident in the "gusto-facial reflexes," which are automatic responses seen in newborns shortly after birth when small amounts of flavorful solutions are introduced into their mouths. Sugars induce a typical acceptance reaction, distinctly different from the rejection caused by bitter and sour substances (Steiner, 1977). When a sweet solution is given to an infant, facial relaxation, tongue protrusion, lip searching, and occasionally a smile can be observed (Steiner et al., 2001). Early studies on the development of sweet taste preferences suggest these tendencies might begin even before birth (Mennella & Beauchamp, 1998).

A recent study using 4D ultrasound scans discovered that fetuses between 32 and 36 weeks of gestation react to the flavors of foods ingested by their mothers in ways similar to postnatal responses (Ustun et al., 2022). The study found that fetuses displayed different facial movements based on the flavor they were exposed to. Notably, there were more facial expressions resembling laughter when exposed to a sweet carrot flavor and more expressions resembling crying in response to a bitter kale flavor.
Our innate desire for sweetness continues into old age, though research shows a decline in this preference from childhood to adulthood (Desor et al., 1975; Desor and Beauchamp, 1987; de Graaf and Zandstra, 1999; Mennella et al., 2011). Adolescence marks a shift in taste preferences, with children favoring higher sucrose concentrations than adults (de Graaf and Zandstra, 1999; Petty et al., 2020).

In a study of 485 participants, it was found that children had higher sucrose taste detection thresholds compared to adolescents. Adolescents, in turn, required higher sucrose concentrations than adults to detect a taste difference from water, indicating that higher levels of sucrose were needed for them to perceive sweetness (Petty et al., 2020). Despite this, no significant correlation was identified between sweet taste detection thresholds and preferences across different age groups. This finding suggests that sweet preference cannot be directly linked to variations in the ability to detect sweetness. It is theorized that the higher preference for sweetness observed in children and adolescents may be partly due to their increased caloric and nutritional needs during periods of significant physical growth. Studies supporting this hypothesis have found connections between the most preferred level of sweetness and children's height, as well as a biomarker related to bone resorption and growth (Coldwell et al., 2009; Mennella et al., 2014). While all humans show a similar response to sweetness immediately after birth, preferences for sweet taste change over time and become highly individualized in adults (Reed and McDaniel, 2006).

1.3 Factors Influencing Sweetness Preference and Liking in Humans

Recent reviews have examined the potential impact of various factors on sweetness preference and liking in humans (Venditti et al., 2020; Armitage et al., 2021). These factors include age, genetics, dietary and lifestyle habits, reproductive hormonal factors, body weight status and weight loss, personality traits, cultural background, prior exposure, and disease status.

Research indicates that genetic differences among individuals may contribute to the observed variability in sweetness perception and preference (Reed and McDaniel, 2006; Keskitalo et al., 2007; Fushan et al., 2010; Reed and Knaapila, 2010; Bachmanov et al., 2011; Joseph et al., 2016). However, it remains unclear how these genetic differences affect food intake and preferences throughout different life stages.

The relationship between sweetness preferences and reproductive hormonal factors is generally inconsistent, as noted in the review by Venditti and colleagues (Venditti et al., 2020). Similarly, the evidence regarding the connection between various personality traits and sweetness preference is limited and varied, with no clear or consistent associations found.

Furthermore, there is no consistent pattern in sweetness preference based on dietary macronutrient composition or meal makeup. However, literature suggests a tendency towards increased sweetness preference during fasting compared to when satiated.

Additionally, although based on limited studies, there is some indication that higher levels of physical activity might be associated with a decrease in sweetness preference (Venditti et al., 2020).

The term "sweet tooth" refers to a strong preference for sweet foods. While not scientifically defined, it raises questions about whether repeated exposure to sweet flavors, whether caloric or non-caloric, could heighten liking and appetite for sweet-tasting products, potentially leading to increased consumption.

Human affinity for sweet foods has led to speculation that a pronounced craving for sweetness could contribute to obesity. It is suggested that individuals' desire for sweet foods and drinks might promote excessive consumption, particularly in a society abundant with convenient and palatable food choices, potentially overriding the body's mechanisms regulating energy balance (Bellisle, 2015).

While it is evident that excessive consumption of energy-dense foods, including those with sweet tastes, can lead to an imbalance between energy intake and expenditure, resulting in weight gain, current evidence does not strongly support the widespread assumption that a strong liking for sweetness directly correlates with overeating and obesity (Venditti et al., 2020; Armitage et al., 2021).

Recent analysis of multiple studies contradicts the notion that individuals with obesity typically have a heightened preference for sweetness. Instead, it suggests that those classified as "sweet dislikers" may have slightly higher levels of body fat (Armitage et al., 2021). Furthermore, current evidence does not definitively support claims that individuals with obesity experience altered sweet taste sensitivity or perception compared to those of normal weight (Ribeiro and Oliveira-Maia, 2021).

Overall, existing data do not support the idea that a preference for sweetness is linked to higher body weight and obesity in adults. Research involving children and adolescents similarly indicates no differences in sweetness preference or consumption of sweet foods based on weight status (Venditti et al., 2020). For example, a study with 366 children aged 7-9 years found no association between adiposity and preference for sugary sweet foods (Hill et al., 2009). Similarly, another study involving 574 children and adolescents aged 10-17 years found no noticeable variations in sensory preferences or taste sensitivity across different body weight categories (Alexy et al., 2011).

In adolescents, findings from the Finnish Health in Teens cohort study involving 4237 girls and boys revealed that increased consumption of sweet-tasting treats was not associated with being overweight or with changes in weight over a 2-year follow-up period (Lommi et al., 2021).
Additionally, a study encompassing both children and adults found that regardless of age, preference for sweetness and liking for both caloric and low-calorie sweeteners did not differ between individuals with or without obesity (Bobowski et al., 2017). These collective results indicate that a heightened preference or liking for sweetness is not linked to body weight status in children, adolescents, or adults.

Despite this, there is a widespread belief that frequent exposure to sweet flavors in the diet could increase our craving for sweetness, potentially leading to overeating and subsequent weight gain. However, there is insufficient clear evidence supporting this notion (Bellisle, 2015; Public Health England, 2015; Rogers, 2018; Appleton et al., 2018; Wittenkind et al., 2018; Venditti et al., 2020; Armitage et al., 2021; Higgins et al., 2022).
A systematic review of 21 studies involving both children and adults concluded that current evidence from controlled human trials does not support the idea that exposure to sweetness in the diet influences later general acceptance, preference, or selection of sweet-tasting foods or beverages (Appleton et al., 2018).
In fact, greater exposure to sweet tastes often leads to a decrease in preferences for sweetness in the short term, a phenomenon known as sensory-specific satiety. This occurs when prolonged exposure to a specific sensory attribute, such as sweetness, reduces the perceived pleasantness and selection of foods and beverages with that same characteristic.

In a 3-month randomized controlled trial, a diet low in sugar and sweetness did not change sweet preference compared to a habitual diet, despite participants reporting increased perceptions of sweetness intensity (Wise et al., 2016). However, the implications of heightened sweetness perception on actual food choices remain unclear.
Results from seven studies examining the impact of exposure to different levels of dietary sweetness do not support claims that exposure to high versus low dietary sweetness affects calorie intake, consumption of sweet foods, or leads to overeating (Higgins et al., 2022).

Current research does not support the idea that repeated exposure to sweet tastes, whether they are caloric or non-caloric, leads to an increased appetite for or greater consumption of sugar-sweetened foods and beverages (Rogers, 2018; Appleton et al., 2018). Both laboratory and field studies have consistently shown that consuming products with a specific sensory attribute, such as sweetness, actually decreases the immediate pleasantness and attractiveness of foods and drinks that share that same attribute. This widely recognized phenomenon is known as "sensory-specific satiety" (Rolls, 1986; Hetherington et al., 2000; Liem and de Graaf, 2004).

In exploring the complexities of human food consumption behaviors introduced in Chapter 1, the concept of 'food addiction' emerges as a contentious yet compelling area of study. Chapter 2 delves deeper into the notion that certain foods, particularly those rich in sweet flavors or a combination of sweetness and fats, may activate brain regions associated with addictive behaviors. While the debate over whether food can truly be addictive remains unresolved, researchers have drawn parallels between food consumption patterns and substance-use disorders, citing similarities in neural responses and behavioral outcomes. However, the absence of formal recognition in diagnostic manuals like the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition by the American Psychiatric Association (APA)) underscores the ongoing challenges in defining and validating food addiction. As this chapter navigates through empirical studies, theoretical frameworks, and critical analyses, it aims to elucidate the intricate relationships between food reward systems, emotional responses, and the potential addictive properties of highly palatable foods.

Chapter 2: Exploring the Controversial Concept of "Food Addiction"

2.1 Exploring the Concept and Controversies of Food Addiction

The idea of "food addiction" rests on certain premises. A key premise is that particular foods, especially those with sweet flavors or a combination of sweetness and fats, activate brain regions also stimulated by addictive substances (Finlayson, 2017). Additionally, it is proposed that behaviors like binge eating can emerge, which mirror those found in substance-use disorders (Greenberg & St. Peter, 2021). However, it's important to note that food addiction is not formally recognized, as it is not included in the DSM-5, the primary diagnostic manual for mental health disorders (American Psychiatric Association, 2013). Moreover, the American Psychiatric Association points out that, despite some similarities between eating disorders and substance abuse, and evidence showing the involvement of brain reward systems in both, the neurobiological processes underlying binge eating differ from those of drug addiction (American Psychiatric Association, 2013).

Despite the established disparities between substance abuse disorders and eating disorders, the concept of "food addiction" has garnered attention from both researchers and the general public (O'Connor, 2021). This notion is grounded in a limited body of animal studies and is further supported by functional magnetic resonance imaging (fMRI) research (Greenberg & St. Peter, 2021). Critics have emphasized the lack of robust scientific evidence confirming that certain foods can override the brain's mechanisms for controlling food consumption. Moreover, the specific addictive components within foods remain undefined (Westwater, Fletcher, and Ziauddeen, 2016).

The pleasurable qualities of sweet flavors, whether nutritive or non-nutritive, have been well-recognized for many years (Sheffield & Roby, 1950). To assess if foods can induce addiction in a similar way to drugs, it is essential to understand how addictive substances like opiates function. As Wise (1987) noted, the behaviors driven by drugs mimic those influenced by naturally rewarding substances. Drugs of abuse can activate similar control mechanisms as other rewarding substances, often through their actions in specific brain circuits mediated by dopamine (Wise, 2004). The interactions between drugs of abuse and the brain’s response to palatable foods indicate shared mechanisms, though this does not confirm that the behaviors are identical. Some mechanisms underlying drug addiction have been identified, particularly those involving dopamine pathways and the amygdala (Weeks, 1962). The rewarding effects of external drugs frequently rely on internal neurotransmitters

(Ban, Brassai, & Vizi, 2020). Both agonists and antagonists of these neurotransmitters can either enhance or mitigate the effects of opiates and other drugs of abuse (Ahn & Phillips, 2002; Kibaly et al., 2019).

2.2 Understanding Sugar Addiction: Evidence and Debates

The concept of sugar "addiction" is largely derived from a small number of animal studies (Greenberg & St. Peter, 2021). Initial experiments with selective d-1 and d-2 dopamine antagonists in sham-feeding animals indicated that the rewarding properties of sweet and fatty stimuli are mediated through dopamine receptors (Schneider, Greenberg, & Smith, 1988). Sham feeding was used to isolate the taste-related stimulation from sucrose or corn oil while minimizing any post-ingestive effects. The use of dopamine antagonists resulted in reduced consumption, suggesting these antagonists decreased the reward value of sweet and fatty substances (Weatherford, Greenberg, Gibbs, & Smith, 1990; Schneider, Gibbs, & Smith, 1986). Further research using microdialysis techniques demonstrated that dopamine release in the nucleus accumbens is essential for the typical rewarding effect of sucrose (Smith, 2004; Stratford, Swanson, & Kelley, 1998). Early studies also showed that dopamine levels increased in a similar manner following cocaine administration (Hernandez & Hoebel, 1988).

Over the past two decades, there has been considerable research into the notion of food or sweet taste "addiction" in humans (Greenberg & St. Peter, 2021). The body of literature presents both supportive and opposing perspectives on this topic (Choo, Ha, & Sievenpiper, 2015; Blanco Mejia et al., 2014; Gearhardt, Corbin, & Brownell, 2009). Studies focusing on human diets, however, do not definitively indicate that specific nutrients or flavors, such as sugar or low-calorie sweeteners, are more likely to cause binge eating or weight gain compared to other food sources (Hunt et al., 2020; Malek et al., 2018; Marriott et al., 2018). In fact, those who consume low-calorie sweeteners generally consume fewer calories and carbohydrates, which suggests that sweet-tasting substances do not inherently lead to overeating or addictive behaviors (Sylvetsky et al., 2019).

To determine if certain foods exhibit addictive properties, researchers have considered whether they meet specific criteria for substance use disorders as outlined in the DSM-V (American Psychiatric Association, 2013). Brownell and his team developed the Yale Food Addiction Scale (YFAS), which incorporates some DSM criteria for substance disorders to quantify 'addiction-like eating' behaviors towards highly palatable, energy-dense foods (Gearhardt, Corbin, & Brownell, 2009). Despite these investigations, it is important to note that the American Psychiatric Association reviewed these findings and opted not to include "food addiction" as a diagnosable disorder in the DSM-V (American Psychiatric Association, 2013).

Research by Cummings et al. (2021) indicates that individuals with higher expectations that consuming highly processed sugary foods would enhance their positive emotions tended to consume more of these foods in a controlled laboratory environment. Although it is clear that emotional motivations drive the consumption of highly processed sugary foods, the precise impact of this behavior on emotions is still not fully understood.

A series of experiments have explored the effects of eating highly processed sugary foods on emotions, yielding varied results. For instance, two studies found that eating chocolate, compared to not eating, mitigated negative emotions induced in a laboratory setting. One of these studies also found that chocolate consumption maintained positive emotions, while the other observed an increase in positive emotions (Macht & Mueller, 2007). These effects were noted within three minutes of consumption. In a different study, participants reported higher levels of positive emotions correlating with the sugar content of the chocolate they consumed (Casperson, Lanza, Albajri, & Nasser, 2019).

However, other studies have produced different findings. One set of experiments found that consuming comfort foods (like chocolate, ice cream, cookies, and brownies) did not significantly alter negative emotions induced in a laboratory setting compared to not eating but did sustain positive emotions for a short duration of three minutes (Wagner, Ahlstrom, Redden, Vickers, & Mann, 2014). Additional experiments indicated that eating comfort foods did not significantly affect negative or positive emotions within an hour of a laboratory-induced stressor (Finch, Cummings, & Tomiyama, 2019). Similarly, consuming Twix® candy showed no significant impact on laboratory-induced negative emotions immediately or within an hour (McKay et al., 2021).

In summary, the experimental evidence suggests that while consuming highly processed sugary foods does not consistently reduce negative emotions, it may more consistently sustain or enhance positive emotions.

Although immediate effects of eating may involve an increase in positive emotions and a decrease in negative emotions, this dynamic could shift several hours later due to subsequent negative cognitive evaluations of the eating episode (e.g., thoughts like "I ate junk"; Smith, Mason, & Lavender, 2018) or delayed physiological responses to eating (e.g., postprandial decreases in blood glucose levels; Ludwig, 2002).

The potential for highly processed sugary food consumption to briefly elevate positive emotions is consistent with research showing that the intake of such foods activates reward and pleasure systems in a manner resembling addictive substances (DiFeliceantonio et al., 2018; Small & DiFeliceantonio, 2019). When addictive substances produce short-lived pleasurable effects, it amplifies their addictive nature (Henningfield & Keenan, 1993; McColl & Sellers, 2006). As the initial pleasurable experience fades, it may trigger a craving for more of the addictive substance. Thus, the fleeting nature of the positive emotions resulting from consuming highly processed sugary foods may serve as a reinforcement and prompt further intake to sustain positive emotions over time.

Although a 4–5% increase in immediate positive emotions following highly processed sugary food consumption may seem statistically minor, intravenous consumption of approximately one standard drink of alcohol (0.02 g/dL BAC) similarly showed a significant association with approximately a 5% increase in positive emotions (Ray, Bujarski, Squeglia, Ashenhurst, & Anton, 2014). Similarly, intravenous administration of a small dose of cocaine (12.5 mg/70 kg) was significantly associated with approximately a 10% increase in positive emotions (Smith, Jones, & Griffiths, 2001).

Chocolate holds a special place in our culture, widely cherished and often craved despite its problematic nature (Schulte, Avena, & Gearhardt, 2015). Its consumption is linked to pleasant feelings, tension reduction, and mood enhancement (Macht & Dettmer, 2006; Meier, Noll, & Molokwu, 2017). Furthermore, chocolate activates specific brain regions differently than other high-sugar, high-fat foods, engaging areas involved in craving responses, which may increase its potential to provoke addictive-like eating behavior (Asmaro & Liotti, 2014). The unique blend of cocoa, sugar, and fat in chocolate plays a vital, though distinct, role in eliciting this addictive-like response. According to Smit, Gaffan, and Rogers (2004), the main psychoactive components of cocoa can produce psychostimulant effects, but they highlighted that attributes like sweetness and texture might be even more influential in this context (Casperson et al., 2019). The activation of sweet taste receptors, the speed at which the information about a food is delivered from the chemosensory and somatosensory neurons in the mouth to the brain, and the magnitude of the activation of the food reward system govern the reinforcing and rewarding effect of sugar (Lee & Owyang, 2017; Treatment for Stimulant Use Disorders, 1999).

Casperson, Lanza, Albajri, and Nasser (2019) found that the percentage of cocoa and sugar content influenced the "desire to consume more chocolate," whereas fat content showed a trend towards significance for this effect (Nasser et al., 2011). DiFeliceantonio et al. (2018) reported a supra-additive effect of combining sugar and fat on food reward in humans, while other studies have shown that the sugar component in a sugar/fat combination is particularly effective at activating reward (Epstein et al., 2011; Stice et al., 2013) and gustatory brain circuits (Stice et al., 2013). Furthermore, research demonstrated that the highly reinforcing properties of sugar are challenging to resist (Casperson, Johnson, & Roemmich, 2017a; Casperson & Roemmich, 2017b). Overall, chocolate's appeal seems to stem from the synergistic interplay of its components.

2.3 The Role of Fat and Sugar in Food Reward Mechanisms

The effects of fat and sugar on food's rewarding aspect involve the activation of both dopamine and opioid neurotransmitter systems (Berridge, 2009; Pecina, 2008; Wise, 2006). While the dopamine system drives the motivation to consume food by instigating a sense of "wanting" (Berridge, 2009; Wise, 2006), the opioid system enhances the pleasurable value associated with desired food, influencing its intake (Berridge, 2009; Pecina, 2008). Consequently, the sensory cues of highly palatable foods like chocolate collaborate to trigger motivational and hedonic reward mechanisms, stimulating the pursuit and consumption of such foods. The subjective effects of food consumption on dopaminergic and opioidergic systems can be discerned using the Addiction Research Center Inventory (ARCI) (Balster & Walsh, 2010). In a prior study, the ARCI, specifically its Morphine-Benzedrine Group (MBG), Morphine (M), and Excitement (E) subscales, were employed in a between-group design, distinguishing groups based on the percentage of cocoa in the sampled chocolate, to unveil indicators of chocolate's psychoactive effects.

The research conducted by Casperson, Lanza, Albajri, and Nasser (2019) highlights the significance of consuming chocolate with a 90% cocoa content, which was found to increase the total number of positive responses and positive responses on the E subscale. Despite its perceived bitter taste, the presence of bioactive compounds in dark chocolate potentially explains these favorable outcomes. Moreover, studies by Smit et al. (year) revealed that methylxanthines, such as theobromine and caffeine, present in dark chocolate can induce psychostimulant effects, consistent with our findings of heightened physical and psychological sensations of excitement following chocolate consumption.

Individuals, including those with obesity, consume highly palatable foods which are mostly sugary (HPFs) for various habitual reasons, primarily coping, seeking reward, social interaction, and conformity (Boggiano et al., 2015; Moore, Rice, Gampher, & Boggiano, 2024).Coping-related HPF eating is notably linked to higher BMI, future BMI increase, binge eating, emotional and restrained eating, excessive concern with body weight and shape, stress reactivity, perceived stress, cravings for HPFs, suggestibility, emotional dysregulation, and self-criticism (Abdulla et al., 2023; Davis et al.,2015; Volkow et al., 2019). These behaviors generally oppose healthy body weight and mental well-being. There is limited understanding of HPF and sugary eating motives within mental health disorders (MHDs). HPF consumption can temporarily mitigate stress responses and negative emotions, making coping-related HPF eating more prevalent in affective and stress-related disorders such as PTSD. Reward-seeking HPF eating is more characteristic of disorders like ADD, ADHD, and substance use disorders. Coping and conformity eating are likely more common in body dysmorphic disorder (BDD) due to the stress-relieving effects of HPFs and the internalization of idealized body images (Moore, Rice, Gampher, & Boggiano, 2024).

The concept of emotional eating suggests that some individuals consume food to manage stress, which can increase their risk of obesity (Bruch, 1973; Kaplan & Kaplan, 1957; Slochower, 1983; Thayer, 2001; Macht & Mueller, 2007). Although this idea has been deemed overly simplistic (Greeno & Wing, 1994), there is supporting evidence for the role of emotional eating in the connection between stress and obesity. Studies in real-world settings have shown that negative emotions can lead people to eat as a way to regulate their feelings (Macht, Haupt, & Ellgring, 2005; Macht & Simons, 2000) and to consume more sweet foods (Pollard, Steptoe, Canaan, Davies, & Wardle, 1995; Striegel-Moore et al., 1999; Macht & Mueller, 2007). Experimental research has found that individuals classified as emotional eaters through surveys (van Strien, Frijters, Bergers, & Defares, 1986) tend to eat more sweet, high-fat foods in response to emotional stress compared to non-emotional eaters (Oliver, Wardle, & Gibson, 2000; Wallis & Hetherington, 2004). Similarly, obese binge eaters are more likely to binge and consume larger quantities of food when experiencing negative emotions (Agras & Telch, 1998; Gluck, Geliebter, Hung,

& Yahav, 2004; Telch & Agras, 1996). Additionally, treatments focused on improving emotion regulation have been effective in managing binge eating disorder (Telch, Agras, & Linehan, 2001; Macht & Mueller, 2007).

The study conducted by Macht and Mueller (2007) demonstrates that consuming chocolate can promptly enhance a negative mood state induced by experimental conditions. Conversely, chocolate had no effect on a neutral mood and only a slight impact on a happy mood. These findings align with the emotional eating theory, which posits that eating can serve as a strategy to manage negative emotions.

To bridge the insights gained from Chapter 2 into the explorations of Chapter 3 on neural mechanisms of food reward, it is essential to recognize the intricate interplay between psychological and neurobiological factors in shaping eating behaviors. Chapter 2 highlighted the multifaceted nature of food preferences and the influence of sensory, cognitive, and environmental cues on food choice. These factors set the stage for Chapter 3's deeper dive into the neural underpinnings of food cravings and satisfaction. Understanding how sensory enjoyment ("liking") and motivational drive ("wanting") are orchestrated by brain circuits, particularly those involving dopamine pathways and mesolimbic systems, elucidates why certain foods become highly sought after and rewarding. By exploring these mechanisms, Chapter 3 expands our comprehension of how individuals navigate food choices and may offer critical insights for clinical practice, particularly in addressing disorders where dysregulation of food reward systems plays a central role.

Chapter 3

Neural Mechanisms of Sugar Cravings and Satisfaction: Implications for Eating Behavior and Clinical Practice

3.1 Exploring 'Wanting' and 'Liking': Distinct Psychological Processes in Food Reward

In everyday language, the terms "liking" and "wanting" are frequently used as synonyms when discussing rewards. For instance, an individual might desire a tasty piece of chocolate because they enjoy its flavor and the sensory experience of eating it. Generally, "liking" refers to the conscious enjoyment and "wanting" to the conscious desire, both of which involve cognitive evaluations and explicit goals managed by brain circuits with a heavy cortical influence. However, in this context, we use quotation marks around 'wanting' and 'liking' to denote distinct psychological processes that differ from their common usage (Berridge & Kringelbach, 2015).

'Wanting' specifically denotes the psychological process known as incentive salience, which may manifest either consciously or unconsciously. This process is driven by the brain's mesolimbic circuitry and is characterized by cue-induced motivation. When rewards, like tasty foods, and their associated signals are endowed with incentive salience by the mesocorticolimbic system, these cues and foods become highly appealing. If experienced consciously, they can trigger subjective cravings. Regardless of consciousness, cue-induced incentive salience can also lead to behavioral impulses to pursue and consume the related rewards (Winkielman & Berridge, 2004; Berridge, 2018).

In laboratory settings, the concept of 'wanting' is commonly assessed in humans through subjective ratings of craving, while in animals, it is evaluated by the degree of food pursuit, consumption, or preference over alternatives. In animals and infant humans, 'liking' can be determined through objective measures of hedonic orofacial expressions exhibited during taste assessments, such as in the affective taste reactivity test (Steiner, 1973; Steiner, 1974; Grill & Norgren, 1978; Steiner, Glaser, Hawilo, & Berridge, 2001; Berridge, 2000; Morales, Berridge, 2020).

The hedonic taste reactivity task assesses affective orofacial responses to various tastes, such as sucrose and quinine, with reactions influenced by physiological, learning, and brain manipulation factors affecting palatability. Originally developed for human infants by Steiner (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004), the test was adapted for rodents by Grill and Norgren (Jenkins & Moore, 1973). Orofacial responses to taste are categorized as positive, neutral, or aversive, reflecting hedonic evaluations. These expressions are conserved across mammalian species.

Morales et al. implanted in rodents oral cannulae to directly infuse taste solutions, enabling precise control over stimulus presentation. This independence from appetitive decisions allows taste reactivity to measure 'liking' without interference from changes in 'wanting' (Berridge, 2000; Castro & Berridge, 2014). Interestingly, diverse tastants, like sucrose, saccharin, salt, and fats, can evoke similar positive 'liking' responses, suggesting palatability-specific rather than sensory-specific hedonic reactions (Davidson et al., 2011; Peciña & Berridge, 2005; Robinson & Berridge, 2013; Shin et al., 2011).

Physiological states, such as hunger and satiety, can modulate hedonic reactions to taste. For instance, hunger intensifies positive 'liking' reactions to sweet tastes, while satiety reduces them, a phenomenon known as alliesthesia (Laeng, Berridge, & Butter, 1993; Cabanac, 1971; Cabanac, 1979; Berridge, 1991; Cabanac & Lafrance, 1990). Similarly, salt appetite influences the hedonic impact of salty tastes (Berridge & Grill, 1984; Clark & Bernstein, 2006; Tindell et al., 2009; Tindell et al., 2006; Berridge & Schulkin,1989).

Learned associations also play a role, as demonstrated by conditioned taste aversions induced by pairing a 'liked' taste with an aversive stimulus (Berridge, Grill, & Norgren, 1981; Parker, 2003; Spector, Breslin, & Grill, 1988; Spector, Norgren, & Grill, 1992; Grill & Norgren, 1978; Wilkins & Bernstein, 2006).

Food reward extends beyond the physical properties of taste stimuli, although the palatability of new sweets and bitters may be influenced by their physical characteristics. Palatability, the hedonic aspect of food reward, arises from a central integrative process that incorporates not only taste but also physiological state and individual associative history.

The distinction between hunger and reward is not absolute, as both concepts are interrelated and arise from different sensory receptors. Food reward involves both an incentive process and a drive reduction process. It is focused on the sensory experiences of taste, smell, sight, and the tactile feel of food and the act of eating. Physiological cues related to deficits modify the value of these incentive stimuli and their representations rather than directly triggering or reinforcing behavior.

The role of the mesotelencephalic dopamine system in mediating reward has been well-documented, with significant contributions from Wise's anhedonia hypothesis. Wise's research demonstrated that moderate suppression of dopaminergic function diminishes the hedonic value of brain stimulation, psychoactive drugs, and preferred foods, distinct from effects on motor coordination or general arousal. For instance, dopaminergic antagonists reduce preference for and consumption of sweet rewards in a manner akin to diluting the reward itself. This line of evidence suggests that dopamine systems play a critical role in food reward.

The anhedonia hypothesis implies that a reduction in dopamine function would lead to decreased liking. However, nearly all supporting evidence for this hypothesis comes from experiments that show reductions in wanting measures of reward. These measures typically require animals to actively engage in behaviors to obtain their reward, such as pressing a lever or licking. Even voluntary consumption, considered a consummatory behavior, involves an appetitive aspect if it requires directed actions toward the reward. For example, studies on the effects of dopamine antagonists on consumption suggest that these drugs specifically impair the appetitive component of consummatory behavior (Olney & Berridge, 2018; Peciña & Berridge, 2000).

The incentive salience hypothesis has significant implications for understanding specific food cravings. A widely held belief is that such cravings are driven by intense likings for particular foods. This is true for some cravings, like salt appetite. However, it may not apply universally. If the dopamine-related wanting system becomes hyperactivated selectively, it can result in a focused and intense craving for a specific target, even if there is no corresponding increase in liking for that food. This scenario resembles the effects of electrical stimulation of the lateral hypothalamus.

To comprehend why a hypothetical craving would target one specific food, it is crucial to recognize that the incentive salience attributed by an activated dopaminergic system is not indiscriminately assigned to all stimuli. Rather, it is guided by associative learning processes. Stimuli that are already significant incentives become even more salient, and new stimuli that are paired with the system's activation can also become future incentives. Therefore, if the incentive salience system is hyperactivated, intense cravings would likely be focused on particular foods, similar to the directed feeding behavior elicited by lateral hypothalamus stimulation.

This concept parallels explanations for addiction development and the focused craving for drug-taking. The key distinction between addiction and food cravings lies in the neural sensitization caused by psychostimulant drugs in dopamine-related systems, which significantly amplifies craving. This intensification is usually more pronounced in drug addiction than in food cravings, although the underlying processes are quite similar (Grill & Norgren, 1978; Steiner et al., 2001; Berridge, 2000).

Differences were observed in how the pleasantness of food was rated throughout a meal, depending on whether participants assessed the taste of the food or the experience of eating it. These differences highlight the complexities in interpreting food palatability, which can be affected by factors such as changes in motivation or intrinsic palatability fluctuations during consumption (Devoto et al., 2018; Robinson et al., 2015; Kringelbach, 2015). 'Liking' is essentially an affective response, reflecting the immediate hedonic impact of a stimulus. Therefore, a measure of 'liking' should ideally track changes in the neural response to the immediate reward of a stimulus. A complication arises when similar methods are used to measure 'liking' and 'wanting' sequentially, as individuals might conflate the two questions, adjusting their responses to maintain consistency and avoid cognitive dissonance. To address this, it is crucial to design integrated measures that treat 'liking' and 'wanting' as distinct processes, preventing one judgment from influencing the other.

Finlayson et al. have shown that 'liking' and 'wanting' for specific food categories diverge more in the hungry state than in the satiated state. When participants were hungry, they 'wanted' high-fat savory foods more than low-fat savory foods without a corresponding increase in 'liking.' Conversely, they 'liked' high-fat sweet foods more than low-fat sweet foods but did not show a difference in 'wanting' for these categories. When satiated, participants 'liked' high-fat savory foods more than low-fat savory foods but did not 'want' them more, and 'wanted' low-fat sweet foods more than high-fat sweet foods but did not 'like' them more.

Engaging excessively in highly rewarding stimuli or behaviors, such as substances, alcohol, certain foods, or refined sugars, despite negative consequences, is a characteristic feature of various psychological disorders, including substance use disorders, eating disorders, and behavioral addictions. Dysfunction in the brain’s reward system is well-documented in contributing to the development and persistence of these disorders. This dysfunction is primarily conceptualized as a hyperactive reward response, characterized by heightened activation of dopaminergic cortico-striatal pathways, to specific disorder-related stimuli like alcohol, palatable food, sugars or pornography (Blum et al., 1996; Schulte et al., 2016). Although the hyper-reward response to specific stimuli is a significant factor in addiction, recent research indicates that this hyperactivity is just one aspect of the intricate reward dysfunction that underpins excessive engagement in maladaptive, reward-driven behaviors.

Excessive engagement in reward-driven maladaptive behaviors may also be perpetuated by hypo-reward responsivity, characterized by low activation of dopaminergic cortico-striatal pathways, to typically rewarding stimuli such as social interactions, work-related accomplishments, and hobbies (Hagerty & Williams, 2020).
When daily activities fail to provide adequate rewards, individuals might experience a decrease in motivation to participate in these activities (Husain & Roiser, 2018).

The motivation to participate in usually enjoyable activities ("wanting" for reward from such activities) tends to diminish over time as the engagement in these activities is inadequately reinforced by the low levels of experienced reward (Berridge & Robinson, 2003). Consequently, a vicious cycle can ensue (as illustrated in black text in Fig. 1 below), where everyday opportunities to experience reward become progressively scarce, potentially leading to or exacerbating anhedonia and depressed mood (Berridge & Robinson, 2003).

In an attempt to achieve sufficient reward, individuals may increasingly seek out stimuli that strongly activate neural reward pathways, such as illicit substances, or excessively engage in naturally rewarding behaviors like consuming palatable foods (Schulte et al., 2016).

Excessive engagement in behaviors or substances that drive maladaptive reward-seeking may intensify as individuals pursue larger quantities or more frequent exposure to a narrow range of highly stimulating rewards.

This hypothesis aligns with maladaptive scaling theory (Zald & Treadway, 2017), which suggests that excessive engagement in highly rewarding behaviors, such as consuming palatable foods and sugars, leads to a decreased hedonic impact of other rewards, like daily activities. This diminished capacity to derive pleasure from everyday activities perpetuates continued participation in highly rewarding but maladaptive behaviors.

Research has shown that corticotropin-releasing factor (CRF) neurons located in the amygdala and nucleus accumbens (NAc), which are traditionally known for their role in mediating the negative effects of stress, also have a significant influence on positive motivations. Specifically, these neurons can control cue-triggered 'wanting' for rewards like sucrose and cocaine (Baumgartner et al., 2021; Baumgartner, Granillo, Schulkin, & Berridge, 2022; Peciña, Schulkin, & Berridge, 2006; Morales, 2023).

Interestingly, research indicates that stress can transform nucleus accumbens (NAc) corticotropin-releasing factor (CRF) neurons from primarily positive to aversive (Lemos et al., 2012). Additionally, studies have demonstrated the strong nature of sugar addiction. For instance, animals with channelrhodopsin (ChR2) expressed in the central amygdala (CeA) vigorously seek out laser-paired rewards such as sucrose and cocaine, and even become attracted to a painful electric shock they can voluntarily contact (Warlow, Naffziger, & Berridge, 2020; Morales, 2023).

3.2 The Overlap of Homeostatic and Hedonic Mechanisms in Food Reward: Implications for Sugar Addiction

The integration of incentive theories with current neurobiological understandings of hunger and appetite reveals a conflict between traditional homeostatic and hedonic concepts in motivation research. While conventional views suggest a clear anatomical division between homeostatic processes in the hindbrain/hypothalamus and hedonic functions in mesolimbic structures, evidence challenges this dichotomy. Studies demonstrate that hindbrain systems can mediate rudimentary hedonic functions, such as benzodiazepine microinjections into the parabrachial nucleus (PBN) inducing hedonic 'liking' reactions in rats (Soderpalm & Berridge,2000). Moreover, decerebrate rats lacking a forebrain can still distinguish between hedonic and aversive taste qualities, indicating that some hedonic processing occurs in the hindbrain. These findings suggest that the anatomical separation of homeostatic and hedonic systems may not be as clear-cut as traditionally (Morales, 2023).

Psychological risk elements, such as impaired reward mechanisms, high impulsivity, and challenges in regulating emotions, are posited to play a role in both binge eating and food addiction (FA). Specifically, both binge eating and FA are typically associated with heightened sensitivity to rewards, increased cravings for food, and an exaggerated response to food-related stimuli. These factors are similarly relevant in the context of sugar addiction, where individuals may exhibit an amplified craving for sugary foods and an intense response to the presence of sugar, mirroring the patterns observed in binge eating and FA (Kober & Boswell, 2018; Maxwell, Gardiner, & Loxton, 2020; Kalan, Smith, Mason, & Smith, 2023)

Research indicates that the reinforcement received from binge eating can enhance learned expectations that consuming food will enhance mood, known as eating expectancies (Hohlstein, Smith, & Atlas, 1998; Kalan, Smith, Mason, & Smith, 2023). However, individuals with food addiction (FA) exhibit lower expectations of positive reinforcement from eating compared to those without FA, which may suggest the development of tolerance in the context of addiction (Meule & Kübler, 2012).

Although there are similarities in the experiences and psychological processes involved in binge eating and food addiction (FA), distinct mechanisms are suggested by addiction and eating disorder theories for each condition. A unique aspect of FA is its connection to the addictive properties of ultra-processed, highly palatable foods, along with symptoms of tolerance and withdrawal. These foods, which are heavily modified, contain high levels of rewarding ingredients such as refined carbohydrates (including added sugars), sodium, hydrogenated oils, and various additives and flavor enhancers (Gibney, 2019; LaFata & Gearhardt, 2019, 2022).

Ultra-processed foods share characteristics with addictive substances, reflected in similar biological and behavioral reactions among individuals with FA and those with substance use disorders. For instance, recent research suggests that FA might involve tolerance, as indicated by reduced striatal responsiveness following consumption of highly palatable, ultra-processed foods (Schulte et al., 2016). However, not all evidence supports the tolerance concept; some studies show that frequent consumption of ultra-processed foods increases the preference for sweet, fatty, and salty tastes (Parnarouskis & Gearhardt, 2022). Additionally, previous studies revealed that individuals who binge eat exclusively consume ultra-processed foods during binge episodes (Ayton, Ibrahim, Dugan, Galvin, & Wright, 2021).

In terms of sugar addiction, these findings highlight the addictive potential of sugar, a prevalent ingredient in ultra-processed foods, in promoting eating behaviors and developing tolerance and withdrawal symptoms.

3.3 Hedonic Hunger and Its Role in Sugar Addiction and Obesity

Hedonic hunger, which emerges during times of relative energy abundance, can override the body's homeostatic mechanisms by amplifying the craving for palatable foods (Ulker, Ayyildiz, & Yildiran, 2021; Karamizadeh et al., 2021). These palatable foods trigger reward pathways by releasing neurotransmitters like dopamine, endocannabinoids, and opioids, resulting in a pleasurable eating experience that encourages further consumption. Over time, this cycle can contribute to weight gain and obesity (Berg Schmidt et al., 2018; Monteleone et al., 2012).

In the context of sugar addiction, hedonic hunger plays a significant role, as sugary foods are particularly effective at stimulating these reward processes. This heightened pleasure response increases the likelihood of repeated consumption, leading to potential weight management challenges and obesity-related health issues.

An impaired interaction between the homeostatic and hedonic systems may contribute to obesity (Egecioglu et al., 2011). Palatable foods enhance the motivational and hedonic aspects of the reward process, reinforcing their consumption. In individuals of normal weight, homeostatic signals can moderate food reinforcement, but this regulation appears to be lacking in individuals with obesity (Egecioglu et al., 2011). Moreover, individuals with obesity may experience alterations in the hedonic set point for food, leading them to assign inappropriate rewarding values to foods. Overeating may result from the heightened responsiveness of reward circuits to palatable foods (Egecioglu et al., 2011; Karamizadeh et al., 2021). Additionally, Morales and Berridge (2020) reported that dopamine receptor levels can be down-regulated in individuals with obesity, possibly due to excessive consumption of sugary foods. It has been proposed that this down-regulation is primarily a consequence of consuming sugary, palatable foods, as these foods trigger excessive or repeated dopamine release, ultimately leading to compensatory down-regulation of dopamine receptors (Morales & Berridge, 2020).

Chapter 4: Strategies to Overcome Sugar Addiction

Overcoming sugar addiction requires a multifaceted approach that addresses both the physical and psychoemotional aspects of dependence. This chapter outlines evidence-based strategies to help individuals reduce their sugar intake and manage cravings effectively. These strategies encompass psychological and nutritional support lifestyle changes, emphasizing the importance of addressing the reward imbalance in daily activities and maladaptive behaviors.

4.1 Psychological Support

4.1.1 Cognitive Behavioral Therapy (CBT) and Dialectical Behavior Therapy (DBT):

Current behavioral treatments for reward-driven maladaptive behaviors largely overlook the hypo-reward response to daily activities. For instance, these treatments typically emphasize either reducing exposure to reward-related cues (e.g., stimulus control; Fairburn, 2008) or enhancing cognitive control over rewards (e.g., teaching patients to "urge-surf" during cravings; Marlatt & Donovan, 2005). While CBT and DBT are effective in reducing engagement in reward-driven maladaptive behaviors, poor outcomes and relapse remain common. These therapies may fall short in addressing reward dysfunction because they inadequately target the hypo-reward response to daily activities. CBT and DBT do encourage participants to engage in "alternative" or pleasurable activities (Fairburn, 2008; Linehan, 2014); however, these treatments primarily use such activities to cope with urges to engage in maladaptive behaviors, focusing more on decreasing negative emotions rather than increasing positive emotions (Juarascio & Presseller, 2020). If patients are unable to derive reward from everyday activities, it is unsurprising that maladaptive behaviors may persist or re-emerge following treatment, as these behaviors remain one of the few available sources of reward. Consequently, developing behavioral treatments that address both aspects of the reward imbalance could enhance outcomes for many psychological disorders.

4.1.2 Reward Re-Training (RRT):

There have already been successful trials to help people overcome food and sugar addiction. For instance, the Reward Re-Training (RRT) program focused on identifying, scheduling, and implementing activities. This approach, similar to behavioral activation (Jacobson et al., 1996), was designed to increase both momentary reward through pleasant event scheduling and sustained reward by engaging in activities meant to provide a deeper, more long-lasting sense of fulfillment from building a meaningful, personally valued life. The trial of RRT yielded significant improvements in both the frequency of binge eating and overall eating pathology. These results indicate that, although RRT did not specifically target eating disorder (ED) pathology, the intervention's focus on enhancing both momentary and sustained rewards indirectly alleviated ED symptoms. Remarkably, the remission rate achieved with RRT was 46.7%, comparable to the 30-50% remission rates reported for Cognitive Behavioral Therapy (CBT), which is currently the first-line psychological treatment for EDs characterized by binge eating (Linardon et al., 2017). These findings suggest that RRT may be an effective alternative or complementary approach to existing treatments for overcoming sugar addiction and related eating disorders.

4.2 Nutritional Strategies

Dietitians, particularly those well-versed in the psychological aspects of eating, such as Registered Dietitians (RDs), are instrumental in assessing an individual's nutritional status, dietary beliefs, and eating patterns (Rosenberg & Feder, 2014). They can create personalized meal plans to support healthy behavioral changes in individuals struggling with food addiction (Setnick, 2013; Waterhous & Jacob, 2011). RDs assist patients in recognizing foods that may provoke compulsive eating, in deciphering food labels, and in understanding appropriate portion sizes, which binge eaters often misjudge (Herrin, 2003). Furthermore, these nutrition professionals work with patients to develop creative, nutritious alternatives to highly palatable foods that meet their taste preferences without leading to overeating (Peeke & Van Aalst, 2012).

Foods that are particularly high in sugar and fat, often referred to as hyperpalatable, are considered a potential risk factor for developing food addiction. Consequently, avoiding these foods might help protect against this condition. The Food Addiction Research Education (2009) advises individuals dealing with food addiction to steer clear of processed foods, artificial sweeteners, flour, gluten-containing grains, and items with hydrogenated, partially hydrogenated, or trans fats. Instead, they should focus on consuming high-quality proteins, mono- and polyunsaturated fats, complex carbohydrates, along with fruits and vegetables. Additionally, reducing intake of caffeine and liquid calories is recommended to help manage cravings (Rosenberg & Feder, 2014). The discussion on whether to permanently or temporarily exclude hyperpalatable foods is ongoing, with more research needed to determine the best approach for sustained recovery from food addiction (Setnick, 2013).

Dietary restraint involves the cognitive effort to restrict food intake, often guided by dietary rules due to concerns about weight and body shape (Schaumberg, Anderson, Anderson, Reilly, & Gorrell, 2016). Extreme and inflexible forms of restraint have been linked to the development of eating disorders and may contribute to binge eating by increasing hedonic hunger and feelings of deprivation from highly palatable foods (Lowe et al., 2009; Schaumberg et al., 2016; Kalan, Smith, Mason, & Smith, 2023). It is also noteworthy that persistent, unsuccessful efforts to reduce or cease consumption are characteristic of both substance use disorders and food addiction (FA). Therefore, for individuals who frequently binge eat, restraint might represent unsuccessful attempts to regulate the intake of highly palatable and rewarding foods.

In the context of sugar addiction, these findings underscore how rigid dietary restraint can exacerbate cravings for sugary foods, highlighting the struggle individuals face when attempting to control their intake. Despite the similarities, research on the relationship between FA and dietary restraint remains sparse and inconclusive, with some studies indicating positive associations and others not finding significant connections (Schulte et al., 2016).

A structured dietary plan can be a valuable tool for individuals struggling with sugar addiction and Binge Eating Disorder (BED) (Waterhous & Jacob, 2011). Similar to those grappling with food addiction, BED sufferers often face challenges in maintaining balanced macronutrient intake, consistent meal timing, and recognizing satiety cues. An individualized meal plan that meets their caloric requirements can provide essential structure for managing both BED and food addiction (Setnick, 2013). Hydration plays an important role as well. Sometimes, thirst is mistaken for hunger or sugar cravings. Drinking plenty of water throughout the day can prevent dehydration and reduce the urge to consume sugary foods.

Individuals with BED, like those with food addiction, may attempt to compensate for binge episodes through periods of dietary restriction (Rosenberg & Feder, 2014). However, these cycles of restriction can lead to physical and psychological deprivation, impairing their ability to regulate food intake. This deprivation may exacerbate their tendency to disregard satiety signals, potentially triggering further overeating during subsequent meals. Moreover, these binge episodes can intensify feelings of guilt and shame associated with disordered eating behaviors, perpetuating the misconception that restrictive eating is a solution (Herrin, 2003, p. 156). A personalized meal plan emphasizing balanced macronutrient distribution, appropriate portion sizes, and regular meal timing can help recalibrate the eating patterns of individuals with disordered eating habits. It aligns dietary intake with specific nutritional needs, potentially reducing physiological urges to engage in compulsive eating (Herrin, 2003; Rosenberg & Feder, 2014).

Given the observation that eliminating one triggering food can lead to problematic behaviors with other foods, nutrition therapy has increasingly focused on abstaining from unhealthy eating patterns rather than specific foods (Setnick, 2013). Behavioral strategies aimed at modifying eating habits have shown promise in managing symptoms of food addiction. These include avoiding distractions while eating, managing leftovers responsibly, planning grocery trips in advance, avoiding shopping while hungry, choosing single-serving portions, opting for foods that require preparation, restricting available funds for food purchases, dining with others, and practicing oral hygiene after meals (Fairburn, 1995; Setnick, 2013). Additionally, adopting mindful eating practices, stocking the kitchen with non-triggering foods, engaging in regular physical activity, and ensuring adequate sleep are practical recommendations from the Food Addiction Research Education (2009).

Self-monitoring techniques play a crucial role in enhancing individuals' awareness of their eating habits and have been effective in reducing binge eating among those with Binge Eating Disorder (BED) (Herrin, 2003), suggesting their potential benefit for individuals struggling with sugar addiction. One common method used is food journaling, where individuals record their daily food intake, levels of hunger and fullness, and emotions related to eating. Reviewing these entries helps individuals differentiate between physical and emotional hunger and fullness, providing valuable insights into emotional states that may contribute to binge or overeating episodes (Herrin, 2003). For example, someone who often feels guilty after eating certain foods like chocolate could benefit from exploring with a therapist other sources of guilt unrelated to food (Setnick, 2013). Additionally, the process of journaling itself helps individuals identify, cope with, and avoid personal triggers that lead to overeating.

4.3 Self-Realization and Fulfillment

While traditional approaches focus on behavioral interventions and dietary modifications, there is growing recognition of the role of self-realization and a sense of fulfillment in life as crucial factors in combating this addiction.

Self-realization involves gaining a deep understanding of oneself, including motivations, emotions, and behavioral patterns (Rosenberg & Feder, 2014). It allows individuals to identify underlying reasons for their addictive behaviors, including those related to sugar consumption. For instance, stress, emotional eating, and seeking pleasure are common triggers for indulging in sugary treats. Through self-realization, individuals can recognize these triggers and develop healthier coping mechanisms.Personal introspection and therapy can aid in this process, helping individuals uncover deeper emotional needs that sugar consumption may temporarily fulfill. By addressing these needs through self-awareness and psychological growth, individuals can reduce their reliance on sugar as a coping mechanism.

A sense of fulfillment in life stems from aligning one's actions and goals with personal values and aspirations. When individuals lead a purpose-driven life, where daily activities and long-term goals resonate with their values, they are less likely to seek fulfillment through unhealthy behaviors such as excessive sugar consumption. Research suggests that people who feel fulfilled in their lives tend to engage less in addictive behaviors (Rosenberg & Feder, 2014). This concept extends to sugar addiction, where individuals who derive satisfaction from meaningful activities and relationships are less inclined to turn to sugary foods for emotional gratification.

From a personal perspective, overcoming sugar addiction often involves a journey of self-discovery and realignment of priorities. Recognizing how sugar addiction disrupts overall well-being and personal goals can motivate individuals to seek healthier alternatives and adopt sustainable dietary habits.

While anecdotal evidence and some studies highlight the benefits of self-realization and fulfillment in reducing sugar addiction, further empirical research is essential. Future studies could explore the effectiveness of interventions that promote self-awareness, purposeful living, and emotional resilience in combating sugar addiction across diverse populations.

Conclusion

Sugar addiction is a complex and pervasive issue with significant implications for public health and individual well-being. This thesis has explored various dimensions of sugar addiction, including its physiological mechanisms, psychological underpinnings, behavioral interventions, and nutritional strategies. By integrating findings from these chapters, this conclusion synthesizes key insights and proposes future directions for research and clinical practice.

The physiological basis of sugar addiction involves the brain's reward system, where repeated consumption of sugary foods can lead to tolerance, dependence, and withdrawal symptoms. Dopamine, a neurotransmitter central to reward processing, plays a critical role in reinforcing sugar-seeking behaviors. Psychological factors such as stress, emotional eating, and maladaptive coping mechanisms further contribute to the development and maintenance of sugar addiction.

Effective psychological interventions, such as Cognitive Behavioral Therapy (CBT) and Dialectical Behavior Therapy (DBT), focus on modifying maladaptive behaviors and enhancing coping strategies. These therapies, although beneficial, may fall short in addressing hypo-reward responses to daily activities, a critical aspect of sugar addiction. The introduction of Reward Re-Training (RRT) highlights a promising approach that enhances both momentary and sustained rewards, thereby reducing binge eating and overall eating pathology associated with sugar addiction.

Nutritional strategies, guided by Registered Dietitians (RDs), play a crucial role in managing sugar addiction and related disorders. Recommendations emphasize avoiding hyperpalatable foods while promoting balanced macronutrient intake, appropriate portion sizes, and mindful eating practices. Flexible dietary approaches that focus on healthy eating patterns rather than strict exclusion are recommended to mitigate cravings and support long-term recovery from sugar addiction.

The incorporation of self-realization and fulfillment in life emerges as a vital component in overcoming sugar addiction. Understanding one's motivations, emotional triggers, and developing healthier coping mechanisms are essential steps towards reducing reliance on sugary foods for emotional gratification. Purpose-driven living, where daily actions align with personal values and aspirations, fosters a sense of fulfillment that mitigates the risk of engaging in addictive behaviors.

Integrating these insights into clinical practice requires a multidisciplinary approach that addresses both the physical and psychoemotional aspects of sugar addiction. Collaborative efforts among healthcare professionals, including psychologists, dietitians, and physicians, are essential for developing comprehensive treatment plans tailored to individual needs. Future research directions should focus on refining existing interventions and exploring novel approaches that integrate psychological support, nutritional strategies, and personal fulfillment. Longitudinal studies examining the effectiveness of combined interventions across diverse populations will provide valuable insights into optimizing treatment outcomes and preventing relapse.

In conclusion, the management of sugar addiction necessitates a holistic approach that acknowledges the interplay between biological, psychological, and behavioral factors. By integrating evidence-based interventions, including psychological therapies, nutritional counseling, and strategies promoting self-realization and fulfillment, individuals can achieve sustainable recovery from sugar addiction. This thesis contributes to the growing body of knowledge on effective interventions and underscores the importance of personalized, comprehensive care in addressing the complexities of sugar addiction in contemporary society.

References:

Acevedo, B. P., Aron, A., Fisher, H. E., & Brown, L. L. Neural correlates of long-term intense romantic love. *Stony Brook University, Stony Brook, N Y*. Albert Einstein College of Medicine, *11794*, USA, 2Department of Anthropology, Rutgers University, and 3Department of Neurology, 3.1Department of Psychology https://students.aiu.edu/submissions/profiles/resources/onlineBook/X6E7P3_addiction%20behavior%20psychology.pdf

Alexy, U., Schaefer, A., Sailer, O., Busch-Stockfisch, M., Huthmacher, S., Kunert, J., & Kersting, M. (2011). Sensory preferences and discrimination ability of children in relation to their body weight status. *Journal of Sensory Studies*, *26*(409–412), 409–412. https://doi.org/10.1111/j.1745-459X.2011.00358.x'

Angela Jacques, a. b., Nicholas Chaaya, a. b., Kate Beecher, a. b., Syed Aoun Ali, a. b., Belmer, A., Bartlett, S., . . . Bartlett, S. (2019). The impact of sugar consumption on stress driven, emotional and addictive behaviors. *Neuroscience and Biobehavioral Reviews*, 103, 178–199. https://doi.org/10.1016/j.neubiorev.2019.05.021 a b 1, Selena Bartlett

https://www.annualreviews.org/content/journals/10.1146/annurev-nutr-071715-050909

Anton, S. D., Martin, C. K., Han, H., Coulon, S., Cefalu, W. T., Geiselman, P., & Williamson, D. A. (2010). Effects of stevia, aspartame, and sucrose on food intake, satiety, and postprandial glucose and insulin levels. *Appetite*, *55*(1), 37–43. https://doi.org/10.1016/j.appet.2010.03.009

Appleton, K. M. (2021). Repeated exposure to and subsequent consumption of sweet taste: Reanalysis of test meal intake data following the repeated consumption of sweet vs non-sweet beverages. *Physiology and Behavior*, *229*, 113221. https://doi.org/10.1016/j.physbeh.2020.113221

Appleton, K. M., Rajska, J., Warwick, S. M., & Rogers, P. J. (2021, June 25). No effects of sweet taste exposure at breakfast for 3 weeks on pleasantness, desire for, sweetness or intake of other sweet foods: A randomised controlled trial. *British Journal of Nutrition*, 1–11. https://doi.org/10.1017/S000711452100235X [Epub ahead of print].

Appleton, K. M., Tuorila, H., Bertenshaw, E. J., de Graaf, C., & Mela, D. J. (2018). Sweet taste exposure and the subsequent acceptance and preference for sweet taste in the diet: Systematic review of the published literature. *The American Journal of Clinical Nutrition*, *107*(3), 405–419. https://doi.org/10.1093/ajcn/nqx031

Armitage, R. M., Iatridi, V., & Yeomans, M. R. (2021). Understanding sweet-liking phenotypes and their implications for obesity: Narrative review and future directions. *Physiology and Behavior*, *235*, 113398. https://doi.org/10.1016/j.physbeh.2021.113398

Bachmanov, A. A., Bosak, N. P., Floriano, W. B., Inoue, M., Li, X., Lin, C., Murovets, V. O., Reed, D. R., Zolotarev, V. A., & Beauchamp, G. K. (2011). Genetics of sweet taste preferences. *Flavour and Fragrance Journal*, *26*(4), 286–294. https://doi.org/10.1002/ffj.2074

Bellisle, F. (2015). Intense sweeteners, appetite for the sweet taste, and relationship to weight management. *Current Obesity Reports*, *4*(1), 106–110. https://doi.org/10.1007/s13679-014-0133-8

Berridge, K. C. (1996). Food reward: Brain substrates of liking and wanting. *Neuroscience and Biobehavioral Reviews*, *20*(1), 1–25. https://doi.org/10.1016/0149-7634(95)00033-b

Berridge, K. C. (2000). Measuringhedonicimpactinanimalsandinfants:Microstructureof affective taste reactivity patterns. *Neuroscience and Biobehavioral Reviews*, *24*(2), 173–198. https://doi.org/10.1016/S0149-7634(99)00072-X

Berridge, K. C. (2018). Evolving concepts of emotion and motivation. *Frontiers in Psychology*, *9*, 1647. https://doi.org/10.3389/fpsyg.2018.01647

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

Berthoud, H.-R., Münzberg, H., & Morrison, C. D. (2017). Blaming the brain for obesity: Integration of hedonic and homeostatic mechanisms. *Gastroenterology*, 152(7), 1728–1738. https://doi.org/10.1053/j.gastro.2016.12.050

Blundell, J., de Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluch, A., Mela, D., Salah, S., Schuring, E., van der Knaap, H., & Westerterp, M. (2010). Appetite control: Methodological aspects of the evaluation of foods. *Obesity Reviews*, *11*(3), 251–270. https://doi.org/10.1111/j.1467-789X.2010.00714.x

Bobowski, N., & Mennella, J. A. (2017). Personal variation in preference for sweetness: Effects of age and obesity. *Childhood Obesity*, *13*(5), 369–376. https://doi.org/10.1089/chi.2017.0023

Čad, E. M., Tang, C. S., de Jong, H. B. T., Mars, M., Appleton, K. M., & de Graaf, K. (2023). Study protocol of the sweet tooth study, randomized controlled trial with partial food provision on the effect of low, regular and high dietary sweetness exposure on sweetness preferences in Dutch adults. *BMC Public Health*, *23*(1), 77. https://doi.org/10.1186/s12889-022-14946-4

Castro, D. C., Cole, S. L., & Berridge, K. C. (2015). Lateral hypothalamus, nucleus accumbens, and ventral pallidum roles in eating and hunger: Interactions between homeostatic and reward circuitry. *Frontiers in Systems Neuroscience*, *9*, 90. https://doi.org/10.3389/fnsys.2015.00090

Coldwell, S. E., Oswald, T. K., & Reed, D. R. (2009). A marker of growth differs between adolescents with high vs. low sugar preference. *Physiology and Behavior*, *96*(4–5), 574–580. https://doi.org/10.1016/j.physbeh.2008.12.010 de Graaf C. Zandstra EH. Sweetness intensity and pleasantness in children, adolescents, and adults

de Ruyter, J. C., Katan, M. B., Kuijper, L. D. J., Liem, D. G., & Olthof, M. R. (2013). The effect of sugar-free versus sugar-sweetened beverages on satiety, liking and wanting: An 18 month randomized double-blind trial in children. *PLOS ONE*, *8*(10), e78039. https://doi.org/10.1371/journal.pone.0078039

Desor, J. A., & Beauchamp, G. K. (1987). Longitudinal changes in sweet preferences in humans. *Physiology and Behavior*, 39(5), 639–641. https://doi.org/10.1016/0031-9384(87)90166-1

Desor, J. A., Greene, L. S., & Maller, O. (1975). Preferences for sweet and salty in 9- to 15-year-old and adult humans. *Science*, *190*(4215), 686–687. https://doi.org/10.1126/science.1188365

Drewnowski, A. (1997). Taste preferences and food intake. *Annual Review of Nutrition*, *17*, 237–253. https://doi.org/10.1146/annurev.nutr.17.1.237

Drewnowski, A., Mennella, J. A., Johnson, S. L., & Bellisle, F. (2012). Sweetness and food preference. *The Journal of Nutrition*, *142*(6), 1142S–1148S. https://doi.org/10.3945/jn.111.149575

Fantino, M., Fantino, A., Matray, M., & Mistretta, F. (2018). Beverages containing low energy sweeteners do not differ from water in their effects on appetite, energy intake and food choices in healthy, non-obese French adults. *Appetite*, *125*, 557–565. https://doi.org/10.1016/j.appet.2018.03.007

Fushan, A. A., Simons, C. T., Slack, J. P., & Drayna, D. (2010). Association between common variation in genes encoding sweet taste signaling components and human sucrose perception. *Chemical Senses*, *35*(7), 579–592. https://doi.org/10.1093/chemse/bjq063

Grill, H. J., & Norgren, R. (1978). The taste reactivity test. I. Mimetic responses to gustatory stimuli in neurologically normal rats. *Brain Research*, *143*(2), 263–279. https://doi. https://doi.org/10.1016/0006-8993(78)90568-1

Hayes, S. C., Strosahl, K. D., & Wilson, K. G. (2009). *Acceptance and commitment therapy: The process and practice of mindful change*. Guilford Press.

Hetherington, M. M., Bell, A., & Rolls, B. J. (2000). Effects of repeat consumption on pleasantness, preference and intake. *British Food Journal*, *102*(7), 507–521. https://doi.org/10.1108/00070700010336517

Higgins, K. A., Rawal, R., Baer, D. J., O'Connor, L. E., & Appleton, K. M. (2022). Scoping review and evidence map of the relation between exposure to dietary sweetness and body weight-related outcomes in adults. *Advances in Nutrition*, *13*(6), 2341–2356. https://doi.org/10.1093/advances/nmac090

Hilbert, A., Bishop, M. E., Stein, R. I., Tanofsky-Kraff, M., Swenson, A. K., Welch, R. R., & Wilfley, D. E. (2012). Long-term efficacy of psychological treatments for binge eating disorder. *The British Journal of Psychiatry*, *200*(3), 232–237. https://doi.org/10.1192/bjp.bp.110.089664

Hill, C., Wardle, J., & Cooke, L. (2009). Adiposity is not associated with children's reported liking for selected foods. *Appetite*, *52*(3), 603–608. https://doi.org/10.1016/j.appet.2009.02.003

Holahan, C. J., Moos, R. H., Holahan, C. K., Cronkite, R. C., & Randall, P. K. (2001). Drinking to cope, emotional distress and alcohol use and abuse: A ten-year model. *Journal of Studies on Alcohol*, *62*(2), 190–198. https://doi.org/10.15288/jsa.2001.62.190

http://www.ncbi.nih.gov/pubmed. (07/08/2015)

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2710609/

https://pubmed.ncbi.nlm.nih.gov/22178258/

Jaime-Lara, R. B., Brooks, B. E., Vizioli, C., Chiles, M., Nawal, N., Ortiz-Figueroa, R. S. E., Livinski, A. A., Agarwal, K., Colina-Prisco, C., Iannarino, N., Hilmi, A., Tejeda, H. A., & Joseph, P. V. A systematic review of the biological mediators of fat taste and smell. (2023). *Physiological Reviews*, *103*(1), 855–918. https://doi.org/10.1152/physrev.00061.2021

Jaime-Lara, R. B., Brooks, B. E., Vizioli, C., Chiles, M., Nawal, N., Ortiz-Figueroa, R. S. E. et al. (2019). Iatridi V, Hayes JE, Yeomans MR, Quantifying Sweet Taste Liker Phenotypes: Time for Some Consistency in the Classification Criteria. *Nutrients*, *11*(1), 129.

Jenkins, H. M., & Moore, B. R. (1973). The form of the auto-shaped response with food or water reinforcers. *Journal of the Experimental Analysis of Behavior*, *20*(2), 163–181. https://doi.org/10.1901/jeab.1973.20-163

Joseph, P. V., Reed, D. R., & Mennella, J. A. (2016). Individual differences among children in sucrose detection thresholds relationship with age, gender, and bitter taste genotype. *Nursing Research*, *65*(1), 3–12. https://doi.org/10.1097/NNR.0000000000000138

Juarascio, A. S., & Presseller, E. K. (2020). Enhancing reward sensitivity to overcome maladaptive behaviors. *Psychological Review*, *127*(5), 771–784.

Keskitalo, K., Tuorila, H., Spector, T. D., Cherkas, L. F., Knaapila, A., Silventoinen, K., & Perola, M. (2007). Same genetic components underlie different measures of sweet taste preference. *The American Journal of Clinical Nutrition*, *86*(6), 1663–1669. https://doi.org/10.1093/ajcn/86.5.1663

Keul, J., & Jakob, E. (1990a). Zur Wirkung von saccharose auf Fahrverhalten, Kreislauf und Stoffwechsel. *Österreichisches Journal für Sportmedizin*, *20*(3), 102–101.

Kringelbach, M. L. *The pleasure of food: Underlying brain mechanisms of eating and other pleasures, Flavour 4 (2015)*, *20*. https://doi.org/10.1186/s13411-014- 0029-2.

Liem, D. G., & de Graaf, C. (2004). Sweet and sour preferences in young children and adults: Role of repeated exposure. *Physiology and Behavior*, *83*(3), 421–429. https://doi.org/10.1016/j.physbeh.2004.08.028

Lommi, S., Engberg, E., Tuorila, H., Kolho, K.-L., & Viljakainen, H. (2021). Sex- and weight-specific changes in the frequency of sweet treat consumption during early adolescence: A longitudinal study. *The British Journal of Nutrition*, *126*(10), 1592–1600. https://doi.org/10.1017/S0007114521001112

Marlatt, G. A., & Donovan, D. M. (2005). *Relapse prevention: Maintenance strategies in the treatment of addictive behaviors*. Guilford Press.

McLaughlin, B. C. J. Low calorie sweeteners: Evidence remains lacking for effects on human gut function. (2016). *Physiology and Behavior*, *164*(B), 482–485.

Mennella, J. A., & Bobowski, N. K. (2015). The sweetness and bitterness of childhood: Insights from basic research on taste preferences. *Physiology and Behavior*, *152*(B), 502–507. https://doi.org/10.1016/j.physbeh.2015.05.015

Mennella, J. A., Finkbeiner, S., Lipchock, S. V., Hwang, L.-D., & Reed, D. R. (2014). Preferences for salty and sweet tastes are elevated and related to each other during childhood. *PLOS ONE*, *9*(3), e92201. https://doi.org/10.1371/journal.pone.0092201

Methven, L., Allen, V. J., Withers, C. A., & Gosney, M. A. (2012). Ageing and taste. *The Proceedings of the Nutrition Society*, *71*(4), 556–565. https://doi.org/10.1017/S0029665112000742

Misra, V., Shrivastava, A. K., Shukla, S. P., & Ansari, M. I. (2016). *Effect of sugar intake towards human health*. ICAR-Indian Institute of Sugarcane Research. UP; Amity University, Lucknow Campus, UP.

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

Pelchat, M. L., Johnson, A., Chan, R., Valdez, J., & Ragland, J. D. (2004). Images of desire: Food-craving activation during fMRI. *NeuroImage*, *23*(4), 1486–1493. https://doi.org/10.1016/j.neuroimage.2004.08.023

Peterson, C. B., Mitchell, J. E., Crow, S. J., Crosby, R. D., & Wonderlich, S. A. (2009). The efficacy of self-help group treatment and therapist-led group treatment for binge eating disorder. *The American Journal of Psychiatry*, *166*(12), 1347–1354. https://doi.org/10.1176/appi.ajp.2009.09030345

Peterson, C. B., Mitchell, J. E., Engbloom, S., Nugent, S., Mussell, M. P., & Miller, J. P. (1998). Group cognitive-behavioral treatment of binge eating disorder: A comparison of therapist-led versus self-help formats. *The International Journal of Eating Disorders*, *24*(2), 125–136. https://doi.org/10.1002/(sici)1098-108x(199809)24:2<125::aid-eat2>3.0.co;2-g

Petty, S., Salame, C., Mennella, J. A., & Pepino, M. Y. (2020). Relationship between sucrose taste detection thresholds and preferences in children, adolescents, and adults. *Nutrients*, *12*(7), 1918. https://doi.org/10.3390/nu12071918

Petrucelli, J. (2004). Treating eating disorders. In R. Coombs (Ed.), *Handbook of addictive disorders: A practical guide to diagnosis and treatment*. Wiley and Sons.

Pickering, C., Alsiö, J., Hulting, A.-L., & Schiöth, H. B. (2009). Withdrawal from free-choice high-fat high-sugar diet induces craving only in obesity-prone animals. *Psychopharmacology*, *204*(3), 431–443. https://doi.org/10.1007/s00213-009-1474-y

Piernas, C., Tate, D. F., Wang, X., & Popkin, B. M. (2013). Does diet-beverage intake affect dietary consumption patterns? Results from the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial. *The American Journal of Clinical Nutrition*, *97*(3), 604–611. https://doi.org/10.3945/ajcn.112.048405

Potenza, M. N. (2006). Should addictive disorders include non-substance-related conditions? *Addiction*, *101*(1)(Suppl. 1), 142–151. https://doi.org/10.1111/j.1360-0443.2006.01591.x

Reed, D. R., & Knaapila, A. (2010). Genetics of taste and smell: Poisons and pleasures. *Progress in Molecular Biology and Translational Science*, *94*, 213–240. https://doi.org/10.1016/B978-0-12-375003-7.00008-X

Ribeiro, G., & Oliveira-Maia, A. J. (2021). Sweet taste and obesity. *European Journal of Internal Medicine*, *92*, 3–10. https://doi.org/10.1016/j.ejim.2021.01.023

Rogers, P. J., Ferriday, D., Irani, B., Hei Hoi, J. K., England, C. Y., Bajwa, K. K., & Gough, T. (2020). Sweet satiation: Acute effects of consumption of sweet drinks on appetite for and intake of sweet and nonsweet foods. *Appetite*, *149*:104631 Rolls B.J. Sensory-specific satiety. Nutr Rev. 1986; 44, 93–101. https://doi.org/10.1016/j.appet.2020.104631

Running, C. A., Craig, B. A., & Mattes, R. D. (2015). Oleogustus: The unique taste of fat. *Chemical Senses*, *40*(7), 507–516. https://doi.org/10.1093/chemse/bjv036

Simon, J. J., Skunde, M., Wu, M., Bendszus, M., Herzog, W., & Friederich, H. C. (2016). Neural and behavioral responses to food rewards distinguish hyper-hedonic from hypo-hedonic individuals. *Neuropsychopharmacology*, *41*(3), 825–834.

Smith, K. E., Mason, T. B., & Smith, C. F. (2020). Real-time prediction of binge eating episodes in binge eating disorder using ecological momentary assessment. *Appetite*, *146*, 104–124.

Steiner, J. E. (1973). The gustofacial response: Observation on normal and anencephalic newborn infants. *Symposium on Oral Sensation and Perception*, (4), 254–278. http://www.ncbi. http://nlm.nih.gov/pubmed/4612820 Retrieved December 13, 2017

Steiner, J. E. (1974). Innate human facial expressions to taste and smell stimulation. *Annals of the New York Academy of Sciences*, *237*, 229–233. https://doi.org/10.1111/j.1749-6632.1974. tb49858.x.

Steiner, J. E. (1977). Facial expressions of the neonate infant indicating the hedonics of food-related chemical stimuli. In J. M. Weiffenbach (Ed.), *Taste and development: The genesis of sweet preference* (pp. 173–188). US Government Printing Office.

Steiner, J. E., Glaser, D., Hawilo, M. E., & Berridge, K. C. (2001). Comparative expression of hedonic impact: Affective reactions to taste by human infants and other primates. *Neuroscience and Biobehavioral Reviews*, *25*(1), 53–74. https://doi.org/10.1016/s0149-7634(00)00051-8

J.E. Steiner, D. Glaser, M.E. Hawilo, K.C. Berridge, Comparative expression of hedonic impact: Affective reactions to taste by human infants and other primates, Neurosci. Biobehav. Rev. 25 (2001) 53–74, https://doi.org/10.1016/S0149- 7634(00)00051-8.

Steinert, R. E., Frey, F., Töpfer, A., Drewe, J., & Beglinger, C. (2011). Effects of carbohydrate sugars and artificial sweeteners on appetite and the secretion of gastrointestinal satiety peptides. *The British Journal of Nutrition*, *105*(9), 1320–1328. https://doi.org/10.1017/S000711451000512X

Sünram-Lea, S. I., Foster, J. K., Durlach, P., & Perez, C. (2001). Glucose facilitation of cognitive performance in healthy young adults: Examination of the influence of fast-duration, time of day and pre-consumption plasma glucose levels. *Psychopharmacology*, *157*(1), 46–54. https://doi.org/10.1007/s002130100771

Ustun, B., Reissland, N., Covey, J., Schaal, B., & Blissett, J. (2022). Flavor sensing in utero and emerging discriminative behaviors in the human fetus. *Psychological Science*, *33*(10), 1651–1663. https://doi.org/10.1177/09567976221105460

Venditti, C., Musa-Veloso, K., Lee, H. Y., Poon, T., Mak, A., Darch, M., Juana, J., Fronda, D., Noori, D., Pateman, E., & Jack, M. (2020). Determinants of sweetness preference: A scoping review of human studies. *Nutrients*, *12*(3), 718. https://doi.org/10.3390/nu12030718

Volkow, N. D., Wang, G. J., Fowler, J. S., Logan, J., Schlyer, D., Hitzemann, R., Lieberman, J., Angrist, B., Pappas, N., & MacGregor, R. (1994). Imaging endogenous dopamine competition with [11C]raclopride in the human brain. *Synapse*, *16*(4), 255–262. https://doi.org/10.1002/syn.890160402

Volkow, N. D., Wang, G. J., Fowler, J. S., Tomasi, D., & Baler, R. (2012). Food and drug reward: Overlapping circuits in human obesity and addiction. In C. S. Carter & J. W. Dalley (Eds.), *Brain imaging in behavioral neuroscience*, *11* (pp. 1–24). Springer. https://doi.org/10.1007/7854_2011_169

Volkow, N. D., & Wise, R. A. (2005). How can drug addiction help us understand obesity? *Nature Neuroscience*, *8*(5), 555–560. https://doi.org/10.1038/nn1452

Westenhoefer, J. (2006a). Carbohydrates and cognitive performance. *Aktuelle Ernaehrungsmedizin*, *31*(Suppl. 1), S96–S102.

Winkielman, P., & Berridge, K. C. (2004). Unconscious emotion. *Current Directions in Psychological Science*, *13*(3), 120–123. https://doi.org/10.1111/j.0963-7214.2004.00288.x

Wise, P. M., Nattress, L., Flammer, L. J., & Beauchamp, G. K. (2016). Reduced dietary intake of simple sugars alters perceived sweet taste intensity but not perceived pleasantness. *The American Journal of Clinical Nutrition*, *103*(1), 50–60. https://doi.org/10.3945/ajcn.115.112300

Witt, A. A. (2015). Reward dysfunction and eating disorder behaviors. *Current Psychiatry Reports*, *17*(8), 45–52.

Wittekind, A., Higgins, K., McGale, L., Schwartz, C., Stamataki, N. S., Beauchamp, G. K., Bonnema, A., Dussort, P., Gibson, S., de Graaf, C., Halford, J. C. G., Marsaux, C. F. M., Mattes, R. D., McLaughlin, J., Mela, D. J., Nicklaus, S., Rogers, P. J., & Macdonald, I. A. (2018). A workshop on 'Dietary Sweetness-Is It an Issue?' *International Journal of Obesity*, *42*(4), 934–938. https://doi.org/10.1038/ijo.2017.296

Wonderlich, S. A., Engel, S. G., & Peterson, C. B. (2018). Examining the heterogeneity of binge eating disorder through machine learning methods. *International Journal of Eating Disorders*, *51*(5), 428–438.

Yunker, A. G., Patel, R., & Page, K. A. (2020). Effects of non-nutritive sweeteners on sweet taste processing and neuroendocrine regulation of eating behavior. *Current Nutrition Reports*, *9*(3), 278–289. https://doi.org/10.1007/s13668-020-00323-3

Zellner, D. A. (2007). Contextual influences on liking and preference. *Appetite*, *49*(3), 679–682. https://doi.org/10.1016/j.appet.2007.04.008

Zhang, R., Noronha, J. C., Khan, T. A., McGlynn, N., Back, S., Grant, S. M., Kendall, C. W. C., & Sievenpiper, J. L. (2023). The effect of Non- nutritive sweetened beverages on postprandial glycemic and endocrine responses: A systematic review and network meta-analysis. *Nutrients*, *15*(4), 1050. https://doi.org/10.3390/nu15041050