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REWARD PROCESSING AND THE PREFERENCE FOR SWEET TASTE

**exploring the relationship between sweet liker
phenotypes and dispositional impulsiveness**

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SUMMARY MASTER'S THESIS**Name and First Name:** Amirzadian Anahit and Stuy Helen**Student ID:** 0578682 and 0580842**Title of the master's thesis:** Reward processing and the preference for sweet taste: exploring the relationship between sweet liker phenotypes and dispositional impulsiveness**Promoter:** Prof. Dr. Kris Baetens

Summary: While links between sweet taste preference and impulsivity exist, the relationship with specific sweet liking phenotypes remains underexplored. This relationship may have implications for understanding reward related systems and dysfunction. This study investigated the association between sweet liking phenotypes and dispositional impulsivity, using the Barratt Impulsivity Scale-11 (BIS-11), the BIS/BAS Scales, the Effortful Control Scale, and the Iowa Gambling Task (IGT). A cross-sectional design was employed with N=97 healthy adult participants. Sweet liking phenotypes were classified based on sweet taste assessment. Analyses revealed no significant differences in BIS/BAS, Effortful Control, BIS-11, or overall IGT learning trends across the sweet liking phenotype groups. Although not confirmed by primary group comparisons, exploratory analysis of IGT performance suggested a potential trend for increased selection of the disadvantageous Deck B over time among individuals with higher sweet liking, pointing to impaired learning from negative outcomes and an insensitivity to punishment. These findings suggest that BIS/BAS, Effortful Control, BIS-11 scores, and Iowa Gambling Task performance may not strongly differentiate sweet liking phenotypes; however, the study's power was limited by the relatively small sample size. Future studies employing dedicated tasks designed to isolate specific impulsivity facets are warranted. Additionally, investigating the neural correlates of this relationship, particularly involving the ventromedial prefrontal cortex, could further clarify its mechanisms.

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Introduction

In recent decades, the importance of food choice patterns has come forward. From an evolutionary perspective, ingredients rich in calories, like sugars, activate our reward systems more profoundly to ensure survival during periods of limited food supply (King, 2013). In contemporary times, the Western diet is marked by excessive sugar and fat consumption, and research indicates that such eating habits are associated with increased impulsivity (Lumley et al., 2016; Yeomans et al., 2023). Individuals with a stronger preference for sweet tastes tend to display increased impulsive behaviors; however, based on limited research exploring specific facets, this association seems restricted to certain dimensions of impulsivity (Weafer et al., 2014), and is not yet explored for many other facets of impulsivity in relation to sweet taste preference. Noteworthy, sweet taste preference is associated with addiction (Armitage et al., 2021; Kampov-Polevoy et al., 2001), a condition frequently characterized by impulsivity (Kovacs et al., 2017).

To investigate the relationship between sweet liking phenotypes and dispositional impulsiveness, this thesis first builds a conceptual framework by reviewing the literature on sweet liking, including its genetic, environmental, and neural basis involving the ventromedial prefrontal cortex (vmPFC) and reward systems, and mental health implications (Keskitalo et al., 2007; Rudenga & Small, 2013; Weafer et al., 2017). It then explores the multifaceted construct of impulsivity, covering trait perspectives and behavioral measures like the Iowa Gambling Task while also considering relevant neural mechanisms like the vmPFC (Bari et al., 2016; Bechara et al., 1994; Gray, 1970; Moeller, 2011; Nigg, 2017). The purpose of this research is to explore the relationship between specific aspects of impulsivity and these distinct sweet taste preferences.

Sweet Liker phenotypes

Embarking on the journey of understanding human behavior involves exploring a specific sense, namely taste. Out of all the tastes, we will narrow our focus on sweetness, a widely recognized and salient stimulus implying pleasure (Iatridi et al., 2018). The hedonic response to sweet tastes is widely considered an innate biological mechanism. This is supported by findings demonstrating positive facial expressions in neonates across various species upon sweet exposure (Desor et al., 1973; Steiner et al., 2001), with evidence also suggesting its presence during prenatal development within the womb (Liley, 1972). As we delve deeper into the exploration of sweet liking, we will discover the complex interactions between phenotypes, etiology (including neurobiology), and mental health implications.

The idea of the sweet liking phenotypes was brought up with the foundational work of Pangborn (1970), focusing on individual patterns of sugar concentration preference ratings. Through this work, three distinct phenotypes of sweet liking were identified: extreme sweet likers (ESL), moderate sweet likers (MSL), and sweet dislikers (DS). More specifically, ESL show an increase in liking as sweetness increases; individuals who like moderate, but not intense sweetness, are referred to as MSL; and the last phenotype indicates more aversion as sweetness increases, namely DS (Pangborn, 1970). More recent research, using methods like hierarchical cluster analysis, has confirmed these distinct liking phenotypes, consistent with Pangborn's earlier findings (Armitage et al., 2021). These phenotypic liking patterns have been found widely across adult populations (Armitage et al., 2021). Furthermore, individual differences in sweet liking preferences are found across age, culture, and gender. Children and adolescents tend to show a greater liking for sweetness than adults; however, this preference seems to decline with age, but then increases in older adults (Venditti et al., 2020). This preference has also been shaped by cultural and ethnic backgrounds, with variations observed between Western and Asian cultures and different preference spectrums across Asian subgroups, although food familiarization may also play a role (Armitage et al., 2021; Venditti et al., 2020). Gender differences in sweet liking preference have also been observed, with males generally exhibiting a stronger preference for sweet tastes than females. In addition, biological males are more commonly categorized as extreme sweet likers. This suggests that genetic variants may underlie individual preferences for sweet taste (Armitage et al., 2021).

Affective reactions derived from sweetness are mostly measured by the substance sucrose (Iatridi et al., 2018). In research studies, the range of tested concentrations is manipulated. It is noteworthy that only at very high concentrations of sucrose (> 0.5 M sucrose) the differences between the three response profiles appear (Armitage et al., 2021). In addition, specificity and sensitivity analyses reveal that 1.0 M sucrose provides the most distinct discrimination between sweet liking phenotypes. However, more studies are needed to validate this method across diverse population groups (Iatridi et al., 2019).

Etiology of sweet liker phenotypes

Although both genetic predispositions and experiential factors contribute significantly to the variation underlying the three sweet liking phenotypes, research indicates a fundamentally innate aspect. Sweet liking preferences are reportedly observable very early, within hours of birth (Mennella et al., 2016).

Variations in sweet liking phenotypes might be partly explained by individual differences in sensitivity to internal appetite cues, often referred to as intuitive eating. Specifically, sweet dislikers appear less attuned to internal regulatory signals like hunger, suggesting their eating behavior may be more influenced by external rather than physiological cues (Hawks et al., 2005).

However, this explanation cannot be interpreted as conclusive (Armitage et al., 2021). Research has also focused on genetic features of the three sweet liking phenotypes. Keskitalo et al. (2007) provided evidence for the partial heritability of sweet preferences, reporting significant genetic influences on hedonic ratings (e.g., 41% heritability for strong sucrose solution pleasantness) and sweet food consumption frequency (50% heritability). Furthermore, a potential genetic factor has been identified specifically related to the frequency of sweet food intake and may be related to sweet taste receptors. Nonetheless, additional genes beyond those responsible for sweet taste receptors are likely to contribute to individual variation in sweet liking (Eriksson et al., 2019). Despite these insights, limited studies have been conducted on this phenomenon.

Environmental factors have also been considered as potential contributors to the differentiation of sweet liking phenotypes (Armitage et al., 2021). However, empirical support for a direct causal link between environmental exposure to sweetness and the development of these stable

phenotypic preferences appears limited. For instance, a recent review of 21 cohort studies did not find consistent evidence supporting the influence of early sweetness exposure on later sweet preference. Nevertheless, this same review found evidence suggesting that increased exposure to sweetness was associated with a reduction, rather than an increase, in preference for sweet foods in short term (Appleton et al., 2018). Consequently, the precise role of environmental exposure in shaping stable sweet liking phenotypes remains unclear, and current understanding of the fundamental causes underlying these interindividual differences is far from complete (Armitage et al., 2021).

Rudenga and Small (2013) explored how individual sweet taste preferences influenced neural activity in response to the taste of sucrose. They used functional magnetic resonance imaging (fMRI) to measure neural activity in participants who received a range of weak and strong sucrose solutions. Their findings revealed that the vmPFC was the only region affected by preference of sweetness, suggesting that this brain area reflects pleasantness regardless of taste quality. Additionally, they observed a significantly greater response in the vmPFC to stronger sweet tastes compared to weaker ones among individuals who enjoyed sweet tastes, as opposed to those who did not. Specifically, their findings indicated that the right vmPFC was more likely to respond to sweet taste stimuli compared to the left vmPFC.

Sweet liking and mental health

Considerable research has explored the important associations between sweet preferences, alcohol use, and addiction (Kampov-Polevoy et al., 2001). Sweet liking has been found to be strongly related not only to Alcohol Use Disorder (AUD), but also to a family history of alcoholism, which may, in turn, elevate the relapse risk (Kampov-Polevoy et al., 1999; Kampov-Polevoy et al., 2014; Salvatore et al., 2015). Individuals with Alcohol Use Disorder (AUD) have a significantly higher tendency to be sweet likers compared to individuals without AUD (Weafer et al., 2017). In a study including actively drinking patients, Garbutt et al. (2009) reported that individuals favoring highly sweet tastes needed ten times more time to achieve two days of abstinence from heavy drinking than those without a strong sweet preference; this finding was subsequently supported by a later trial (Garbutt et al., 2016). Hereby, we can conclude that sweet likers share a potential risk for relapse and potentially poorer recovery outcomes (Braun et al., 2021). Conversely, in early recovery, an increase in sugar consumption and sweet cravings has been observed (Alarcon et al., 2020; Gottfredson & Sokol, 2020). The use of sweets in this case is to regulate negative affect during recovery (Braun et al., 2021). There is evidence to suggest that individuals who have experience with drug use tend to exhibit a preference for sweet tastes (Weafer et al., 2017). Studies have indicated an association between sweet liking and the use of drugs, suggesting a shared underlying neurobiological mechanism. Sweet tastes as well as drugs of abuse are known to activate mesolimbic dopaminergic and opiodergic reward pathways, which may be involved in the subjective experience of reward linked with both stimuli (Berridge et al., 2008; Weafer et al., 2017). Additionally, research has demonstrated that both sweet liking and the intake of a stimulant drug elicit heightened activation in the ventral striatum. The shared activation of reward pathways underlying both sweet taste and stimulant drug reward suggests that individuals with increased sensitivity to sweet taste reward may also exhibit heightened sensitivity to drug reward. Nevertheless, the extent to which sweet taste preference can predict sensitivity to the immediate rewarding effects of drugs in humans has not been revealed in existing literature (Weafer et al., 2017).

Beyond the significant links observed with substance use disorders, evidence also suggests associations between sweet taste preference and other forms of psychopathology including depression, although studies on sweet taste response in unipolar major depressive disorder have not

consistently found altered responses (Dichter et al., 2010), and eating disorders (Berridge et al., 2010), particularly binge-eating disorder (Goodman et al., 2018).

Dispositional impulsiveness: towards a definition

Impulsivity is widely recognized as a multifaceted phenomenon with various underlying dimensions (Bari et al., 2016). Historical perspectives on impulsivity highlight three fundamental viewpoints: categorizing impulsive behavior in clinical populations, viewing impulsivity as a personality trait, and considering it from a behavioral perspective (Moeller, 2011). For the purpose of this study, we will focus on the personality trait and behavioral perspectives of impulsivity, as incorporating all three would extend beyond the scope of this thesis.

Impulsivity as a personality trait

When examining dispositional impulsivity, it's crucial to consider inherent influences that shape impulsivity. Temperament, as conceptualized by Rothbart (1989), encapsulates relatively consistent individual variations in reactivity and self-regulation that are largely rooted in biological factors. These differences are subsequently shaped by the interplay of genetic inheritance, maturation, and life experiences.

This temperamental reactivity can be understood within the framework of Gray's Reinforcement Sensitivity Theory (RST; Gray, 1970; Santens et al., 2020). RST proposes that individual differences in reactivity stem from variations in the sensitivity of two fundamental brain systems: the Behavioral Inhibition System (BIS), which responds to punishing stimuli and is primarily linked to anxiety, and the Behavioral Activation System (BAS), which responds to reinforcing stimuli and is closely associated with impulsivity and reward-seeking behavior (Gray, 1982; Gray & McNaughton, 2000). Gray and McNaughton's (2000) revision made a clear-cut distinction between anxiety, mediated by BIS, and fear, mediated by the Flight/Freezing/Fight system (FFFS).

Carver and White (1994) developed and validated the BIS/BAS questionnaire to measure individual differences in the strength of the BIS and BAS. They also explored relationships with other personality models, such as Cloninger's (1986, 1991) theory. Notably, they reported that Cloninger's trait of Reward Dependence showed positive correlations with sensitivity in both the BIS and the BAS (Carver & White, 1994).

In Rothbart and colleagues' (1994) psychobiological model of temperament, Effortful Control (EC) functions as the self-regulatory component, conceptualized by Rothbart et al. (2003) as the capacity to inhibit a dominant response in favor of a less dominant one. Furthermore, review studies emphasize EC's moderating effect on the association between BIS/BAS reactivity and psychopathology (Bijttebier et al., 2009; Santens et al., 2020). According to Nigg (2017), impulsivity can be seen as a breakdown in self-regulation, with EC identified as a top-down aspect of this self-regulation.

Barratt's theory of impulsivity integrates cognitive, behavioral, environmental, and biological factors (Barratt, 1993). His empirical work, which established the distinctness (orthogonality) of impulsivity from anxiety (Barratt, 1967; Stanford et al., 2009; Bari et al., 2016), guided the development of the Barratt Impulsiveness Scale (BIS) and its widely used successor, the BIS-11 (Patton et al., 1995). After more than four decades of investigating impulsivity, Barratt, working with Moeller and colleagues, eventually offered a definition of impulsivity: "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others" (Moeller et al., 2001, p. 1784). Despite the insights offered by the BIS-11, Barratt maintained that a more complete assessment of individual impulsivity required the integration of behavioral, questionnaire, and physiological measures (Moeller, 2011).

Impulsivity: A behavioral perspective

Although self-report questionnaires provide insights into impulsivity, their utility is constrained by factors like limited self-awareness and potential response biases (e.g., social desirability), particularly in clinical populations. Behavioral measures thus present an important alternative for assessing this construct (Bari et al., 2016).

One prominent behavioral task used to investigate decision-making and aspects of impulsivity is the Iowa Gambling Task (IGT). The IGT was developed to investigate the nature of decision-making (Bechara et al., 1994). The original IGT involves presenting participants with four decks of cards. Participants start with a \$2,000 loan of fake money and are instructed to maximize their earnings. Participants are informed that certain cards yield more benefits compared to others. Specifically, two decks (A and B) offer larger immediate rewards, but they also come with higher penalties, leading to

reduced long-term gains. Notably, deck A delivers these larger penalties more often than deck B. In contrast, the other two decks (B and D) provide smaller immediate rewards but have significantly lower penalties, with deck C exhibiting a slightly higher penalty frequency than deck D. Participants must identify the reward and penalty patterns to maximize their long-term financial gain (Bechara et al., 1994). Bechara et al. (1994) studied patients with damage to the vmPFC. While control participants understood the reward and punishment contingencies of the IGT and improved over time, those with impaired vmPFC function showed consistently poor performance, despite their otherwise mostly intact intellectual abilities.

The findings from the IGT have significantly contributed to our understanding of the neural mechanisms underlying decision-making, particularly in the context of Damasio's (1996) somatic marker hypothesis (SMH). In situations of complexity and uncertainty, the somatic marker hypothesis (SMH) suggests that part of the brain's emotional circuitry, notably the vmPFC, represents and regulates 'somatic marker' biasing signals from the body to facilitate decision-making (Damasio, 1996). Especially amid complexity and uncertainty, these marker signals aid in narrowing down the problem space by tagging response options with an 'emotional' signal. Only marked options undergo thorough cognitive processing (Damasio, 1996). According to SMH, individuals with damage to the vmPFC will encounter impaired decision-making due to the inability to activate the somatic marking system (Damasio, 1996).

Standard IGT analysis involves a net score, calculated as advantageous choices (C + D) minus disadvantageous choices (A + B) across six blocks of 20 trials, indicating a preference for advantageous decks. However, some individuals exhibit a strategy of loss minimization, reflected in a separate net score: choices from low-loss frequency decks (B + D) minus high-loss frequency decks (A + C) (Hultman et al., 2022).

While the IGT offers valuable insights into decision-making under uncertainty, it is important to note that numerous other behavioral tasks have been developed to measure the diverse sub-facets of impulsivity (Voon & Dalley, 2016; Dalley & Robbins, 2017; Voon, 2020). Studies identify distinct categories of impulsivity, such as impulsive action and impulsive choice. Impulsive action, or motor impulsivity, encompasses sub-components like waiting impulsivity (assessed with the 4-Choice Serial Reaction Time task) and response inhibition (assessed with Go/NoGo task and Stop Signal Task)

(Dalley & Robbins, 2017; Voon, 2020; Voon & Dalley, 2016). These behavioral measures are largely independent of self-reported impulsivity (Caswell et al., 2015), with the Stop Signal Task being an exception in its correlation with the BIS-11 motor subscale. Impulsive choice, or decisional impulsivity, encompasses components such as the tendency to devalue delayed rewards in favor of immediate gratification (temporal or delay discounting) and the inclination to make rapid decisions without sufficient deliberation (reflection impulsivity) (Dalley & Robbins, 2017; Voon, 2020; Voon & Dalley, 2016). Reflection impulsivity, for instance, can be assessed using the Matching Familiar Figures Task (MFFT) (Kagan, 1966; Voon, 2020).

Neurobiology of impulsivity

Having outlined the various types of impulsivity, we will now delve into their neural connections and how they relate to brain function. McDonald et al. (2017) investigated the underlying networks of trait impulsivity, measured by the BIS-11, using voxel-based lesion-symptom mapping analysis on 131 patients. They found heightened global impulsivity associated with lesions in the bilateral prefrontal cortex (PFC), left superior, middle, and inferior temporal gyrus, and left hippocampus. Furthermore, a cluster within the PFC was associated with the motor impulsivity subtrait of the BIS-11. Additionally, functional neuroimaging by Zhang et al. (2015) confirmed a link between the BIS-11 and heightened physiological arousal in both genders, and their findings suggested that the neural bases of altered arousal regulation, specifically involving the vmPFC, are particularly relevant to women.

According to RST (Gray & McNaughton, 2000), the BAS, which encourages approach towards rewards (Adrián-Ventura et al., 2019), is associated with the brain's dopaminergic reward network, encompassing the Ventral Tegmental Area (VTA), the Ventral Pallidum (VPal), the Ventral Striatum (VS), and key regions of the Prefrontal Cortex (PFC) including the medial prefrontal cortex (mPFC), such as the anterior cingulate cortex (ACC) and the vmPFC (Pickering & Gray, 2001; Adrián-Ventura et al., 2019; Haber & Knutson, 2010; Standen et al., 2022).

Nouchi et al. (2016) used voxel-based morphometry to explore the neuroanatomical correlates of effortful control. They found that attentional control (ATC) was significantly correlated with the vmPFC, while inhibitory control (IC) was associated with larger gray and white matter volume in the dorsal part of the anterior cingulate cortex (dACC), the supplementary motor area (SMA), and the pre-SMA. Activation control (ACTC) correlated with smaller gray matter in the insula and putamen, and ATC was also linked to larger white matter in the inferior frontal gyrus, orbital frontal gyrus, ACC, and insula.

Both Peters and D'Esposito (2020) and Mok et al. (2021) reported that individuals with lesions in the vmPFC demonstrated more pronounced discounting of delayed rewards but less pronounced discounting of probabilistic rewards compared to controls. However, the underlying mechanism behind this relation remains unknown.

Linking sweet liking and impulsivity

The fact that the vmPFC is implicated in both the complex construct of impulsivity (Mok et al., 2021; Peters & D'Esposito, 2020; Zhang et al., 2015) and the fundamental preference for sweet tastes (Rudenga & Small, 2013) underscores the intricate neural architecture underlying these behaviors and warrants a closer examination of how this shared involvement might contribute to their relationship.

Self-report questionnaires have provided initial insights into the relationship between trait impulsivity and sweet taste perception. Exploring the links between reward sensitivity, effortful control, eating behavior and liking, Mackey et al. (2018) studied adults with overweight and obesity using a psychobiological temperament model. Their findings linked higher BIS sensitivity and lower effortful control to greater liking and wanting of palatable high-fat, sweet foods and more Disinhibition, a form of eating-related impulsivity. Neseliler et al. (2017) reported that BIS activity correlated with increased vmPFC activation and decreased dorsolateral prefrontal cortex (dlPFC)-vmPFC connectivity when viewing high-calorie food under stress. Though existing self-report research provides preliminary insights into impulsivity and sweet taste, the current study addresses a crucial gap by examining the relationship between distinct sweet liking phenotypes and the widely adopted BIS-11, a link previously unexamined to our knowledge.

Regarding behavioral tasks, Weafer et al. (2014) found that a preference for sweet taste was correlated with impulsivity measured by a delay discounting task, but not with impulsivity measured by the go/no-go task. The association between delay discounting and sweet taste liking suggests that they share an underlying neurobiological mechanism, one that does not play a role in the go/no-go task.

It is noteworthy that the associations between sensitivity to rewarding stimuli (e.g., to sucrose) and impulsivity (in both choice and action) are significant, as they may illuminate psychological pathways to pathological behaviors like substance dependence (Weafer et al., 2014).

Given the evidence suggesting a specific link between sweet taste preference and the choice-related aspect of impulsivity (as indicated by the correlation with delay discounting), the present study aims to further explore this relationship using a phenotypic approach to sweet liking and a comprehensive assessment of dispositional impulsiveness.

Research questions

The present study aims to explore the relationship between sweet liker phenotypes and dispositional impulsiveness, using both self-report measures and the IGT. Our primary hypothesis posits that individuals with a preference for sweet tastes will exhibit higher levels of impulsivity. Specifically, we anticipate the strongest effects among sweet likers, followed by intermediate sweet likers, and lower levels of impulsivity among sweet dislikers. However, these effects may not be consistent across all facets of impulsivity; further details on the specific subfacets are provided in the following sections.

Within the context of self-report measures, we hypothesize that the sweet liker phenotype will be associated with the highest scores on the BIS-11, followed by intermediate sweet likers, and the sweet disliker phenotype will show the lowest scores. This expectation is rooted in the vmPFC's role in sweet taste preference (Rudenga & Small, 2013), coupled with findings associating higher overall BIS-11 scores with diminished vmPFC regulation of physiological arousal (Zhang et al., 2015).

Regarding the BIS/BAS, we hypothesize that the sweet liker phenotype will exhibit the highest scores on the BAS-Reward Responsiveness, BAS-Drive, and BAS-Fun Seeking scales, followed by the intermediate sweet likers, and the sweet disliker phenotype will show the lowest scores. Furthermore, we hypothesize that BIS scores will differ across the sweet liking phenotypes, with the sweet disliker phenotype exhibiting the highest scores, followed by the intermediate sweet liker phenotype, and the sweet liker phenotype showing the lowest scores. These hypotheses are based on the theoretical framework of the Reinforcement Sensitivity Theory (RST) (Gray, 1982; Gray & McNaughton, 2000), which posits BIS and BAS as systems governing responses to punishment and reward, respectively. Given that sweet liking functions as a primary reward (Iatridi et al., 2018), we hypothesize how individual differences in BIS and BAS sensitivity relate to sweet liking phenotypes.

In terms of the ATQ-EC, we hypothesize that the sweet liker phenotype will exhibit the lowest scores, followed by the intermediate liker phenotype, and the disliker phenotype will show the highest scores, particularly on the subscale of Attentional Control (ATC). This expectation is based on the work of Nouchi et al. (2016), who found an association between this scale and the vmPFC. Additionally, empirical evidence supports this predicted direction, as Mackey et al. (2018) reported that in adults

with overweight and obesity, lower effortful control was a significant predictor of greater liking high-fat sweet foods.

Sweet liking is associated with vulnerability to addictive behavior (Weafer et al., 2017). This addictive behavior is often characterized by deficits in decision-making and IGT performance (Kovacs et al., 2017). Furthermore, empirical evidence supports this link by showing sweet liking is related to aspects of impulsive choice relevant to the IGT, such as delay discounting (Weafer et al., 2014). Given the role of the vmPFC in both sweet preference and IGT performance (Bechara et al., 1994; Mok et al., 2021; Peters & D'Esposito, 2020; Rudenga & Small, 2013; Zhang et al., 2015), we hypothesize that sweet liking phenotypes would be associated with differences in IGT performance. Specifically, we predict that the sweet liker phenotype would exhibit a greater tendency to select disadvantageous decks (A and B), which are characterized by larger immediate rewards but ultimately incur higher long-term penalties, leading to the poorest overall performance on the IGT. This tendency would be followed by the intermediate liker phenotype, with the disliker phenotype showing the best overall performance, primarily driven by advantageous deck selections. Furthermore, we hypothesize that the sweet liker phenotype demonstrate a greater preference for high-loss frequency decks (A and C) compared to both the intermediate liker and disliker phenotypes.

Method

Study design

A cross-sectional design was employed to examine the reward-related characteristics of the three sweet liking phenotypes.

Study Participants

This study was conducted as part of a larger, collaborative investigation involving eight master's thesis students. This effort resulted in a total pool of 107 healthy adults recruited through personal communication channels between November 2024 and March 2025, including the 30 participants recruited by the authors of the present thesis. Participants included healthy adults who had the capacity to give informed consent. The exclusion criteria for the participants consisted of diabetes, smoking more than five cigarettes a week, self-reported history of diagnosed eating disorders or gambling addiction, current respiratory illness, recent (less than two weeks) dental procedure, being on a weight loss or a medically induced special diet. The participants were also asked to abstain from eating, smoking, chewing gum, and toothbrushing for two hours prior to testing. There were no restrictions applied to water consumption.

The data of 97 participants were included in this study. The age of the participants varied between 17 and 85 years ($M = 32.07$, $SD = 17.75$). Figure A1 in Appendix A illustrates the frequency of participants across age, where we observed the largest group of participants consists of young adults. The sample consisted of 36 men (37.1%), with an average age of 32 years ($M = 31.75$, $SD = 17.62$). A total of 61 women who participated in this study (62.9%), with an average age of 32 years ($M = 32.26$, $SD = 17.97$).

Study assessments and Procedures

Ethical approval for this study was obtained from the UZ Brussel Clinical Trial Center on 07/06/2024 (BUN 1432021000589). This study was performed in accordance with the Declaration of Helsinki, the conditions and principles of Good Clinical Practice, the protocol and applicable local regulatory requirements and laws. Throughout the study, investigators maintained full compliance with established ethical standards.

The procedure participants followed in this study is illustrated in Figure 1. Before the start of the assessments, each participant provided Informed Consent before performance on any form of assessment. Anonymity was guaranteed, as each participant was assigned a personal ID code upon enrolment. Data collection and processing focused solely on information essential for the study (participant gender, age, and assessment answers), with appropriate safeguards implemented to ensure confidentiality and ethical compliance.

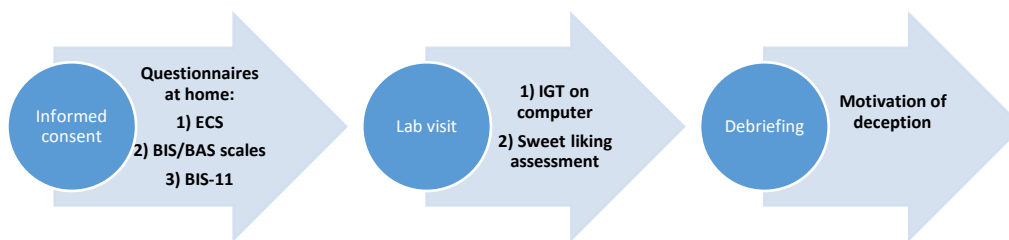
After the participants signed the Informed Consent, either in written or digital form, they received a link providing access to the questionnaires which they completed from home. The questionnaires were administered digitally using Qualtrics (<https://www.qualtrics.com>). Participants used their personal ID code for identification of the assessment. The link was sent one week prior to their scheduled laboratory visit at the Vrije Universiteit Brussel, however, participants had full autonomy in determining when to complete the questionnaires before their laboratory visit. These questionnaires were the Behavioral Inhibition/Behavioral Activation System Scales (BIS/BAS Scales; Carver & White, 1994; Dutch version Franken et al., 2005), the Effortful Control Scale (ECS; Evans & Rothbart, 2007; Dutch version: Hartman & Majdandžić, 2001), and the Barratt Impulsivity Scale-11 (BIS-11; Patton et al., 1995). In alignment with broader research objectives of six other Master's thesis students, all participants also had to complete the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997), the NEO Five-Factor Inventory Version 3 Neuroticism (NEO-FFI-3-Neuroticism; McCrae & Costa, 2007), the Sensory Processing Sensitivity Questionnaire (SPSQ; Dutch version; De Gucht et al., 2022), and the Eating Disorder Inventory-3 (EDI-3; Garner & Van Strien, 2014). Completing all the questionnaires required approximately 60 minutes.

Upon completion of the online questionnaires, the respective Master's thesis student reached out to participants to schedule a timeslot to visit the Posner lab at the Vrije Universiteit Brussel. During this visit, participants performed the IGT computer task (IGT; Bechara et al., 1994) and the sweet liking assessment. The Informed Consent form featured deception. Although participants were informed that they will receive monetary compensation at the end of the experiment, varying within the range of €0 up to a maximum of €5 based on their performance on the IGT, in reality all participants were awarded the same maximal amount. This is fundamental for the IGT, as the manipulation is dependent on participants' belief that their performance would determine their actual

monetary compensation. Participants received a modest maximal compensation to minimize potential harm, such as stress, caused by this procedure. Immediately after the sweet liking assessment, all participants were debriefed about this deception. It was clarified that all participants would receive €5 if they were willing to share their bank credentials. They also signed a personal declaration form to ensure strict confidentiality towards other participants concerning this deception.

Figure 1

This diagram illustrates the sequence of main steps participants followed in this study.



Materials: Questionnaires

The Effortful Control Scale (ECS; Evans & Rothbart, 2007; Dutch version: Hartman & Majdandžić, 2001) is the effortful control scale from the Adult Temperament Questionnaire (Evans & Rothbart, 2007) and assesses activation control, attentional control, and inhibitory control through three subscores. Activation control describes the ability to initiate goal-directed behavior even when a strong tendency to avoid is present. Attentional control pertains to the capacity to focus and shift attention as desired. Finally, inhibitory control examines the extent to which an individual can suppress inappropriate behaviors. The questionnaire consists of 19 items, which are answered on a 7-point Likert scale ranging from 1 = 'not at all applicable' to 7 = 'completely applicable' (translated from Dutch). In the current sample, internal consistency was assessed using Cronbach's alpha. Modest internal consistency was observed for Activation Control (7 items, $\alpha = .62$) and Inhibitory Control (7 items, $\alpha = .62$). Attentional Control (5 items) showed weak to modest internal consistency ($\alpha = .54$), while the total ECS (19 items) demonstrated acceptable internal consistency ($\alpha = .74$). These values indicate varying levels of internal consistency across the subscales and an acceptable level for the overall scale.

The Behavioral Inhibition/Behavioral Activation System Scales (BIS/BAS Scales; Carver & White, 1994; Dutch version: Franken et al., 2005) is a self-report questionnaire assessing individual differences in personality traits related to reactive temperament, specifically BIS and BAS sensitivity. The scale comprises two main subscales, BIS and BAS, with BAS further divided into three subscales: Reward Responsiveness, Drive, and Fun Seeking. Participants respond to the 24 items using a four-point scale (1 = 'very true for me' to 4 = 'very untrue for me', translated from Dutch). Franken et al. (2005) established the Dutch version of the BIS/BAS Scales as a brief, reliable, and valid instrument, reporting Cronbach's alphas of .79 (BIS - good), .61 (BAS Reward Responsiveness - modest), .68 (BAS Drive - modest), and .59 (BAS Fun Seeking - modest). In the current sample, BIS total score (7 items) showed acceptable to good internal consistency ($\alpha = .76$). Internal consistency was questionable to acceptable for the BAS Reward Responsiveness (5 items, $\alpha = .68$) and BAS Drive (4 items, $\alpha = .67$) subscales. The BAS Fun Seeking subscale (4 items) demonstrated poor internal consistency ($\alpha = .48$), while the Total BAS scale (13 items) showed acceptable internal consistency ($\alpha = .74$).

The Barratt Impulsivity Scale, Version 11 (BIS-11; Patton et al., 1995) is a self-report questionnaire designed to assess the personality construct of impulsiveness. The Dutch translation (Lijffijt & Barratt, 2005) was used. The BIS-11 comprises three subscales: Motor Impulsiveness (11 items), Cognitive Impulsiveness (8 items), and Non-planning Impulsiveness (11 items). Higher subscale scores indicate a higher level of impulsiveness. The Attentional Impulsiveness subscale measures difficulties with task focus, the presence of intrusive thoughts, and the experience of racing thoughts. Motor Impulsiveness assesses the tendency to act spontaneously and the consistency of one's lifestyle. Finally, Non-planning Impulsiveness reflects the tendency to carefully think and plan, as well as the enjoyment of challenging mental tasks. This instrument uses a 4-point scale ranging from rarely/never to almost always (translated from Dutch). Stanford et al. (2009) noted that the internal consistencies (Cronbach's Alpha) reported for the BIS-11 total score across various translations fall within an acceptable range (.71–.83). In their own adult sample, they reported Cronbach's Alphas of .83 for the total score, .74 for Attentional Impulsiveness, .59 for Motor Impulsiveness, and .72 for Non-planning Impulsiveness. In the current sample, internal consistency was assessed also using Cronbach's alpha. The total BIS-11 scale indicated good reliability ($\alpha = .82$).

For the subscales, both the Attentional Impulsiveness ($\alpha = .68$) and Motor Impulsiveness ($\alpha = .70$) subscales showed moderate to acceptable reliability, while the Non-planning Impulsiveness subscale ($\alpha = .66$) indicated moderate reliability.

Decision-making was assessed using a computerized version of the Iowa Gambling Task (IGT; Bechara et al., 1994), programmed and ran using E-Prime 3.0 software (Psychology Software Tools, 2021). The task consisted of six blocks, with each block containing 20 trials, making a total of 120 trials. Participants were given standardized instructions, which were presented visually on the screen and simultaneously read aloud by the experimenter. The complete text of these instructions, in both Dutch and English, can be found in Appendix B. On each trial, participants were presented with four virtual decks of cards displayed on the screen and were instructed to select one deck by clicking on it. While there was no time limit for their choice, the total reaction time for each selection was recorded by the software. Following each selection of a card, participants received immediate digital feedback indicating the number of points either gained or lost on that trial. This feedback remained visible on the screen until the participant initiated the next trial by pressing the spacebar. Throughout the task, their total accumulated score was continuously displayed both numerically and via two visual bar graphs, with green representing positive scores (profit) and red indicating negative scores (loss). The payoff structure for the four card decks was adapted from the methodology outlined by Hultman et al. (2022), with specific details presented in Table C1. Specifically, each deck was programmed with a predetermined, repeating sequence of point gains and losses. To minimize any potential biases related to the physical location of the decks on the screen, the on-screen position of each deck (corresponding to the underlying A, B, C, and D payoff schemes) was randomized across individual participants. The frequency of selections for each of the four decks (A, B, C, and D) was recorded across the six blocks of trials for each participant. To examine the relationship between task progression and deck selection, we calculated the Pearson correlation coefficient for each participant between the block number (1 to 6) and the frequency of their choices for each of the four decks (A, B, C, and D). Following the analysis of individual deck choices, we examined deck preferences by creating sum scores for combinations of decks. For each participant, we calculated the total number of selections for the disadvantageous decks (A + B) and the advantageous decks (C + D) within each of the six blocks. We also calculated sum scores for the alternative pairings of Decks A and C (high-loss frequency) and

Decks B and D (low-loss frequency) within each block. Subsequently, we computed the Pearson correlation coefficient between the block number and the frequency of these sum scores (A+B, C+D, A+C, B+D).

Materials: Sweet liking

The procedure for the sweet liking task followed recommendations outlined in a recent methodological review (Iatridi et al., 2019). The taste stimuli consisted of six sugar concentrations of 1.000 M, 0.500 M, 0.250 M, 0.125 M, 0.063 M, and 0 M (water), prepared using standard white casting sugar dissolved in Spa mineral water, selected for its low mineral content. Solutions were prepared using serial dilution on the day of testing and used within four hours. Each solution (10 mL) was presented at room temperature in transparent, disposable 30 mL medicine cups. For each participant, an individual paper sheet was prepared showing their ID number, the necessary rating scales, and the stimulus symbols in a random sequence. The transparent disposable cups were positioned on these sheets.

The assessment was conducted in individual test cubicles equipped with a spittoon. Participants completed two blocks of tasting. In each block, the six concentrations were presented once in a randomized order, with participants blinded to the specific concentration. A "sip and spit" protocol was employed for each sample: participants were instructed to place the entire 10 mL solution in their mouth, swirl it for 10 seconds, and then expectorate it completely into the spittoon. Immediately following expectoration, they rated their liking and the perceived intensity of the stimulus before rinsing their mouth thoroughly with the provided mineral water.

Liking for each stimulus was rated using a horizontal Visual Analog Scale (VAS) anchored with "dislike extremely" at the left end (scored 50) and "like extremely" at the right end (scored +50), with the midpoint representing neutrality (0). Perceived intensity was rated using a vertical generalized Labeled Magnitude Scale (gLMS) with descriptors ranging from "no sensation" (scored 0) to "strongest imaginable sensation of any kind" (scored +100).

To classify participants into sweet liking phenotypes, the average liking score across the six sucrose concentrations (0 M to 1 M) was calculated for each participant, averaging the ratings obtained from the two testing blocks.

Classification into sweet liking phenotypes proceeded after calculating an average liking score for each participant across the six sucrose concentrations (1 M to 0 M), using the mean rating from the two testing blocks. Participants were subsequently assigned to one of three phenotype groups

based on this overall average score from the -50/+50 VAS scale. Those scoring above +15 were designated 'Likers', individuals scoring below -15 were designated 'Dislikers', and participants with scores ranging from -15 to +15 inclusive were classified as 'Intermediate'. The selection of these specific numerical thresholds (+/- 15) were adopted from the work of Iatridi et al. (2019), who reported these values as providing optimal discrimination between sweet liker, sweet disliker, and intermediate phenotypes when applied to liking ratings for a 1 M sucrose solution.

Data Analysis

Analysis of the questionnaires and tasks were conducted using IBM SPSS Statistics (version 29.0.0 (20)). The alpha level for determining statistical significance was set at .05 for all analyses.

Prior to the main analyses, data were screened for errors and completeness, leading to the exclusion of three participants and resulting in a final sample size of N=97 for analysis. A power analysis using G*Power (version 3.1) indicated that, assuming an alpha of .05 and 80% power, a total sample size of 180 participants would be sufficient to detect moderate effect sizes (i.e., higher than $d = 0.46$). As the current study included 97 participants, it should be noted that the statistical power to detect effects of this magnitude was limited, a factor potentially contributing to non-significant findings.

Descriptive statistics (means, standard deviations) were calculated for demographic variables and primary outcome measures. To evaluate the internal consistency of the self-report measures administered in this study, Cronbach's alpha (α) coefficients were calculated for the total scores and subscales of each questionnaire.

Preliminary analyses involved comparing male and female participants on key variables using independent samples t-tests. These comparisons included age, scores on all subscales of the BIS-11, BIS/BAS, ECS total score and subscales, BIS/BAS total score and subscales, the average sweet liking rating, and the individual correlations representing IGT deck learning trends.

To analyze learning across the IGT, a repeated measures Analysis of Variance (ANOVA) was conducted. The within-subject factors were Deck (2 levels: correlations of the advantageous decks (A+B) vs. correlations of the disadvantageous decks (A+B) and Block (6 levels: Block 1 through Block

6). The dependent variable was the mean selection frequency. Assumptions for the repeated measures ANOVA were checked. Normality was assessed using Shapiro-Wilk tests, and violations were noted. Mauchly's test of sphericity was used to assess the sphericity assumption. As sphericity was violated for the Deck x Block interaction, the Greenhouse-Geisser correction was applied to the degrees of freedom for interpreting this interaction effect. Significant main effects and interactions were further explored using estimated marginal means and pairwise comparisons where appropriate.

The primary analyses focused on comparing the three sweet liking phenotype groups (Sweet Liker, Intermediate, Disliker) on the main outcome variables using one-way between-subjects ANOVAs. Separate ANOVAs were conducted for the BIS-11 total score and subscales, the BIS and BAS total scores and subscales, the EC total score and subscales, and the IGT learning trend correlation coefficients. Prior to conducting the ANOVAs, assumptions were checked for each dependent variable. Normality within each group was assessed using Shapiro-Wilk tests. Homogeneity of variances across groups was assessed using Levene's test. Violations of assumptions were noted in the results section, but ANOVAs were typically conducted because of the general robustness of the test, particularly given the sample sizes. Effect sizes for the ANOVAs were reported using eta squared.

Additionally, exploratory correlational analyses were performed using Spearman rank correlation (ρ) to examine potential monotonic trends between the ordered sweet liking phenotype rank (1=Liker, 2=Intermediate, 3=Disliker) and the questionnaire scores (BIS-11, BIS/BAS, EC) as well as the IGT learning trend correlation coefficients.

Finally, given the noted violations of the normality assumption for the IGT learning trend correlation coefficients, non-parametric Kruskal-Wallis tests were conducted as a sensitivity analysis to confirm the findings of the primary ANOVAs for these specific variables.

Artificial Intelligence (AI) - tools

The use of Open AI, namely ChatGPT (GPT-3.5) and Gemini (2.5 Flash), were utilized for checking grammar and spelling, and refining language for parts of the written text. Following its use, we have thoroughly reviewed and edited the content and take full responsibility for the academic integrity of this work.

Results

Participant Characteristics

In this study, a total of 103 participants participated in the IGT and the sweet liking experiment, and 107 people filled in the questionnaires. However, we included and analyzed the data of 97 participants as we removed participants due to errors in the data and incomplete assessments.

Gender differences across age, questionnaire scores, sweet liking phenotypes, and IGT parameters were examined using independent samples t-tests, the results are summarized in Table 1. An independent samples t-test revealed that there was no significant difference between men and women in age ($t(95) = 0.14, p = .892$). However, we saw gender differences on the BIS Total Scale ($t(95) = 5.04, p < .001$) where women ($M = 22.08, SD = 2.69$) scored significantly higher than men ($M = 19.00, SD = 3.26$). There was no significant difference between men and women on the BAS total score ($t(95) = -0.30, p = .764$), and the BAS Drive subscale ($t(95) = -0.39, p = .700$). On the BAS Fun seeking subscale ($t(95) = -2.75, p = .007$) and the BAS Reward Responsiveness subscale ($t(95) = 2.52, p = .014$) we observed significant gender differences. Where women ($M = 17.59, SD = 1.98$) scored significantly higher on the BAS Reward Responsiveness subscale than men ($M = 16.56, SD = 1.92$) we observed the opposite on the BAS Fun Seeking subscale, where men ($M = 11.14, SD = 1.78$) scored significantly higher than women ($M = 9.98, SD = 2.12$). On the BIS-11 total score ($t(52.19) = -1.60, p = .115$), BIS-11 Attentional Scale ($t(95) = -0.91, p = .364$), BIS-11 Motor Scale ($t(53.78) = -1.78, p = .081$), and the BIS-11 Non-Planning subscale ($t(60.46) = -1.22, p = .229$) there were no significant gender differences. The EC total score ($t(95) = 1.12, p = .264$) and its subscales Activation Control ($t(95) = 1.41, p = .162$), Attentional Control ($t(95) = 0.42, p = .677$), and Inhibitory Control ($t(95) = 0.63, p = .533$) also revealed no significant gender differences. Observing the average rating of the sweet liking assessment, there was no significant difference between men and women ($t(95) = 1.21, p = .230$). Analysis of the IGT revealed no significant difference between men and women for the correlation of Deck A ($t(95) = -1.62, p = .109$), Deck B ($t(95) = 0.18, p = .857$), Deck C ($t(95) = -1.51, p = .135$), and Deck A + B ($t(95) = -0.91, p = .366$). Lastly, significant gender differences have been revealed for the correlation of Deck D ($t(95) = 2.91, p = .004$) where women ($M = 0.18, SD = 0.56$) scored significantly higher than men ($M = -0.16$

, $SD = 0.50$), and Deck A + C ($t(95) = -2.69$, $p = .008$) where men ($M = 0.04$, $SD = 0.54$) scored significantly higher than women ($M = -0.27$, $SD = 0.55$).

Table 1*Means, Standard Deviations, and Independent Samples t-tests of Gender Differences*

Logistic parameter	Women		Men		<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
Age	32.26	17.97	31.75	17.62	0.14	95	.892	0.03
BIS Total	22.08	2.69	19.00	3.26	5.04	95	<.001	1.06
BAS Total	38.31	4.90	38.61	4.43	-0.30	95	.764	-0.06
BAS Drive	10.74	2.23	10.92	2.17	-0.39	95	.700	-0.08
BAS Fun-seeking	9.98	2.12	11.14	1.78	-2.75	95	.007	-0.58
BAS Reward response	17.59	1.98	16.56	1.92	2.52	95	.014	-0.53
BIS-11 Total	58.51	7.39	61.94	11.54	-1.60	52.19	.115	-0.38
BIS-11 Attentional	16.57	3.12	17.22	3.80	-0.91	95	.364	-0.19
BIS-11 Motor	18.46	3.31	20.11	4.95	-1.78	53.78	.081	-0.41
BIS-11 Non-Planning	23.48	3.77	24.61	4.80	-1.22	60.46	.229	-0.27
EC Total	4.67	0.58	4.51	0.76	1.12	95	.264	0.24
Activation Control	4.64	0.78	4.39	0.93	1.41	95	.162	0.30
Attentional Control	4.25	0.92	4.17	0.91	0.42	95	.677	0.09
Inhibitory Control	4.99	0.80	4.88	0.95	0.63	95	.533	0.13
Sweet liking phenotype ^a	2.34	0.79	2.14	0.83	1.21	95	.230	0.25
Correlation of Deck A	-0.41	0.44	-0.26	0.41	-1.62	95	.109	-0.34
Correlation of Deck B	0.05	0.60	0.03	0.52	0.18	95	.857	0.04
Correlation of Deck C	-0.09	0.54	0.08	0.53	-1.51	95	.135	-0.32
Correlation of Deck D	0.18	0.56	-0.16	0.50	2.91	95	.004	0.61
Correlation of Deck A+B	-0.17	0.52	-0.06	0.54	-0.91	95	.366	-0.19
Correlation of Deck A+C	-0.27	0.55	0.04	0.54	-2.69	95	.008	-0.57

Note. *M* = Mean; *SD* = Standard Deviation. Degrees of freedom vary based on whether the assumption of equal variances was violated.

^a 1 = Sweet Liker, 2= Intermediate and 3= Sweet Disliker.

IGT

To analyze the mean selection frequency within the combined Deck conditions, a repeated measure ANOVA was conducted with Deck and Block as within-subject factors. The Decks consisted of 2 levels, with the advantageous (Deck C and D) and disadvantageous (Deck A and B) Decks combined. Block was assigned 6 levels.

Firstly, we considered the assumption of normality within the combination of each Deck and Block using Shapiro-Wilk tests. The assumption of normality was violated for nearly all conditions ($p < .05$), with the exception of combined Decks AB with Block 3 and combined Decks CD with Block 3 ($p > .05$). However, considering the small sample size and given that the repeated measure ANOVA is generally considered robust to violations of the normality the analysis continued.

Mauchly's test of sphericity was significant for the Deck x Block interaction ($\chi^2 (14) = 53.40, p < .001$), indicating that sphericity was violated. As a result, Greenhouse-Geisser-corrected degrees of freedom were used to explore this interaction further.

The main effect of Deck was found to be significant, $F(1, 96) = 8.03, p = .006, \eta^2 = .08$. This indicates a significant difference, averaged across all blocks, in mean selection frequency between the combined disadvantageous Decks AB and the combined advantageous Decks CD.

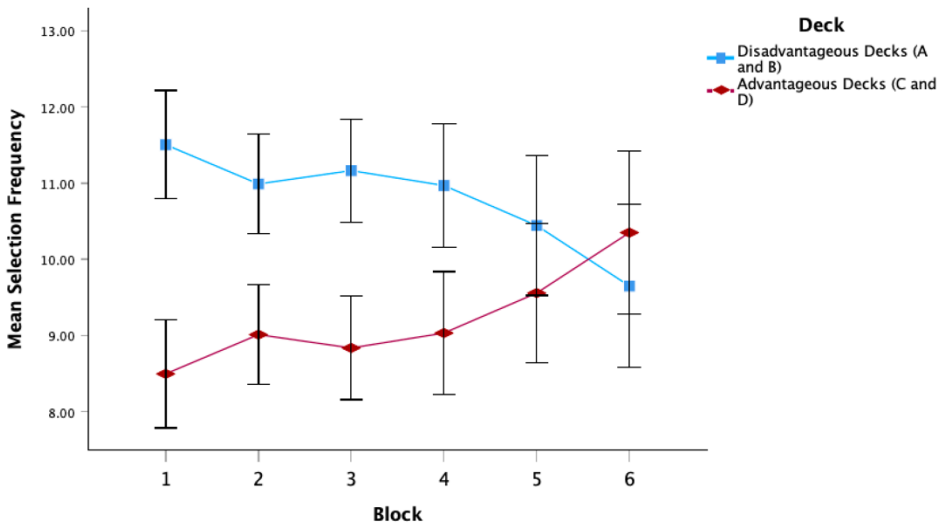
No significant main effect was observed for Block, $F(5, 480) = 0.00, p = 1.000$, suggesting no significant change in mean selection frequency across all six Blocks and for each Deck.

The interaction effect of Deck x Block was significant, $F(4, 384.01) = 3.83, p = .005, \eta^2 = .04$, indicating a significant difference in mean selection frequency between the combined Decks AB and the combined Decks CD, which varied across all six Blocks. See Table 2 for a summary of ANOVA results. Specifically, observing the estimated marginal means for this interaction effect shows that in the first five Blocks the selection frequency for Decks AB was higher than for Decks CD. This implies that the disadvantageous Decks were selected more in the beginning of the IGT. However, in Block six we saw a reversed pattern where Decks CD were chosen more than Decks AB. See Table 3 for means and standard deviations per condition, and Figure 2 for an illustration of this pattern.

Pairwise comparisons revealed that there is a significant difference between Decks AB and Decks CD in the first four Blocks ($p < .05$). However, in Block five and six the difference is no longer significant. See Table 4 for detailed pairwise comparison results.

Figure 2

Mean Selection Frequency for Advantageous (Decks C and D) and Disadvantageous (Decks A and B) Decks Across Blocks



Note. Error bars represent 95% confidence intervals.

Table 2

Analysis of Variance for Mean Selection Frequency Across Deck Type and Block

Source	<i>df</i>	<i>F</i>	<i>p</i>	η^2
Deck	1, 96	8.03	.006	0.08
Block	5, 480	0.00	1.000	0.00
Deck x Block	4, 384.01	3.83	.005	0.04

Note. Degrees of freedom for effects violating the assumption of sphericity have been corrected using the Greenhouse-Geisser method.

Table 3

Means and Standard Deviations for Mean Selection Frequency Across Deck Type and Block

Deck Type	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
A and B	11.51	3.53	10.99	3.25	11.16	3.37	10.97	4.00	10.44	4.55	9.65	5.31
C and D	8.49	3.53	9.01	3.25	8.84	3.37	9.03	4.00	9.56	4.55	10.34	5.31

Note. *M* = Mean; *SD* = Standard Deviation.

Table 4

Pairwise Comparisons of Mean Selection Frequency Between Advantageous and Disadvantageous Decks Within Each Block

Block	Mean Difference	Std. Error	<i>p</i> (Adjusted)	95% CI	
				Lower	Upper
1	3.01	0.72	<.001	1.59	4.43
2	1.98	0.66	.003	0.67	3.29
3	2.33	0.68	<.001	0.97	3.69
4	1.94	0.81	.019	0.33	3.55
5	0.89	0.92	.340	-0.95	2.72
6	-0.70	1.08	.517	-2.84	1.44

Note. CI = confidence interval. Comparisons adjusted using Bonferroni correction.

BIS-11 and sweet liking

To examine the first hypothesis regarding the relationship between impulsivity and sweet taste preference, BIS-11 scores were compared across the three sweet liking phenotype groups (Liker, Intermediate, Disliker) using a between-subjects one-way ANOVA. Prior the assumption of normality was assessed within each group using Shapiro-Wilk tests. The results indicated that the normality assumption was met ($p > .05$) for the Non-Planning Impulsiveness subscale across all three groups, and for the Attentional, Motor, and Total scores within the Disliker group ($N = 22$) and the Motor and Total scores within the Intermediate group ($N = 27$). However, significant deviations from normality ($p < .05$) were observed for the Attentional Impulsiveness subscale in the Intermediate ($p = .024$) and Liker ($p = .004$) groups, for the Motor Impulsiveness subscale in the Liker group ($p = .003$), and borderline for the BIS-11 total score in the Liker group ($p = .046$). Given that the one-way ANOVA is generally considered robust to moderate violations of the normality assumption the main analyses proceeded. Table 5 presents the means, standard deviations, and one-way ANOVA results for BIS-11 scores across the sweet liking phenotype groups. Separate one-way between-subjects ANOVAs were conducted to compare BIS-11 scores between the sweet liking groups. The assumption of homogeneity of variances was assessed using Levene's test (based on mean). This assumption was met for the BIS-11 total score ($p = .811$), the Attentional Impulsiveness subscale ($p = .975$), and the Non-Planning Impulsiveness subscale ($p = .659$). However, the assumption of homogeneity of variances was violated for the Motor Impulsiveness subscale ($F(2, 94) = 4.53, p = .013$). No significant differences were found between the groups for the BIS-11 total score, $F(2, 94) = 0.61, p = .547, \eta^2 = .01$, nor for any of the subscales: Attentional Impulsiveness, $F(2, 94) = 0.33, p = .724, \eta^2 = 0.01$; Motor Impulsiveness, $F(2, 94) = 1.57, p = .214, \eta^2 = 0.03$; and Non-Planning Impulsiveness, $F(2, 94) = 0.58, p = .560, \eta^2 = 0.01$.

Additionally, to explore potential monotonic trends between the ordered sweet liking phenotype categories (1=Liker, 2=Intermediate, 3=Disliker) and impulsivity, Spearman rank correlations were calculated. Table 6 provides descriptive statistics and correlation coefficients. These analyses revealed no significant monotonic association between sweet liking phenotype rank and BIS-11 total score ($p = -.12, p = .263$), nor with any of the subscales (Attentional: $p = -.01, p = .940$; Motor: $p = -.14, p = .182$; Non-Planning: $p = -.10, p = .316$).

Table 5

Means, Standard Deviations, and One-Way Analyses of Variance for BIS-11 Scores Across Sweet Liking Phenotype Groups

Measure	Liker (N=22)		Intermediate (N=27)		Disliker (N=48)		<i>F</i> (2, 94)	<i>p</i>	η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
BIS-11 Total	61.59	9.74	59.78	9.01	58.96	9.23	0.61	.547	0.01
Attentional	16.45	3.22	17.22	3.65	16.75	3.35	0.33	.724	0.01
Motor	20.41	5.09	18.74	3.38	18.65	3.82	1.57	.214	0.03
Non-planning	24.73	4.48	23.81	4.58	23.56	3.86	0.58	.560	0.01

Note. *M* = Mean; *SD* = Standard Deviation.

Table 6

Descriptive Statistics and Spearman Rank Correlations Among Sweet Liking Phenotypes and BIS-11

Scores

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5
1. Sweet liking phenotype ^a	2.27	0.81	—				
2. BIS-11 Total	59.78	9.25	-.12	—			
3. Attentional	16.81	3.38	-.01	.64**	—		
4. Motor	19.07	4.05	-.14	.82**	.33**	—	
5. Non-planning	23.90	4.19	-.10	.83**	.38**	.54**	—

Note. ^a 1 = Sweet Liker, 2= Intermediate and 3= Sweet Disliker.

p* < .05. *p* < .001.

BIS/BAS and sweet liking

To examine the second hypothesis regarding the relationship between impulsivity and sweet taste preference, BIS/BAS scores were compared across the three sweet liking phenotype groups using a between-subjects one-way ANOVA. Prior the assumption of normality was assessed within each group using Shapiro-Wilk tests. The results indicated that the normality assumption was met ($p > .05$) for the BIS scale, the BAS Fun Seeking subscale, and the BAS total score across all three groups, as well as for the BAS Drive subscale in the Liker (1) and Intermediate (2) groups. However, significant deviations from normality ($p < .05$) were observed for the BAS Drive subscale in the Disliker (3) group ($p = .024$), and for the BAS Reward Responsiveness subscale in all three groups (Liker (1), $p = .034$; Intermediate (2), $p = .043$; Disliker (3), $p = .012$). Given that the one-way ANOVA is generally considered robust to moderate violations of the normality assumption the main analyses proceeded. Table 7 presents descriptive statistics and one-way ANOVA results for BIS/BAS scores across the sweet liking phenotype groups. Separate one-way between-subjects ANOVAs were conducted to compare BIS-11 scores between the sweet liking groups. The assumption of homogeneity of variances was assessed using Levene's test (based on mean). This assumption was met for the BIS total score ($p = .194$), the BAS total score ($p = .890$), and all BAS subscales (Drive: $p = .835$; Fun Seeking: $p = .132$; Reward Responsiveness: $p = .188$).

No significant differences were found between the groups for the BIS total score, $F(2, 94) = 0.49$, $p = .615$, $\eta^2 = 0.01$, BAS total score $F(2, 94) = 0.75$, $p = .477$, $\eta^2 = 0.02$, nor for any of the subscales: Drive, $F(2, 94) = 0.94$, $p = .394$, $\eta^2 = 0.02$; Fun Seeking, $F(2, 94) = 0.37$, $p = .692$, $\eta^2 = 0.01$; and Reward Responsiveness, $F(2, 94) = 0.65$, $p = .525$, $\eta^2 = 0.01$.

Additionally, to explore potential monotonic trends between the ordered sweet liking phenotype categories (1=Liker, 2=Intermediate, 3=Disliker) and impulsivity, Spearman rank correlations were calculated. Table 8 provides descriptive statistics and correlation coefficients. These analyses revealed no significant monotonic association between sweet liking phenotype rank and BIS total score ($\rho = -.04$, $p = .670$), BAS total score ($\rho = -.10$, $p = .352$), nor with any of the subscales (Drive: $\rho = -.10$, $p = .327$; Fun Seeking: $\rho = -.07$, $p = .470$; Reward Responsiveness: $\rho = -.06$, $p = .574$).

Table 7

Means, Standard Deviations, and One-Way Analyses of Variance for BIS/BAS Scores Across Sweet Liking Phenotype Groups

Measure	Liker (N=22)		Intermediate (N=27)		Disliker (N=48)		<i>F</i> (2, 94)	<i>p</i>	η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
BIS Total	20.91	2.65	21.44	3.32	20.67	3.50	0.49	.615	0.01
BAS Total	39.50	4.79	38.19	4.91	38.06	4.59	0.75	.477	0.02
Drive	11.36	2.38	10.70	2.02	10.60	2.21	0.94	.394	0.02
Fun-seeking	10.59	1.53	10.59	2.22	10.23	2.20	0.37	.692	0.01
Reward response	17.55	2.11	16.89	2.34	17.23	1.77	0.65	.525	0.01

Note. *M* = Mean; *SD* = Standard Deviation.

Table 8

Descriptive Statistics and Spearman Rank Correlations Among Sweet Liking Phenotypes and BIS/BAS Scores

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. Sweet liking phenotype ^a	2.27	0.81	—					
2. BIS Total	20.94	3.26	-.04	—				
3. BAS Total	38.42	4.71	-.10	.12	—			
4. Drive	10.80	2.20	-.10	-.07	.79**	—		
5. Fun-seeking	10.41	2.07	-.07	-.03	.76**	.41**	—	
6. Reward response	17.21	2.01	-.06	.44**	.68**	.37**	.25*	—

Note. ^a 1 = Sweet Liker, 2= Intermediate and 3= Sweet Disliker.

p* < .05. *p* < .001.

EC and sweet liking

To examine the third hypothesis regarding the relationship between impulsivity and sweet taste preference, EC scores were compared across the three sweet liking phenotype groups using a between-subjects one-way ANOVA. The normality assumption was met for all EC variables across all three groups (all $p > .05$). The assumption of homogeneity of variances was met using Levene's test for the EC total score ($p = .463$), and all EC subscales (Activation Control: $p = .182$; Attentional Control: $p = .223$; Inhibitory Control: $p = .861$). Table 9 presents descriptive statistics and ANOVA results. No significant differences were found between the groups for the EC total score, $F(2, 94) = 1.36$, $p = .262$, $\eta^2 = 0.03$, nor for any of the subscales: Activation Control, $F(2, 94) = 1.19$, $p = .309$, $\eta^2 = 0.03$; Attentional Control, $F(2, 94) = 0.15$, $p = .858$, $\eta^2 = 0.003$; and Inhibitory Control, $F(2, 94) = 1.495$, $p = .230$, $\eta^2 = 0.03$.

Additionally, to explore potential monotonic trends between the ordered sweet liking phenotype categories (1=Liker, 2=Intermediate, 3=Disliker) and impulsivity, Spearman rank correlations were calculated. Table 10 summarize descriptive statistics and correlations. These analyses revealed no significant monotonic association between sweet liking phenotype rank and EC total score ($\rho = .08$, $p = .423$), nor with any of the subscales (Activation Control: $\rho = .13$, $p = .216$; Attentional Control: $\rho = .07$, $p = .492$; Inhibitory Control: $\rho = -.08$, $p = .463$).

Table 9

Means, Standard Deviations, and One-Way Analyses of Variance for EC Scores Across Sweet Liking Phenotype Groups

Measure	Liker (N=22)		Intermediate (N=27)		Disliker (N=48)		<i>F</i> (2, 94)	<i>p</i>	η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
EC Total	4.59	0.67	4.45	0.71	4.71	0.60	1.36	.262	0.03
Activation Control	4.53	0.77	4.35	0.93	4.66	0.82	1.19	.309	0.03
Attentional Control	4.14	0.74	4.21	0.90	4.27	0.99	0.15	.858	0.003
Inhibitory Control	4.98	0.89	4.72	0.92	5.07	0.79	1.50	.230	0.03

Note. *M* = Mean; *SD* = Standard Deviation.

Table 10

Descriptive Statistics and Spearman Rank Correlations Among Sweet Liking Phenotypes and EC Scores

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5
1. Sweet liking phenotype ^a	2.27	0.81	—				
2. EC Total	4.61	0.65	.08	—			
3. Activation Control	4.54	0.84	.13	.77**	—		
4. Attentional Control	4.22	0.91	.07	.74**	.49**	—	
5. Inhibitory Control	4.95	0.85	.08	.71**	.27**	.29**	—

Note. ^a 1 = Sweet Liker, 2= Intermediate and 3= Sweet Disliker.

p* < .05. *p* < .001.

IGT and sweet liking

To examine the third hypothesis regarding the relationship between impulsivity and sweet taste preference, the distribution of individual participants' correlation coefficients (Pearson's r) between block number and deck choice frequency were compared across the three sweet liking phenotype groups using a between-subjects one-way ANOVA. Prior the assumption of normality was assessed within each group using Shapiro-Wilk tests. These tests indicated that the assumption of normality was frequently violated for these correlation coefficients. Specifically, normality ($p > .05$) was only observed for the correlation of Deck A choices within the Intermediate group; the correlation of Deck B choices within the Liker and Intermediate groups; the correlation of Deck C and Deck D choices within the Liker group; and the correlation of Deck A+B and Deck A+C choices within the Liker and Intermediate groups. For all other combinations of deck choice correlations and phenotype groups, the normality assumption was not met ($p < .05$). Subsequently, the assumption of homogeneity of variances was examined using Levene's test (based on mean). This assumption was met for all tested IGT learning trend correlation coefficients (all $p > .360$). Table 11 presents descriptive statistics and ANOVA results. No significant differences were found between the groups for the correlation of Deck A ($F(2, 94) = 0.31, p = .738, \eta^2 = 0.01$), the correlation of Deck B ($F(2, 94) = 2.44, p = .093, \eta^2 = 0.05$), the correlation of Deck C ($F(2, 94) = 0.21, p = .810, \eta^2 = 0.02$), the correlation of Deck D ($F(2, 94) = 1.22, p = .300, \eta^2 = 0.03$), the correlation of Deck A+B/C+D ($F(2, 94) = 1.31, p = .276, \eta^2 = 0.03$) or the correlation of Deck A+C/B+D ($F(2, 94) = 0.20, p = .818, \eta^2 = 0.004$).

Additionally, to explore potential monotonic trends between the ordered sweet liking phenotype categories (1=Liker, 2=Intermediate, 3=Disliker) and IGT learning trends, Spearman rank correlations were calculated between the phenotype rank and the individual correlation coefficients for deck choice frequency over blocks. Table 12 summarizes descriptive statistics and correlations. These analyses revealed a statistically significant negative association for the correlation of Deck B ($\rho = -.22, p = .031$), suggesting that participants in higher-ranked phenotype groups (i.e., towards Disliker) showed a stronger tendency to decrease their choice of Deck B over time compared to those in lower-ranked groups (i.e., towards Liker). No significant monotonic associations were found between sweet liking phenotype rank and the correlation of Deck A ($\rho = .03, p = .757$), the correlation of Deck C (ρ

= -.06, $p = .535$), the correlation of Deck D ($\rho = .15$, $p = .140$), the correlation of Deck A+B ($\rho = -.14$, $p = .174$), or the correlation of Deck A+C ($\rho = .03$, $p = .761$).

To confirm these findings, given the previously noted violations of the normality assumption for some variables, non-parametric Kruskal-Wallis tests were also conducted. These tests yielded similar results, confirming the lack of statistically significant differences in the distribution of IGT learning trend correlations across the three sweet liking phenotype groups (all $p > .083$).

Table 11

Means, Standard Deviations, and One-Way Analyses of Variance for IGT Learning Trends (Correlations of Deck Choices with Block Number) Across Sweet Liking Phenotype Groups

Measure	Liker ($N=22$)		Intermediate ($N=27$)		Disliker ($N=48$)		$F(2, 94)$	p	η^2
	M	SD	M	SD	M	SD			
Correlation of Deck A	-0.41	0.39	-0.32	0.45	-0.34	0.45	0.31	.738	0.01
Correlation of Deck B	0.19	0.56	0.15	0.52	-0.08	0.59	2.44	.093	0.05
Correlation of Deck C	-0.01	0.53	0.02	0.55	-0.06	0.55	0.21	.810	0.004
Correlation of Deck D	-0.08	0.55	0.01	0.55	0.13	0.57	1.22	.300	0.03
Correlation of Deck A+B	-0.05	0.54	-0.04	0.55	-0.21	0.50	1.31	.276	0.03
Correlation of Deck A+C	-0.22	0.52	-0.13	0.58	-0.13	0.59	0.20	.818	0.00

Note. M = Mean; SD = Standard Deviation.

Table 12

Descriptive Statistics and Spearman Rank Correlations Among Sweet Liking Phenotype and IGT Learning Trends (Correlations of Deck Choices with Block Number)

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Sweet liking phenotype ^a	2.27	0.81	—						
2. Correlation of Deck A	-0.35	0.43	.03	—					
3. Correlation of Deck B	0.05	0.57	-.22*	-.21*	—				
4. Correlation of Deck C	-0.03	0.54	-.06	.15	-.40**	—			
5. Correlation of Deck D	0.05	0.56	.15	-.31*	-.34**	-.37**	—		
6. Correlation of Deck A+B	-0.13	0.52	-.14	.29*	.79**	-.36**	-.56**	—	
7. Correlation of Deck A+C	-0.15	0.56	.03	.55**	-.51**	.82**	-.46**	-.18	—

Note. ^a 1 = Sweet Liker, 2= Intermediate and 3= Sweet Disliker.

* $p < .05$. ** $p < .001$.

Discussion

Present study

The present study aimed to investigate potential differences between sweet liking phenotypes (Liker, Intermediate, Disliker) concerning two primary domains: self-reported impulsivity, which was measured using the BIS-11, BIS/BAS, and EC scales, and learning patterns exhibited during IGT. Overall, the primary hypotheses regarding significant group differences on these measures were largely not supported by the current data.

BIS-11

To the best of our knowledge, the current study is the first to directly investigate the relationship between trait impulsivity measured by the Barratt Impulsiveness Scale (BIS-11), and sweet liking phenotypes. While previous neurobiological research, such as the work by Zhang et al. (2015) linking the BIS-11 to specific prefrontal cortex regions including the vmPFC, provided a theoretical rationale for a potential association, no prior studies, to our knowledge, had directly examined this relationship using the BIS-11. However our findings did not support the hypothesis that impulsivity, as measured by the BIS-11 total score or its subscales, differed significantly across the sweet liking phenotype groups identified in this sample. The complex pathway from brain structure to trait impulsivity to specific sweet taste preferences might not be linear or strong enough to yield a significant association in a sample of this size.

BIS/BAS

The present study did not identify a significant direct association between BIS sensitivity and sweet liking phenotype categories. This finding therefore suggests that, within our sample and using our specific methodology for assessing hedonic responses to basic sweet tastes, baseline BIS levels do not straightforwardly differentiate individuals into Likers, Intermediates, or Dislikers. This contrasts with some initial hypotheses suggesting that lower BIS might characterize Sweet Dislikers due to potentially different patterns in impulsivity.

However, the relationship between BIS and sweet liking appears nuanced, as evidenced by other research. For instance, Mackey et al. (2018) investigated adults with overweight and obesity and

reported that a more sensitive BIS, in conjunction with lower effortful control, predicted greater liking for high-fat, sweet foods (assessed via the Leeds Food Preference Questionnaire (LFPQ)). Similarly Neseliler et al. (2017) found that higher BIS activity in individuals exposed to acute stress was associated with specific neural responses to high-calorie food cues. These included increased activation in the vmPFC, a region understood to specifically encode the subjective pleasantness of stimuli and to respond more strongly to affectively positive tastes independent of mere intensity or physiological significance (Rudenga & Small, 2013), and notably, decreased functional connectivity between the dlPFC and the vmPFC.

Our finding of no direct link between BIS and sweet liking therefore contrasts with these studies (Mackey et al., 2018; Neseliler et al., 2017), which suggest higher BIS can be associated with preference to palatable foods, and with our initial hypotheses. A key reason for this divergence may be the nature of the stimuli used. While our study assessed hedonic reactions to basic sweet solutions, both Mackey et al. (2018) and Neseliler et al. (2017) investigated responses to more complex palatable foods, using the LFPQ and food images, respectively. It is plausible that BIS influences the learned associations, complex sensory appeal, and caloric density of actual foods differently than it affects innate or learned preferences for simple tastes. Although recent evidence supports the notion that phenotypic differences in sweet taste liking are primarily specific to liking foods high in sweetness (Armitage et al., 2023). The reason why BIS relates to responses to complex sweet food stimuli (Mackey et al., 2018; Neseliler et al., 2017) but not to the direct hedonic response to simple sweet solutions remains complex and warrants further investigation.

Secondly, contextual factors are crucial. Neseliler et al. (2017) highlighted the role of acute stress, a condition not assessed in the current study. Similarly, Mackey et al. (2018) focused on a specific population (adults with overweight/obesity) where the interplay between temperament, reward sensitivity, and eating dysregulation may be particularly pronounced.

Beyond BIS, the present study also investigated the role of BAS in relation to sweet liking phenotypes. No significant differences in BAS total scores or its subscales (Reward Responsiveness, Drive, and Fun Seeking) were observed across the sweet liker, intermediate liker, and disliker groups. It is noteworthy that Carver and White (1994) did not empirically validate a BAS Total score and instead recommended the use of the three subscales to capture distinct facets of the reward system,

our study adhered to this by examining the subscales. This absence of a direct association between BAS scores and sweet liking phenotypes resonates with key aspects of the findings by Mackey et al. (2018). In their study involving adults with overweight and obesity, BAS sensitivity did not emerge as a significant direct predictor of heightened 'liking' or 'wanting' for palatable high-fat, sweet foods. The convergence of these findings strengthens the proposition that the broad motivational tendencies encompassed by BAS may not be primarily associated with the subjective intensity of hedonic 'liking' for sweet stimuli.

Furthermore, it is important to consider potential issues regarding construct validity when interpreting the relationship between temperament dimensions and reward-related traits like sweet liking. This complex interplay is illustrated by positive correlations between Cloninger's trait of Reward Dependence and both BIS and BAS sensitivity (Carver & White, 1994). Beyond this general complexity, specific concerns have been raised regarding the construct validity of the BAS Fun-Seeking subscale itself for measuring pure reward sensitivity. Some research has suggested that this subscale may better characterize an aspect of impulsivity rather than reward sensitivity (Franken & Muris, 2006; Sutton et al., 2022). This potential divergence in what the BAS Fun-Seeking subscale truly measures, alongside the broader complexity in relating BIS/BAS to other reward constructs, could contribute to the lack of direct associations observed between BIS/BAS scores and sweet liking phenotypes in the present study.

Effortful Control

The present study also investigated the role of effortful control concerning sweet liking phenotypes. No significant differences in EC total scores or its subscales (Activation Control, Inhibitory Control, Attentional Control) were observed across the Liker, Intermediate, and Disliker groups. It is noteworthy that these EC subcomponents are considered distinct neurocognitive functions, a view supported by neuroimaging research; for instance, Nouchi et al. (2016) identified differing neuroanatomical correlates for attentional control (e.g., involving the vmPFC) and inhibitory control (e.g., involving the dACC and SMA). However, in the context of basic sweet liking within our sample, these neurally distinct facets of EC did not show significant associations with sweet liking. This lack of significance, which again could be influenced by the study's statistical power, contrasts with the findings of Mackey et al. (2018). In their study with adults with overweight and obesity, lower EC was

a significant predictor of both greater 'liking' and 'wanting' for high-fat, sweet foods. The divergence between our null finding for effortful control with basic sweet taste liking and the findings reported by Mackey et al. (2018) that link EC to responses to complex palatable foods, which probably arises from methodological and sample differences, indicates that EC as a top-down self-regulatory capacity may exert a more discernible influence on consumption patterns and disinhibited eating of highly palatable, energy-dense foods in populations struggling with weight regulation, rather than on baseline hedonic responses to simple tastes in a general population sample.

IGT

Analysis of IGT performance revealed that participants learned and adapted their decision-making strategies over time. A significant interaction between deck type and block indicated an initial preference for disadvantageous decks (A and B), which gradually shifted to advantageous decks (C and D) in later blocks, demonstrating adaptive learning from feedback.

While the main group-based analyses did not yield significant differences, exploratory Spearman rank correlations indicated one statistically significant association suggesting that participants in higher-ranked phenotype groups (i.e., towards Disliker) showed a stronger tendency to decrease their choice of Deck B over time compared to those in lower-ranked groups (i.e., towards Liker). This may suggest that participants ranked towards the sweet liker phenotype group are more likely to choose Deck B over time. This could indicate impaired learning from negative outcomes, and insensitivity to future negative consequences. However, this isolated finding must be interpreted with considerable caution. Not only was this an exploratory result arising from multiple comparisons, but more importantly, subsequent primary analyses comparing the Deck B learning trends directly across the three sweet liking phenotypes did not yield significant differences, thus failing to corroborate this correlational observation at the group level.

Although the present study did not find significant differences in IGT learning trends among the sweet liking phenotype groups, the multifaceted nature of the IGT itself warrants consideration. This task integrates feedback-based learning with responses to both probabilistic outcomes and delayed consequences. Notably, research concerning the vmPFC, a region critical for optimal IGT performance, indicates a dissociation whereby individuals with vmPFC lesions exhibit more pronounced

discounting of delayed rewards but, conversely, less pronounced discounting of probabilistic rewards (Mok et al., 2021; Peters & D'Esposito, 2020). This suggests that if sweet liking phenotypes were to differ primarily in their evaluation of delayed outcomes (i.e., delay discounting), the complex interplay of probabilistic elements and feedback learning within the IGT might have attenuated such differences. Consequently, future research aiming to precisely specify the relationship between sweet liking and intertemporal choice could benefit from employing dedicated delay discounting tasks, which offer a more direct assessment of this particular construct.

Indeed, evidence supports an association between hedonic responses to sweet taste and this specific facet of impulsivity. Weafer et al. (2014) demonstrated that individuals who more steeply discounted delayed rewards also reported significantly greater liking for high concentrations of sweet solutions. Interestingly, this relationship was specific to impulsive choice and was not observed for impulsive action (measured by the go/no-go task).

Consequently, this leaves the potential associations between sweet liking and numerous other distinct sub-facets of impulsivity largely unexplored and open for future investigation. For instance, further research is warranted to examine potential links with other components of impulsive choice, such as reflection impulsivity or waiting impulsivity (Voon & Dalley, 2016; Dalley & Robbins, 2017; Voon, 2020).

Strengths of the study

In this study, most questionnaires demonstrated a range of moderate to acceptable internal consistency. We see that the total scale of the Dutch version of the used questionnaires (ECS, BIS-11, BIS/BAS) provides acceptable internal consistency. By utilizing both self-report questionnaires and a behavioral task, this study achieved a more comprehensive assessment of impulsivity and reward-related individual differences. This multi-method approach is a recognized strength (Bari et al., 2016; Moeller, 2011). Including the IGT as a measurement for reward sensitivity and impulse control beyond self-report enhances ecological validity for real-life decision-making, as it has randomized deck positions and an organized payoff scheme. Additionally, a total of 120 trials enables an analysis over time of decision-making patterns. Beyond the inherent design of the IGT, ecological validity was further enhanced in the present study by employing a specific form of deception regarding monetary

incentives. The use of a standardized method for the sweet liking assessment, suggested by Iatridi et al. (2019), ensures comparability with existing research. To ensure consistency over the sucrose solutions, these would be diluted on the day of testing using the same measurements and administered under the control of the investigators. Moreover, these would be divided into the same amount for each assessment to facilitate consistency. To minimize carryover and contextual effects, the assessment would take place in individual test cubicles, and participants had to rinse their mouths thoroughly with mineral water between tasting each sucrose solution. Additionally, to further strengthen reliability, the sucrose solutions were presented twice in a randomized order. Finally, classifying into sweet liking phenotypes using defined thresholds on a VAS based on the same framework of Iatridi et al. (2019) supports the robustness and comparability of the results.

Another key strength of this study lies in the comprehensiveness of the statistical analysis. Adding exploratory correlational analysis gives insights into the relationships of sweet liking phenotypes, decision-making behavior, and impulsivity. Combining parametric and non-parametric tests such as ANOVA's, repeated measure ANOVA, t-tests, Kruskal-Wallis tests allowed for a robust analysis of group differences and within-subject effects, while addressing potential violations of assumptions.

Limitations of the study and Suggestions for Future Research

This study is subject to several limitations. Firstly, the general absence of significant findings should be considered in light of the study's modest sample size, which inherently limited the ability to detect moderate effect sizes. The observed effect sizes were generally small, suggesting that the differences may have been subtle. When combined with the limited sample size, these modest effects may have fallen below the threshold of statistical detectability. Although Weafer et al. (2014) reported a significant effect with a similar sample size, their study involved only two groups, while the present study compared three. Dividing participants across more conditions reduced the number per group, which likely contributed to lower statistical power. Differences in methodology, effect size, or sample variability may also explain the discrepancy in findings. Replicating this present study in a larger sample would be recommended in terms of generalizability.

Another limitation relates to the study's participant age distribution. The sample predominantly consisted of young adults and older adults, leaving a notable age gap between 30 and 48 years. This limits the generalizability of findings to a broader adult population, particularly middle-aged cohorts. Furthermore, this age distribution raises concerns about the age-neutrality of self-report measures. Research by Derksen et al. (2023) on the Dutch BIS/BAS Questionnaire, in particular the BIS scale and BAS-Drive and BAS-Fun Seeking scale, found a lack of age-neutrality with significant differential item and test functioning between young and older adults. This age distribution is also particularly relevant when considering sweet-liking. Research suggests a U- or J-shaped curve characterizing sweetness preference across the lifespan, with high preference in childhood, a decrease with advancing age, and then an increase again in elderly (Venditti et al., 2020). Notably, despite these age-related considerations, the current study did not conduct analyses to investigate potential age-related differences in scores on the questionnaires or performance on the IGT, nor for sweet liking. Future research should explicitly account for age.

Furthermore, our sample is gender-imbalanced, including a larger proportion of women than men. The observed gender difference in BIS Total scores, with women reporting higher inhibition, is consistent with much of the existing literature (Carver & White, 1994; Jung et al., 2021; Leone et al., 2001; Ma-Kellams & Wu, 2020; Pagliaccio et al., 2016). Importantly, this difference cannot be attributed to age, as there were no significant age differences between male and female participants in our sample. In the study of Jung et al. (2021), they investigated sex differences in the BIS based on neurofunctioning, by analyzing resting-state fMRI data in healthy adults. This demonstrated that BIS sensitivity is linked to functional connectivity patterns involving the vmPFC, and importantly, that these neural correlates of BIS show significant sex differences. Given the vmPFC's role in valuation and the sex-specific neural underpinnings of BIS sensitivity, future research investigating the link between BIS and sweet liking should carefully explore potential sex-specific effects or interactions.

Additionally, we used sweet liking phenotypes based on the work of Iatridi et al. (2019). However, there is no method more superior than other methods. This suggests that there is not yet a method that provides more reliable results. To maintain consistency over the different sweet liking phenotypes, a widely accepted method should be considered in future research. However, this may

remain a challenge as it is not assured it can be translated to different ethnic populations (Iatridi et al., 2018).

Moreover, the sample of this study considered only healthy adults within the Belgian population. These findings may not be generalizable to populations with different typical sugar intake. This is particularly relevant because typical sugar intake levels and official dietary guidelines vary considerably across countries. These differences can influence the nature of the relationship between sweet liking and actual sugar intake in diverse populations (Iatridi et al., 2019). Adding to this, research shows that cultural and ethnic backgrounds may shape sweetness preferences (Venditti et al., 2020). Our study did not gather data on participants' ethnicity or cultural background, which limits our ability to account for these important influences.

Lastly, this study was solely based on the subjective measures of sweet liking, the questionnaires, and the task performance on the IGT. However, it did not include a measurement for brain activity, which could have provided insight into the underlying neural mechanisms involved during task performance. Future research including brain imaging techniques, such as fMRI or EEG, could enhance this research by clarifying neural correlates associated with reward processing and decision making.

Clinical implications

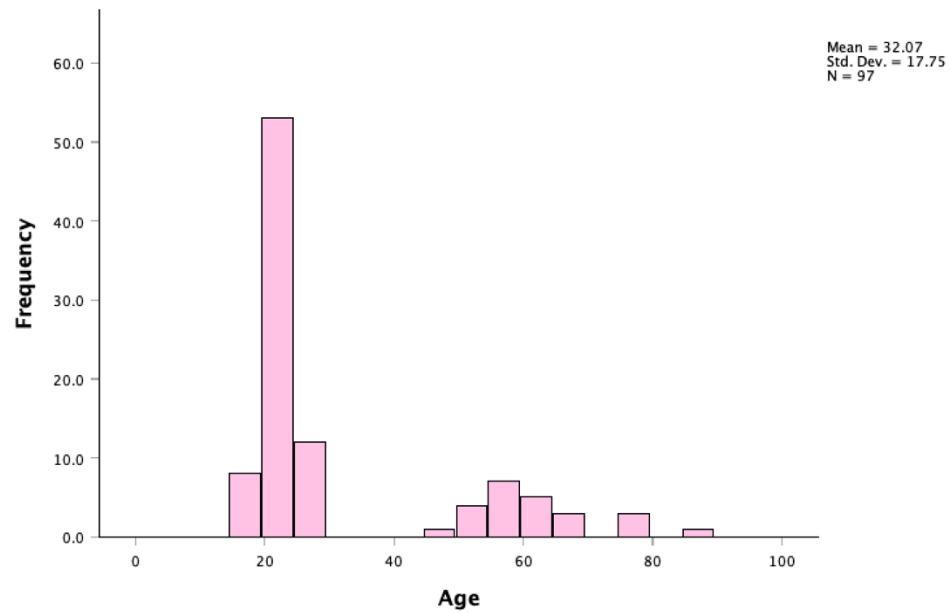
As highlighted in the introduction, sweet liking has been consistently associated with an increased risk for alcohol and substance use disorders (Weafer et al., 2017). Theoretically, it is suggested that shared neurobiological reward pathways play a role in this link (Berridge et al., 2008; Weafer et al., 2014; Weafer et al., 2017), raising the expectation that related constructs such as impulsivity and decision-making could be important factors. However, despite theoretical links between sweet liking, addiction, and constructs like impulsivity and decision-making, the findings from our study, which specifically investigated the role of trait impulsivity and a specific aspect of decision-making (measured by the IGT) in individuals with different sweet liking phenotypes within a non-clinical sample, did not reveal direct associations between these specific constructs and sweet liking. This suggests that the complex interplay between sweet liking and addiction vulnerability may involve other factors, or that the relationships are more nuanced than captured by these specific measures in a non-clinical sample. Our findings underscore the need to investigate more nuanced mechanisms that may mediate the known clinical link between sweet liking and addiction.

Conclusion

To conclude, the present research shows no significant association between the sweet liking phenotype groups and the questionnaires considering behavioral and dispositional impulsivity. This study also revealed a potential tendency for increased selection of the disadvantageous Deck B over time between high sweet likers, which may suggest impairment in learning from negative outcomes and insensitivity to punishment. However, this was not confirmed by primary group comparisons. To further elucidate these complex relationships, future research should investigate other facets of impulsivity and explore the neural correlates underlying the impulsivity-sweet taste relationship, particularly those involved in reward processing, decision-making, and sweet taste perception itself. Moreover, increasing the sample size may identify potential interactions.

Appendix A**Figure A1**

Distribution of Participant Ages in the Study Sample.



Appendix B

Iowa Gambling Task Participant Instructions

The instructions, presented in Dutch on the screen at the beginning of the task, were also read aloud to each participant by the experimenter.

Dutch Instructions

Welkom! U begint dit spel met 2000 punten. De bedoeling is dat u zo veel mogelijk punten verzamelt. Hoe meer punten u heeft aan het einde van de taak, hoe groter het bedrag dat u zal ontvangen: €0 tot €5. Tijdens elke beurt kiest u met de muis een kaart van één van vier stapels. Elke kaart levert een aantal punten op. Sommige kaarten kosten u tegelijkertijd echter ook een aantal punten! Indien u te veel punten verliest, kan u in het rood gaan en zo toch nog uw score proberen te verbeteren. Sommige stapels zijn beter dan andere. De plaats van de stapels op het scherm verandert NIET in de loop van de taak. Druk SPATIE om te beginnen.

English Translation

Welcome! You start this game with 2000 points. The goal is to collect as many points as possible. The more points you have at the end of the task, the greater the amount you will receive: €0 to €5. During each turn, choose a card from one of four decks with the mouse. Each card yields a number of points. However, some cards also cost you a number of points at the same time! If you lose too many points, you can go into the red and still try to improve your score. Some decks are better than others. The position of the decks on the screen does NOT change during the task. Press SPACE to begin.

Appendix C

Table C1

The Win-Loss-Contingencies During the First 10 Trials and Repeated Throughout the IGT

Deck	A		B		C		D	
Trial	Gain	Loss	Gain	Loss	Gain	Loss	Gain	Loss
1	100	0	100	0	50	0	50	0
2	100	0	100	0	50	0	50	0
3	100	-150	100	0	50	-50	50	0
4	100	0	100	0	50	0	50	0
5	100	-300	100	0	50	-50	50	0
6	100	0	100	0	50	0	50	0
7	100	-200	100	0	50	-50	50	0
8	100	0	100	0	50	0	50	0
9	100	-250	100	-1 200	50	-50	50	0
10	100	-350	100	0	50	-50	50	-250
Net Gain	-250		-250		+250		+250	
	10 wins		10				10 wins	
Frequency	5		wins 1		10 wins 5		1 loss	
wins/loses	losses		loss		losses			

Note. Adapted from "Exploring decision-making strategies in the Iowa gambling task and rat gambling task," by C. Hultman, N. Tjernström, S. Vadlin, M. Rehn, K. W. Nilsson, E. Roman, and C. Åslund, 2022, *Frontiers in Behavioral Neuroscience*, 16, 964348 (<https://doi.org/10.3389/fnbeh.2022.964348>). Original values were in SEK; values presented here are in points.

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