The Effects of Bitter Taste on Consumer Behaviour

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ABSTRACT

THE EFFECTS OF BITTER TASTE ON CONSUMER BEHAVIOUR

Lianze Hou

Bitter taste is innately aversive. The association between bitterness and difficult situations have been widely documented across various disciplines. A set of psychological adaptations may have co-evolved with the physiological responses to bitter taste, in responding to the recurrent challenge of harsh environments in human evolutionary history. Bitter taste is proposed to activate psychological mechanisms evolved for obtaining and retaining resources. In connection with consumer behaviour, experiencing bitter taste may alter consumers' preference toward high-calorie food and body-enhancing products. In this thesis, three experimental studies demonstrate how bitter taste influences consumers' behaviours. Study 1 finds that Chinese participants who drink bitter quinine-sulfate water solution consume significantly more high-calorie food, compared to those who drink plain water. Study 2 and 3 show that, in the Canadian cultural context, participants who imagine drinking a bitter beverage report higher competitive orientation and weigh the body-enhancing product attributes more in the choice task, compared to those who are primed with drinking plain water. This thesis contributes to introducing Darwinian principles to sensory marketing and adds to the existing literature on the effects of bitter taste on consumer behavior. Furthermore, it provides managerial implications for policy makers and marketing managers regarding how to promote healthy diets and how to improve the effectiveness of marketing campaigns for self-enhancing products.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1:
INTRODUCTION

Taste, as one of our basic senses, presumably evolved to inform us about the nutritional value and safety of our food. Humans have six primary tastes: sweet, salty, sour, umami, fatty, and bitter (Keast & Costanzo, 2015). Among them, sweet, umami, and fatty are usually involved in detecting desirable components of food which provide energy and essential materials for our metabolisms. Salty and sour can be regarded as either nutritious or toxic depending on their concentrations. Bitter taste, which is experienced as aversive and unpleasant, is presumed to be an indicator of toxic compounds in food. Because poisons can cause irreparable damage to our body, their detection in food is paramount. The set of compounds that elicits bitter taste is much larger and diverse compared to other tastes and we have evolved much more unique receptors for bitter detection than for detecting any other taste (Breslin, 2013). Also, the taste of bitterness can be detected at a much lower threshold (Drewnowski & Gomez-Carneros, 2000). The taste of a bitter compound can evoke strong rejection responses, thus preventing us from taking in more potentially poisonous food. These physiological mechanisms are significant adaptations that offered our ancestors protection from organic toxic compounds produced by plants or bacterial metabolites.

In addition to being a signal of a potentially noxious substance, bitter taste is associated with harsh environments and food shortage in human evolutionary history (Chen & Chang, 2012). Normally, individuals will have strong aversive reflexes and immediately stop taking in more food after experiencing a sharp bitter taste (Glendinning, 1994). Having to tolerate bitter taste implies a shortage of alternative nutritious foods. The consumption of bitter and poisonous foods in famine times has been documented in anthropology and economic history (Mokyr & Grada, 2002; Ocho et al., 2012; Slavková, 2019). Evolutionary psychologists proposed that our brain is a toolkit of cognitive adaptations selected to solve specific problems common in ancestral environments, and to maximize the chance of passing our genes to the next generation (Cosmides, 1989). Bitter taste, as a cue of harsh environments and food shortage, may provide a sensory context activating survival-related psychological mechanisms that prepare individuals for retaining and obtaining resources (e.g., value high-calorie foods, do more preparation for potential competition), to increase the chance of surviving the harsh environment.

In modern society, the psychological mechanisms activated by bitter taste could have broad influences on many aspects of our life, considering how common it is for people to start a day with a cup of coffee and end a day with a can of beer. Despite the prevalence of bitter-tasting products and the importance of sensory factors in marketing efforts, the effects of gustatory experience of bitter taste on consumer behaviour are still under-researched in the marketing discipline. To enrich our understanding of the effects of bitter taste, this thesis investigates the effects of bitter taste on consumer behavior and decision-making via three experimental studies. The main research findings include that experiencing bitter taste, compared to neutral taste, leads consumers to:

- Consume more high-calorie food.
- Show higher competitive orientation.
- Prefer to choose products that boost physical or cognitive performance.

A key theoretical contribution of this project is the infusion of Darwinian principles within the sensory marketing literature. Also, findings of this research may assist governments and policy makers in decreasing the consumption rate of high-calorie foods and thus promoting a healthier diet. Moreover, marketers could benefit from this research as the findings suggest that marketing campaigns of body-enhancing products may work better if they are placed in locations where people are primed with or consume bitter-tasting foods or drinks.

This thesis firstly reviews empirical studies investigating the effects of sensory inputs on consumer behaviour in a variety of marketing contexts. Secondly, it discusses how evolutionary psychology provides a powerful framework for the sensory studies and contributes to greater methodological pluralism, greater interdisciplinarity, and consilience. Next, through the lens of evolutionary theory, this thesis explores why bitter taste may serve as a cue of harsh environments and how it may affect consumer-related phenomena, followed by four novel hypotheses. Then three experimental studies are included in the thesis to test the posited hypotheses. The methodology and results of three studies are presented, followed by a general discussion related to the findings and conclusions. Finally, limitations, future research, and managerial implications are discussed.

CHAPTER 2:
SENSORY MARKETING AND CONSUMER BEHAVIOUR

The main purpose of this research project is to investigate how bitter taste, as one of the basic senses, affects consumer behaviour. A literature review of previous studies in the sensory marketing field is presented in this chapter to provide insights into the potential effects of bitter taste on consumer behaviour. The following sections begin by exploring empirical studies that have demonstrated significant effects of sensory factors on a variety of consumer behaviours. The scope of literature view is then narrowed down to the studies investigating the effects of tastes on specific consumer behaviours. Finally, evolutionary psychology is presented as a powerful framework for understanding the effects of bitter taste on consumer behaviour.

2.1 Sensory Experience and Consumer Behaviour

Sensory marketing is defined as "marketing that engages the consumers' senses and affects their perception, judgment and behavior" (Krishna, 2012, p. 333). Today's markets are highly competitive as modern consumers are constantly evolving and increasingly demanding. A growing number of companies are investing heavily on new techniques and strategies that create pleasurable sensory experiences. Marketers use sensory cues with all possible sensory dimensions to influence their customers' perceptions, memories, and decision-making, aiming to strengthen the connection between customers and the brand. Behavioral researchers also exhibit great interest in the effect of sensory experience on consumer behaviour. Contrary to the computer metaphor of information processing (cold cognition) in traditional models of judgement and decision-making, researchers are reaching a wide consensus that we cannot fully understand consumer behaviour without taking the sensory factors into account. After all, it is through the five basic senses (i.e., touch, smell, taste, hearing and sight) that consumers experience products and interact with the world (Krishna & Schwarz, 2014). Empirical studies on all sensory modalities show that sensory and bodily experiences can largely influence consumers' perceptions, attitudes, and decision-making even before people consciously realize it (De Luca & Botelho, 2019; Krishna, Cian, & Sokolova, 2016). The following paragraphs will review previous literatures on effects of the five sensory modalities on consumer behaviour.

2.11 Haptics

The sense of touch occurs across the whole body, reflecting the stimuli received by a variety of receptors in our skin. Consumers collect information of temperature, humidity, pressure, coarseness, vibration, and weight through the sense of touch, and use the information to judge the quality and value of a product or a service. The information input can be critical to consumers' product evaluation, willingness to pay, and purchase decision making. For example, Grohmann, Spangenberg, and Sprott (2007) found that the tactile input polarizes consumers' evaluation for products wherein the tactile information is diagnostic. Consumers give higher evaluations for the high-quality product and lower evaluations for the low-quality product when they are able to touch the products than when they are not (Grohmann, Spangenberg, & Sprott, 2007). Szocs and her colleagues (2016) found that the weight of containers may influence consumers' feelings and perceptions about alcohol consumption. Consumers report more positive feelings and fewer negative feelings when they consume alcohol from lighter containers,

and also report higher perceived intoxication (Szocs, Biswas, & Borges, 2016). Peck and Childers (2003) found that, with the help of information collected from the sense of touch, consumers are more confident in their decision-making. Moreover, touch experience helps create a bond between the person and an object. Peck, Barger, and Webb (2013) documented that people report higher degree of perceived ownership of a product after touching it physically or imaginarily. And consumers are more likely to give a higher valuation of, to report a higher willingness to pay for, and to impulsively purchase the product they touched, thanks to the endowment effect (Peck & Childers, 2006; Peck & Shu, 2009).

Besides being an important source of information for consumers to evaluate a concrete product, the sense of touch may also affect how consumers behave and think in a variety of marketing contexts. Hornik (1992) demonstrated how casual interpersonal touch affects consumer behaviour in three empirical studies. Consumers who are casually touched by an experimenter respond more favorably to external stimuli presented in the marketplace. They give higher evaluation to the store/restaurant, make more purchases, give more tips, and comply more with the experimenters' requests. Hornik also discussed the importance of nonverbal communications in marketing research. The role of interpersonal touch on consumer behaviour and cognition has emerged as an important topic in marketing science since then. Subsequent research has further examined the boundaries of the interpersonal touch effect in different marketing contexts. For example, Orth, Bouzdine-Chameeva, and Brand (2013) found that a salesperson's touch increases consumer trust when consumers have an inherent need for touch or when personal touching behaviour is less prevalent in their background culture. Martin (2012) asked confederates to "accidentally" brush past behind participants using their arms when the participants viewed the target products. The results showed that participants spend less time in the store and report more negative evaluations to both the store and brands after being touched by a stranger, especially when the stranger is male. The accidental interpersonal touch effect is more salient for consumers with higher trait anxiety and when the social visibility is high in the situation (Martin & Nuttall, 2017). Additionally, the sense of touch may serve as a contextual cue that shapes people's cognition and behaviour (Ackerman, Nocera, & Bargh, 2010). Wang, Zhu, and Handy (2016) demonstrated that haptic sensation of roughness primes people to pay specific attention to those in misfortune or hardship, resulting in a higher empathy level and a higher willingness to donate to charities. And people may assimilate their bodily sensation of tactile stimuli with product assessment when their visual access to the product's features is limited. For example, when standing on a carpeted floor, consumers rate a product placed far away as having a more comforting appearance, compared to when standing on the hard tile floor (Meyers-Levy, Zhu, & Jiang, 2010).

2.12 Smell

The sense of smell also serves as an important source of information for consumers to evaluate products in the marketplace. The close biological link between olfaction and memory allows people to remember a smell for a long time, and to quickly retrieve the smell-associated memories and emotions when they encounter it again (Krishna, 2012). The scent cues presented in the marketplace therefore affect consumers' recall and recognition of products and brands. For example, product scent significantly enhances consumers' long-term memory for product information (De Luca & Botelho, 2020; Lwin, Morrin, & Krishna, 2010; Morrin, Krishna, &

Lwin, 2011). And the presence of a pleasant ambient scent in a room where people incidentally encode brand information enhances recall and recognition of the brands (Morrin & Ratneshwar, 2003). However, compared with ambient scent, product scent contributes to a more long-lasting enhancement to consumers' product recall (Krishna, Lwin, & Morrin, 2010). Moreover, the presence of pleasant ambient scents may lead to more positive evaluations of the products and shopping experience, resulting in higher purchase intention and willingness to pay. For example, Morrison and his colleagues (2011) diffused vanilla aroma throughout a retail store and collected consumers' responses using a store exit survey in a field experiment. They found that consumers report a higher pleasure level, more time and money spent, a higher overall satisfaction and more approach behaviours when the vanilla aroma is present than when it is not. Also, Lwin and her colleagues (2016) demonstrated that olfactory input leads consumer to pay more attention to a semantically congruent visual object in the ad and enhances memory as well as purchase intention for the object. Therefore, stores may distribute specific scents near product displays to attract consumers' attention and enhance sales (Doucé et al., 2013; Doucé & Janssens, 2013).

Besides providing essential information for people to evaluate products and brands, the sense of smell may also affect consumers' environmental perceptions and behavioural tendencies in subliminal or subconscious manners. For example, Madzharov, Block, and Morrin (2015) used both experimental and field studies to demonstrate that ambient scents may affect consumers' perception of temperature and space in retail environments. Warm (vs. cool) ambient scent may serve as an environmental cue of higher (vs. lower) social density and therefore increase consumers' power-compensatory preference. Consumers interacted with warm (vs. cool) ambient scent experience a greater (vs. lesser) need for power and show higher preference towards luxury products and brands. Also, Lefebvre and Biswas (2019) found that ambient scent temperature influences food consumption by changing people's perception of ambient temperature, which implies potential energy expenditure. When exposed to cool (vs. warm) ambient scent, consumers tend to perceive the ambient temperature as lower and they exhibit higher preference to and consume higher amounts of high-calorie foods. Moreover, scents may change people's behaviours by making certain mental concept more accessible. Holland, Hendriks, and Aarts (2005) found that the scent of cleaning products subconsciously increases people's mental accessibility of the cleaning concept and lead people to keep their environments clean. The effect was also successfully replicated in a field study where passengers littered significantly less in train compartments scented by an all-purpose cleaner (de Lange et al., 2012).

2.13 Audition

Audition in marketing takes many forms and consumers are constantly exposed to various auditory marketing communications. Auditory sub-areas that are well researched include but are not limited to music, voice, language, and sound symbolism (Krishna, 2012). The auditory factors in marketplace may directly influence consumers' product evaluations and purchase intentions. For example, consumers' foods evaluation and flavor perception may be influenced by the sounds in the marketplace (Spence, 2015a). Both background noise and loud music lower consumers' sensitivity in detecting and discriminating similar olfactory or gustatory stimuli, and therefore affect how consumers evaluate products (Spence, 2014). Consumers' perception of the taste of wines and liking ratings of wines are significantly affected by the type of music played in the background (Spence, Velasco, & Knoeferle, 2014). Moreover,

background music may facilitate product recall and increase consumers' purchase intention and willingness to pay, when the music is congruent with the products in term of the country of origin, utilitarian, or social identity (North, Sheridan, & Areni, 2016; Peng-Li et al., 2020). The products for which softness is a central attribute (e.g., towel, T-shirt) are perceived as more pleasantly soft and receive more positive evaluations when the music in the background has higher softness (Imschloss & Kuehnl, 2019). Besides the sound of music played in the background, the sounds people make when they prepare or consume foods or drinks also affect consumers' product evaluation and purchase intention (Spence, 2012a; Spence, 2015b; Spence & Wang, 2015). For example, potato chips are perceived as both crisper and fresher if consumers receive enhanced auditory feedback of the sound elicited during their biting actions (Zampini & Spence, 2004). And sparkling water is judged to be more carbonated when the water sound is increased by either holding the water close to the ear or amplifying the overall water sound level (Zampini & Spence, 2005). At last, language used by the service provider, as another auditory factor in the marketplace, may also affect the perceived quality of service and the size of tips given by the consumers (van Vaerenbergh & Holmqvist, 2013).

In addition to the direct effects on consumers' product evaluation and purchase intention, the auditory factors in marketing communications affect consumers' cognitive and behavioral tendency in various marketing contexts (Krishna, Cian, & Sokolova, 2016; Michel, Baumann, & Gayer, 2017). For example, Chebat, Chebat, and Vaillant (2001) demonstrated that music in the marketplace might divert consumers' attention away from a salesperson's arguments. Compared to slow tempo music, fast tempo music attracts significantly higher attention onto the music itself and reduces consumers' cognitive resources allocated to processing sales speech and sales encounters, hence affecting the persuasiveness of commercial messages. Strick and her colleagues (2015) found that emotionally moving music reduces consumers' awareness of the manipulative intent of the advertiser, leading to increased persuasiveness of the audiovisual advertising. Moreover, phonetic properties of sounds may alter people's judgement and expectation of object size and shape (Knoeferle et al., 2017; Spence, 2012b). Both behavioural and neurophysiological evidence shows people tend to map auditory stimuli to specific visual features (Kovic, Plunkett, & Westermann, 2010; Revill et al., 2014). For example, lower pitch in voice or music is usually linked to larger product size (Lowe & Haws, 2017). Also, Yorkston and Menon (2004) found that compared to the ice cream brand name with the phonetic sound [i], a name with the sound [ä] is rated as having higher creaminess, richness, and smoothness.

2.14 Vision

Vision is the dominant sense that consumers rely on to collect information, and visual factors in marketing communications is doubtlessly the most researched field in sensorial marketing (Krishna, 2012). The visual design of product, package, and advertising strongly influences how consumers evaluate a product or a brand (Krishna, Cian, & Sokolova, 2016). For example, artistic elements contribute to more favorable consumer responses to a product (Hagtvedt & Patrick, 2008). The visual salience of a product package usually affects consumers' product evaluation in a positive way (Krishna, Cian, & Aydınoğlu, 2017). And a dynamic imagery design of brand logos increases consumer engagements, leading to more positive brand attitudes (Cian, Krishna, & Elder, 2015). Moreover, visual attributes of products or brand logos may be associated with certain concepts in people's mind. Jiang et al. (2016) found that a

circular (vs. angular) brand logo activates a "softness" (vs. "hardness") concept through mental imagery, therefore affecting consumers' attitudes toward the product or the brand and consumers' willingness to pay.

In addition to directly influencing consumers' product or brand evaluation and purchase intention, vision factors also play essential roles in various marketing contexts. For example, advertisers may present visual stimuli that match their advertising stories to make the story more easily comprehended, especially for political and health ads of which narratives are usually difficult to understand (Chang, 2013). Marketers and policy makers may use people's visual biases to manage consumers' package size impression, facilitating healthier consumption trends (Ordabayeva, & Chandon, 2013). Moreover, recent studies are examining some visual factors that specifically affect consumer experience in online marketing contexts. For example, Choi and Taylor (2014) investigated 3D virtual advertising in online shopping environments. They found that 3D interaction allows consumers to generate more vivid mental imagery about using the product. Cowan and Ketron (2019) reviewed the literature on the usage of virtual reality technique in marketing communications, and they concluded that although the new technique could play an important role in developing consumer involvement, marketers should be aware of the potential risk of information overload. Moreover, the usage of emoticons in online service encounter may affect consumers' attitudes towards the service. Li, Chan, and Kim (2019) found that consumers perceive a service employee as warmer but less competent when an employee uses emoticons during the online service interaction than when the employee does not use emoticons. When online communications between consumers and brands have become the new norm in this post-pandemic world, marketing managers may need to learn more about how the visualization of language and emotions on screens may affect consumer-brand relationships.

2.2 Tastes and Consumer Behaviour

Humans can distinguish between six primary tastes: sweet, salty, sour, umami, bitter, and fat tastes (Keast, & Costanzo, 2015). Sweet, umami, and fat tastes usually indicate the existence of desirable components in foods, i.e., carbohydrate, protein, and fat, which provide energy and key materials for our metabolisms. The combination of sweet, umami, and fat tastes in food is universally welcomed and is widely added to industrially produced foods to produce delicious taste (Mouritsen, 2016; Zhang et al., 2020). Thanks to our innate preference for high-sugar, high-protein, and high-fat foods, which is evolved as an adaptation to the scarcity of nutritious foods in our human evolutionary past, modern humans are suffering from several chronic health problems, such as obesity and diabetes, as the instinctive craving for high-calorie food meets modern consumerism (Chakravarthy & Booth, 2004; Saad, 2013). Saltiness and sourness play important roles in determining the flavor of foods and drinks. The desirability of saltiness and sourness is largely determined by the intensity of taste and the context in food flavors. Moderate salt concentrations, providing desirable amounts of vital ions to the human body, are usually considered tasty, whereas high concentrations of salt are perceived as aversive. This mechanism helps to keep the osmotic balance of our body fluids. Similarly, high acid concentrations are unpleasant and even detrimental. Moderate sour taste, signaling desirable amounts of vitamin C, is perceived as delightful, especially when mixed with sweet tastes and in the context of fruit flavors (Breslin, 2013). The preference for salty and sour taste differs greatly among populations, in alignment with the variety of culinary cultures around the world (Brown et al., 2009; Prescott

et al., 1998). Bitter taste, however, is universally perceived as aversive and unpleasant by most people as well as other mammals (Glendinning, 1994). On the one hand, bitterness is a taste that the food industry has devoted to removing from products. On the other hand, bitter taste is usually linked to bioactive compounds in foods that contribute to our health (Bravo, 1998; Cavallo et al., 2019; Drewnowski & Gomez-Carneros, 2000). Despite being aware of the link between bitter taste and some health benefits, many modern consumers would not like to compromise on the taste of healthy foods (Raghunathan, Naylor, & Hoyer, 2006; Verbeke, 2006). However, bitterness is more acceptable for foods that have psychoactive effects and incentive value, such as coffee and tea (Garcia-Burgos & Zamora, 2015). The preference for and sensitivity to bitter taste are strongly influenced by genetic factors. Nevertheless, being familiar with and having repeated exposures to bitter taste can lower people's avoidance to or even promote a preference for bitter-tasting foods (Beckett et al., 2014; Diószegi, Llanaj, & Ádány, 2019; Ventura & Worobey, 2013).

In addition to being essential attributes that determine consumers' liking of a dish, tastes are linked to a variety of individual differences in consumer preferences. It has been documented that personal preference for certain taste is linked to several personal dispositional factors. Also, exposure to different tastes during food or drink consumption was found to have subsequent effects on consumers' cognitions and behavioural tendencies. The following sections review existing literatures on the effects of tastes on consumer behaviours and the relationship between taste preferences and individual differences. Moreover, the literature review includes some consumer behaviour research on spiciness because it is an important food-related sensory factor that may significantly affect consumer behaviours, although the sensation of spiciness is technically a type of pain rather than a taste (Yang, & Zheng, 2017). Following the review of past literature, the embodied cognition theory, which is usually used to explain and predict taste-behaviour relationships, is briefly discussed. Finally, the last section introduces evolutionary psychology as a superior theoretical framework for providing powerful explanations and generate novel hypotheses regarding various taste-behaviour relationships.

2.21 Tastes and Interpersonal Behaviours

Sweet foods are universally welcomed, and it is the same for "sweet" people. Personal preferences for and the consumption of sweet foods significantly predict individual prosocial personalities, prosocial motivation, and prosocial behaviours (Fetterman, Meier, & Robinson, 2017). Participants who consumed sweet foods rate themselves as more agreeable and are willing to volunteer more time in a subsequent unrelated task to help others, compared to those in a control group (Meier et al., 2012). Also, sweet taste experience leads to more positive attitudes towards surrounding people and objects. For example, Ding, Ji, and Chen (2016) found that participants rate unfamiliar faces as less dangerous and more trusted after having consumed sweet drinks than bitter drinks. Similarly, Schaefer et al. (2020) found people who tasted sweet candies rate faces as more attractive than people who tasted salty snacks. And even imagining sweet tastes will lead participants to have a more favorable attitudes toward the target advertisements and products (Ahn & Min, 2020). Moreover, the consumption of sweet food may have effects on people's cognitions and behaviours in romantic relationships. For example, Wang and Chen (2019) demonstrated that sweet taste enhances people's cognitive sensitivity to romantic words. Also, Ren et al. (2015) found that single individuals who consumed sweet foods

rate a hypothetical relationship more positively and show greater interest in starting a romantic relationship with a potential partner, compared to those who consumed non-sweet food or drink.

Unlike sweetness, spicy, sour, and bitter tastes are often linked to negative interpersonal behaviours. Ji et al. (2013) found that spicy and sour preferences are significantly correlated with trait anger. Batra, Ghoshal, and Raghunathan (2017) demonstrated that participants who consumed spicy food show higher semantic activation of aggression-related thoughts and perceive a higher aggressive intent in others, compared to those who consumed plain food. They also found that mere exposure to a visual or verbal prime of spicy food is enough to activate these aggressive cognitions. Finally, bitter preference was found to be a significant predictor of antisocial personality traits (Sagioglou & Greitemeyer, 2016). Sagioglou and Greitemeyer (2014) also discovered that participants who consumed a bitter drink report higher hostile mood, more feelings of anger, and increased feelings of irritation. And participants tend to evaluate experimenter more negatively after having consumed a bitter beverage in the experiment.

2.22 Tastes and Moral Judgement

Taste experience may affect how people evaluate and judge others' behaviour. In alignment with the idiomatic metaphor "revenge is sweet", the sweet taste leads people to judge a harmful act more leniently when it is perceived as a vengeful response (Hellmann, Thoben, & Echterhoff, 2013). The physical disgust triggered by bitter taste is associated with moral disgust. Participants who consumed a bitter beverage convey significantly harsher moral judgements in a following moral-judgment task, compared to those who consumed sweet juice or neutral water (Eskine, Kacinik, & Prinz, 2011). A proximate neuroscientific explanation is that tastes can activate the orbitofrontal cortex, which is related to value-based decision-making (Fellows, 2011; Zald, Hargen, & Pardo, 2002).

2.23 Tastes, Sensation-Seeking, and Risk-Taking

Tastes are also linked to sensation-seeking and risk-taking behaviours. The liking of spicy food serves as a significant predictor of trait sensation-seeking (Byrnes & Hayes, 2013). The amount of spicy foods consumed yearly is positively correlated with consumers' self-reported sensation-seeking, sensitivity-to-reward, and risk-taking (Byrnes & Hayes, 2016). Wang et al. (2016) also found that a preference for spicy food is positively correlated with a propensity to take risks, and spicy food consumption significantly increases risk-taking behaviours in the Iowa Gambling Task. Interestingly, male participants who put more spicy sauce in their meal during a tasting session are also likely to have higher endogenous testosterone levels, which may provide a physiological explanation to the relationships between spicy preference and risk-taking (Bègue et al., 2015). Moreover, Vi and Obrist (2018) investigated the effects of five basic tastes (sweet, sour, bitter, salty, and umami) on participants' performance in the Balloon Analogue Risk-Taking task. They found that participants are more willing to take risks after experiencing sourness than any other tastes. The finding is consistent across participants from two different countries (UK and Vietnam) and across individuals with different levels of risk-taking and styles of thinking.

2.24 Tastes, Variety-Seeking, and Impulse Buying

Tastes may influence consumers' decisions on the variety and the quantity of products to be purchased. Mukherjee, Kramer, and Kulow (2017) found that consumers tend to purchase a greater variety of products after consuming spicy food than after consuming non-spicy food, suggesting that spicy taste increases variety-seeking. Moreover, Cai et al. (2017) found a significant interaction effect between mood and bitter taste on consumers' saving decisions and impulsive purchases. Happy consumers tend to save more and spend less after experiencing bitter taste whereas unhappy consumers tend to save less and spend more after tasting something bitter. At last, the umami taste may decrease the amounts of food purchased by consumers as it provides an earlier trigger of food satiation. It has been documented that umami gustatory sensation increases fullness ratings and reduces the appetitive motivation after a short-time interval, therefore reducing subsequent food intake (Masic & Yeomans, 2014; Rogers & Blundell, 1990).

2.25 Theories on Taste-Behaviour Relationships

The embodied cognition theory is usually used to explain and predict taste-behaviour relationships. According to the theory, the processing of abstract concepts is pertinent to our sensory-motor experiences, forming close associations between our mind and body (Barsalou, 2008; Wilson, 2002). People's early sensory experiences of various tastes are used as a concrete foundation for the development of more abstract concepts and goals in the later life cycle stages (Williams, Huang, & Bargh, 2009). For example, "sweet" metaphors make it much easier for people to understand and communicate the agreeableness of others based on their early pleasurable experience of the gustatory sensation (Meier et al., 2012). Such taste-related metaphors are commonly used in our everyday discourse. The embodied cognition theory suggests gustatory sensations that are metaphorically related to abstract thoughts may influence various high-level cognitive activities, such as goal pursuits and judgements, and therefore affect consumers' behaviours and decision-making (Krishna & Schwarz, 2014). For instance, Xu, Wan, and Schwarz (2020) proposed that a bitter taste experience should affect Chinese and Canadian participants' fairness judgements differently because bitterness is metaphorically associated with concepts of injustice or being treated unfairly in the English language but not in the Chinese language. They demonstrated that the consumption of bitter lotus seeds increases perceived unfairness for Chinese participants who lived in Canada when they are tested in English rather than when they are tested in Chinese.

Beyond the embodied cognition theory, evolutionary psychology can also provide powerful explanations and generate novel hypotheses regarding various taste-behaviour relationships. From an evolutionary psychology perspective, our gustatory sensations are evolved adaptations that provide us with environmental information essential to our survival and reproductive success (Breslin, 2013). Tastes, as environmental cues, indicate the quality and quantity of nutrition that is currently available and therefore direct people's behaviours in allocating efforts to maximize the chance of survival and reproductive success. For example, people universally like the combination of sweetness and moderate levels of sourness in the context of fruit flavor because the taste mix indicates favorable amounts of sugar and acids that fuel our metabolisms. And with the nutritious food sustaining body energy, people are more incline to behave in a future-oriented manner to increase the chance of reproductive success

(Wang & Dvorak, 2010). In contrast, bitter taste serves as an environment cue of food scarcity, leading to less future-oriented behaviours (Chen & Chang, 2012). The evolutionary principles do not conflict with the embodied cognition theory but provide a meta-theoretical framework for the coevolution of body and cognition, guiding the development of embodiment approaches (Kaschak & Maner, 2009; Glenberg, 2010).

In order to investigate the effects of bitter taste on consumer behaviour, a theoretical framework is needed as a guidance for hypothesis development. Chapter 2 reviewed previous studies in the sensory marketing field and provided two alternative theoretical approaches: embodied cognition theory and evolutionary psychology. Also, the findings related to bitter taste have been summarized in the Table 2.1. In the next chapter, numerous examples are presented to illustrate the benefits and significance of introducing Darwinian theory into marketing research.

Table 2.1 Summary of Findings Related to Bitter Taste in the Field of Sensory Marketing

Topic	Author(s)	Findings
Tastes and Interpersonal Behaviours	Ding, Ji, and Chen (2016)	Participants rate unfamiliar faces as less dangerous and more trusted after having consumed sweet drinks than bitter drinks.
	Sagioglou and Greitemeyer (2014)	Participants who consumed a bitter drink report higher hostile mood, more feelings of anger, and increased feelings of irritation than those who consumed plain water. And participants tend to evaluate experimenter more negatively after drinking a bitter beverage than drinking neutral water in the experiment.
	Sagioglou and Greitemeyer (2016)	Bitter preference is a significant predictor of antisocial personality traits.
Tastes and Moral Judgement	Eskine, Kacinik, and Prinz (2011)	Participants who consumed a bitter beverage convey significantly harsher moral judgements in a following moral-judgment task, compared to those who consumed sweet juice or neutral water.
	Xu, Wan, and Schwarz (2020)	The consumption of bitter lotus seeds increases perceived unfairness for Chinese participants who lived in Canada when they are tested in English rather than when they are tested in Chinese language.
Tastes, Variety-Seeking, and Impulse Buying	Cai et al. (2017)	Happy consumers tend to save more and spend less after experiencing bitter taste whereas unhappy consumers tend to save less and spend more after tasting something bitter.

CHAPTER 3:
EVOLUTIONARY PSYCHOLOGY AND MARKETING

Chapter 2 discusses that evolutionary psychology can guide this research project in developing novel hypotheses, and Chapter 3 provides numerous examples to demonstrate why using evolutionary psychology as the theoretical framework can greatly benefit the marketing discipline in general. A growing number of marketing researchers are recognizing the importance of adopting the evolutionary framework in understanding consumer behaviour (Saad & Gill, 2000; Saad, 2007; Saad, 2011; Saad, 2013). Saad (2017) discussed in detail how the infusion of Darwinian theory in marketing research benefits the field by promoting methodological pluralism, interdisciplinarity, and consilience. Evolutionary psychology posits that consumer behaviour can be explained by a few powerful and parsimonious meta-theories. This provides scholars in general and marketing scholars in particular with consilience across the humanities, social sciences, and natural sciences because these disciplines have no impassable boundary when viewed through an evolutionary lens (Saad, 2008; Wilson, 1998). The boundaryless environment encourages researchers to conduct interdisciplinary studies involving a variety of methodologies, yielding improved reliability and validity of research findings. The following sections reviews studies that have applied Darwinian principles and discuss in detail the benefits of incorporating the evolutionary theory within marketing research programs.

3.1 Evolutionary Psychology Yields Greater Methodological Pluralism

Evolutionary psychology provides marketing scholars with a biological-based theoretical framework that examines consumption phenomena in the wider human context, across disciplinary boundaries (Saad, 2013). Without a fixation on any specific field, researchers can freely adopt any new methodology, no matter in which discipline it was firstly developed or mainly used, to study consumption phenomena.

For example, the introduction of evolutionary psychology has greatly increased the number of methodologies involved in the studies on the consumption of beautification products. Traditionally, empirical studies conducted in this field relied heavily on survey-based methods. Researchers usually develop and distribute questionnaires that ask respondents to self-report hypothesized constructs (e.g., branding factors, product factors, and individual difference factors) through online survey platform or by mail (Guthrie, & Kim, 2009; Lee et al., 2003; Parvin, & Chowdhury, 2006). The conclusions of these studies were largely based on correlational data which have limitations in demonstrating causal relationships among variables. Such methodological fixation can reduce the validity of research findings (Davis et al., 2013; Pham, 2013). However, evolutionary behavioral scientists are not constrained by methodological fixation. They are very open to importing methodologies from other fields or disciplines for the purpose of examining the evolutionary roots and evolved functions of beautification products. For instance, Saad and Stenstorm (2012) examined the relationship between physiological factors, such as women's hormonal fluctuations associated with the menstrual cycle, and female consumers' behavioral pattern in appearance-related consumption. The study tracked participants for a 35-day period and estimated each phase of the menstrual cycle by using the reverse-cycle-day method, which provided a proxy for physiological hormonal fluctuations. And participants were not only required to complete longer surveys on a few occasions, but also asked to take a 35-day shopping diary recording their daily buying behaviours. The study design improves the ecological validity

of the research findings by including survey data, behavioural data, and physiological data into analyses. Congruent with the posited hypothesis, women were found more likely to consume beautification products in the fertile phase of their menstrual cycle (Saad & Stenstorm, 2012). Durante and her colleagues (2011) drew similar conclusion using a different methodology. In their study, female participants were asked to provide their urine samples to complete the luteinizing hormone test. The test results were used to identify the high fertility phase. Participants in this study also completed a virtual shopping task on a retail website in a well-controlled laboratory setting (Durante et al., 2011). Some other novel methodologies, such as biographical measures and outfit illustration, were also introduced to marketing science by the evolutionary psychologists Durante, Li, and Haselton (2008). The usage of multiple measures in studying women's hormonal shifts and desires towards beautification products provides convergent evidence that greatly improves the ecological validity of the research findings.

The examples highlight the greater methodological pluralism brought by evolutionary psychology in marketing science. An open mind toward created greater consilience between the business sciences and the natural sciences allows marketing researchers to flexibly choose the most appropriate methodology in their research. By using different research methods, researchers alleviate the pitfalls of the common method bias on their data and therefore draw more robust conclusions. Also, methodological pluralism allows researchers to inspect a given phenomenon from different angles, which is pertinent to the development of theories.

3.2 Evolutionary Psychology Yields Greater Interdisciplinarity

Adopting an evolutionary framework in the business sciences also contributes to greater interdisciplinarity. The human universal preference for high-calorie food is a powerful mechanism that evolved to tackle recurring food shortage in our species' evolutionary past (Saad, 2011). This instinct is so powerful that it cannot easily be overridden by conscious cognitive control, and this has led to many negative consequences to modern humans' health and well-being. The evolutionary explanation to this phenomenon has attracted researchers from many different disciplines to study this "maladaptive" adaptation in the current environment due to the mismatch hypothesis (Eaton & Konner, 1985; Saad, 2007; Saad, 2013), hoping to find a solution to the problem of obesity. The evolutionary framework, serving as a meta-theory for explaining human behaviour, introduces a boundaryless academic landscape that allows consumer researchers to focus on the research questions that are interesting to them without being constrained by one particular discipline where the question is mainly studied. The following paragraphs will discuss some empirical studies demonstrating that incorporating an evolutionary approach has promoted interdisciplinarity.

With an understanding that consumers' craving for high-calorie food has an evolutionary basis, Talukdar, and Lindsey (2013) conducted two empirical studies in which they tried to meld research streams from economics and psychology. They proposed a novel hypothesis, which is contrary to the assumption of standard economic theories, that consumers' demand sensitivity to price changes varies depending on whether the product is healthy or unhealthy food. Results show that, for healthy food, demand sensitivity is greater for price increase than for price decrease. However, for unhealthy food, the relationship is reversed. The findings provide us with a new economic perspective toward healthy/unhealthy food product – they have a different price elasticity than other products. The theoretically significant findings will promote additional

economic research regarding the food industry as this special case of price elasticity should be taken into consideration in mathematical models. On a related one, Smith (2004) suggested that consumers' dietary decision-making strategy, which maximizes Darwinian fitness in ancestral environments, results in problematic dietary choices in modern human decision environments. By integrating evidence from biology, medical science, and behavioral science, the author described an evolutionary equilibrium where culture (information from peers and parents), taste (chemical signals), and aftereffects (post-ingestive consequences) are three signals deciding consumer food choices. The author argued that unhealthy food choices are assigned high value in spite of health consequences because the three signals are conveyed via marketing campaigns in modern environments. He also pointed out that treating consumers' dietary choice problem simply as a conventional economic choice problem would fail to generate detailed predictions, as knowledge from biology and evolutionary theory is ignored. The article provides a powerful example in demonstrating how an evolutionary approach directly contributes to interdisciplinary thinking.

The overconsumption of high-calorie food has also received much attention from researchers in the field of neuroscience. For example, Berridge (2009) reviewed neuroscientific findings on "wanting" and "liking" system for processing food rewards and generated several evolutionary explanations for the overconsumption of high-calorie food. Neuroscientific evidence suggests that the separation of wanting and liking mechanisms is related to eating disorder. Wanting might have evolved firstly as a form of goal directedness to pursue innate incentives, such as high-calorie food, in advance of perceived hedonic experience from consuming the food. Adopting an evolutionary framework, the author argued that the separation of wanting and liking is adaptive in our human evolutionary past having allowed our ancestors to overconsume high-calorie foods whenever possible, rather than only when they felt hungry. This again demonstrates that adopting an evolutionary framework can help to promote interdisciplinarity (in this case, linking neuroscience to consumer behavior).

In summary, incorporating evolutionary psychology in consumer research can contribute to greater interdisciplinarity. The epistemological approach adopted by evolutionary psychology researchers provides an integrated view of science disciplines and encourages using interdisciplinary evidence in scientific research.

3.3 Evolutionary Psychology Yields Greater Consilience

Evolutionary theory can serve as a meta-theory to help organize knowledge and findings generated in consumer behavior, allowing them to be correctly placed and stored at the right position in a consilient, coherent, and cumulative body of knowledge (Saad, 2007; Wilson, 1998). For example, research on conspicuous consumption has benefited greatly from a greater consilience brought by incorporating evolutionary approach in consumer behavior. In traditional consumer research, conspicuous consumption was merely considered an extravagant way of spending money. However, through an evolutionary lens, researchers have re-examined conspicuous consumption in a much broader context, with a cumulative body of knowledge including ethology, physiology, and evolutionary biology. The increase of consilience contributed to a better understanding to the phenomenon and promoted the positing of novel hypotheses.

The evolutionary lens has inspired researchers to compare human conspicuous consumption with animals' costly signaling behaviors (Saad, 2007; Saad & Vongas, 2009), which

have been well documented in ethology and evolutionary biology. The comparison promotes various novel hypotheses regarding the communicative functionality of conspicuous consumption and sexual differences within the consumer realm. For example, researchers hypothesized that, same as other animals, human consumers use conspicuous consumption as a sexual signaling method to advertise mating value and attract a mate (Griskevicius et al., 2007). The hypotheses were tested and supported by many empirical studies. Men tend to purchase luxurious sport cars to signal their wealth and status and deter same-sex rivals (Hennighausen et al., 2016). And the conspicuous consumption significantly enhances human males' attractiveness to human females (Janssens et al., 2011; Sundie et al., 2011). Thanks to the evolutionary lens, conspicuous consumption is placed in a unified tree of knowledge where it is logically and coherently connected with other physiological phenomena, such as hormonal fluctuations. Researchers therefore opened up a new field, evolutionary consumption, and introduced physiological measures into consumer research (Saad & Gill, 2000; Saad, 2008; Saad, 2013; Saad, 2019; Saad & Vongas, 2009); which subsequently promoted a number of studies on the relationships among physiological factors (e.g., testosterone, estrogen, progesterone, menstrual cycle, and digit ratios) and conspicuous consumption (Lens et al., 2012; Nepomuceno et al., 2016; Stenstrom et al., 2011). As illustrated by the aforementioned examples, evolutionary theory provides researchers with a metatheoretical framework that connects many phenomena and theories across scientific disciplines. By adopting an evolutionary approach, marketing scientists are able to link conspicuous consumption to a consilient, coherent, and cumulative body of knowledge. The superior organization of knowledge has greatly contributed to the sprout of new ideas.

Chapter 2 and 3 demonstrate the benefits of adopting an evolutionary approach and explain why evolutionary psychology is selected as the theoretical framework in this research project. Through the lens of evolutionary theory, the ensuing chapter reviews empirical studies from multiple disciplines to illustrate the evolutionary functions of bitter taste, forming the basis for further hypothesis development.

CHAPTER 4:
BITTER TASTE AND EVOLUTIONARY PSYCHOLOGY

Chapter 4 provides empirical evidence from multiple disciplines to discuss the evolutionary functions of bitter taste, forming a basis for developing novel hypotheses on how bitter taste affects consumer behaviours. Viewed through the lens of evolutionary psychology, the sense of taste presumably functions to inform us about the nutritional value and safety of our food (Breslin, 2013). Bitter taste, which is experienced as aversive and unpleasant, is considered as an indicator of undesirable poisonous compounds in food (Scott & Mark, 1987). Besides, because of the recurring co-occurrence of bitter food consumption and food shortage in human history, bitter taste has also been proposed to activate psychological mechanisms for coping with harsh environments (Chen & Chang, 2012). The following two sections review research evidence on the aforementioned evolutionary functions of bitter taste and discuss the theoretical implications to consumer behaviour research.

4.1 Bitter Taste as an Indicator of Toxic Compounds

All mammals have the ability to distinguish bitter-tasting substance (Shi et al., 2003). Among mammals, the sensitivity to bitterness is determined by the relative occurrence of possibly toxic compounds in the species' diets (Glendinning, 1994). To us omnivores, the number of toxic substances existing in inorganic substances or produced by plants or bacterial metabolites is substantial. And many poisons can cause irreparable damage to our body and reproductive fitness. Following the logic of error management theory (Haselton & Buss, 2000; Johnson et al., 2013), the cost of failing to reject bitter and toxic substance is much larger than the cost of failing to accept bitter but non-toxic substance. Since the asymmetric costs of errors recur over generations, humans have been equipped with various physiological, cognitive, and behavioural adaptations specifically for this recurrent evolutionary problem.

The taste of bitter compounds can evoke a series of rapid and automatic aversive physiological responses, such as tongue retraction, gaping, increased latency to swallow, and nausea, which prevent us from taking in more potentially poisonous food (Glendinning, 1994). Also, bitter taste can activate the left amygdala, the right posterior orbitofrontal cortex (OFC), and the anterior OFC, which are pertinent to the detection of threat and the value-based decision-making (Fellows, 2011; Zald, Hargen, & Pardo, 2002). Individuals tend to associate the negative physical experience toward bitter taste with surrounding objects or activities that they are doing or about to do. For example, participants tend to give more negative evaluations to objects and unfamiliar faces after tasting a bitter drink (Ding, Ji, & Chen, 2014). And people make harsher moral judgements if they have a bitter taste lingering in their mouth (Eskine, Kacinik, & Prinz, 2011). The generalization of a negative bitter experience to other activities/objects is in alignment with error management theory – the cost of failing to avoid a dangerous activity/object that is linked to bitter sensation is much higher than the cost of failing to accept a benign activity/object which accidentally co-occurs with the bitter experience. Since the detection of toxic substance is paramount, bitter taste can be perceived at a much lower threshold than any other tastes – bitter quine is detectable at 25-μmol/L concentration whereas sweet sucrose can only be detected on the order of 10,000 μmol/L (Hladik, & Simmen, 1996). Moreover, the set of compounds that elicits bitter taste is much larger and diverse than other tastes (Breslin, 2013). And the bitter sensation lingers longer in our mouth than other tastes, efficiently preventing future consumption of the

potentially poisonous food by creating a memorable unpleasant experience (Drewnowski, & Gomez-Carneros, 2000).

To maximize the chance of survival and reproductive success, people's sensitivity to bitter stimuli has evolved to change along with their vulnerability to toxic substances across the human life cycle stages. Children are more vulnerable to toxic chemicals than adults; and chemical exposures early in life have significant long-term negative impacts on people's health (Landrigan & Goldman, 2011). To avoid taking in toxins, babies are born equipped with rejection reflexes to bitter taste and children are much more sensitive to bitter taste than adults (Mennella & Bobowski, 2015). The heightened bitter sensitivity in children largely contributes to their aversion to vegetables (Keller & Adise, 2016). Moreover, women are more vulnerable to toxic exposures during the first trimester of pregnancy when the fetus is developing all the major body organs and systems (Fessler, 2002). During this period, women rated more foods as having bitter taste and perceived stronger bitterness from food, compared to before their pregnancy (Duffy et al., 1998; Nordin et al., 2004). Also, pregnant women who report severe nausea and vomiting during pregnancy tend to be more sensitive to bitter stimuli than those who have low exposure to nausea and vomiting (Sipiora et al., 2000).

At last, bitter taste perception confers some protection against the consumption of several addictive products that contain toxic substances harmful to health. People who have a stronger perception of bitterness are less likely to become addicted to nicotine (Enoch, Harris, & Goldman, 2001; Mangold et al., 2008). Also, individuals who have a genotype that reduces the sensitivity of bitter taste receptors report lower alcohol consumption and have lower risk for alcohol dependence (Bachmanov & Beauchamp, 2007; Wang et al., 2007).

4.2 Bitter Taste as a Cue of Harsh Environment

In addition to being an indicator of potentially toxic substances, bitter taste has also been proposed as a cue of harsh environments (Chen & Chang, 2012). The authors argued that bitter taste is often experienced together with the challenges in harsh environments throughout human history. In extreme environments, nutritious foods are scarce or taste much more bitter than in good times. Many edible plants increase the production of secondary metabolites, most of which taste bitter to humans, to defend against herbivores and pathogens when grown in impoverished environments (Akula & Ravishankar, 2011). For example, the seed in narrow-leafed lupin contains more quinolizidine alkaloids if they are affected by drought stress during the vegetative growth phase (Christiansen, 1997). Soybean produces a higher level of trigonelline in response to salinity and water deficit stress (Cho, Lightfoot, & Wood, 1999; Cho et al., 2003). And potatoes have a higher concentration of glycoalkaloids if they are affected by extreme temperatures, water-logging stress, or drought stress during growth of the plant (Uluwaduge, 2018). During tough times when good-tasting nutritious foods are extremely limited, people have to add more previously aversive bitter-tasting foods to their diet. The increasing tolerance for bitter taste under the pressure of food shortage serves as an adaptation that leads to diet breadth expansion and contributes to higher survival probability. For instance, during starvation, fruit flies have significantly lower sensitivity to bitter tastants and exhibit enhanced sugar sensitivity, allowing them to accept foods which they would normally reject (Inagaki, Panse, & Anderson, 2014). For humans, despite having a high concentration of aversive bitter glycoalkaloids, stressed or green potatoes are often consumed by people in times of food shortages (Barceloux, 2009). Also, to cope with food stress due to frequent

and recurrent droughts, semi-pastoralist people in Ethiopia are found to gather and consume specific wild food plants that are not normally consumed because of their unpleasant taste (Ocho et al., 2012). In addition, the co-occurrence of bitter taste experiences and hardships in extreme environments is so frequent in human history that bitterness is often semantically associated with negative experience and predicament in many languages (Zhou & Tse, 2020). In the Chinese language, *bitterness (苦,* pronunciation*: Koo)* also means *hardship*. And *eating bitter things* (*吃苦,* pronunciation*: Chi Koo*) refers to *enduring hardship* or *suffering*. It is the same in the Japanese language. *Bitterness (hiragana く,* pronunciation*: Ku)* is semantically equivalent to *suffering, discomfort, and hardship*. Similarly, in the English language, *bitter experience* is associated with very unpleasant feelings; and *bitter pill* means an unwanted or unpleasant situation that someone is forced to accept. In summary, a bitter taste experience is not only an indicator of toxic compounds in food but also serves as a cue closely associated with hardships and challenges in impoverished environments caused by natural disasters such as droughts and cold waves.

Human minds are equipped with evolved psychological mechanisms to respond to the problem of food shortage in harsh environments. The most direct impact of hunger is that people become more willing to spend money on food rather than things unrelated to food (Orquin, & Kurzban, 2016). Besides, food deprivation enhances survival motivations and drives people to obtain resources to satisfy their immediate needs. Hungry individuals are more likely to express seemingly generous preferences in order to satisfy their otherwise self-interests. For example, Aarøe and Petersen (2013) found that participants who are manipulated to have low blood glucose levels in an experiment report higher agreement with social welfare statements, but do not actually allocate more money to others in the dictator game. Petersen et al. (2014) also found that hungry individuals tend to express cooperative intentions and support for sharing, whereas in fact they selfishly take more money from another player who has been endowed with some money in the Taking Game (Güth, Schmittberger, & Schwarze, 1982). Moreover, scarcity of food may promote aggressive intraspecific competition as an evolutionary stable strategy to access food (Fattorini et al., 2018). It has been documented that people facing famine behave ruthlessly and do whatever possible, even at the cost of their own families, to aggressively compete for limited food resources (Dirks et al., 1980). In laboratory settings, hunger is found to cause negative, high arousal emotions, leads individuals to experience the feeling of “hate”, and to rate other people more negatively (Maccormack & Lindquist; 2019; Solianik et al., 2016). And a number of empirical studies found that lower blood glucose levels may contribute to more aggressive behaviours in humans (Gailliot, & Baumeister, 2007). Using two laboratory experiments, Denson et al. (2010) demonstrated that glucose consumption, compared to non-caloric sweetener, significantly reduces aggression in people who have high trait aggression. In addition, DeWall et al. (2011) found that the regional prevalence of metabolic disorders which are marked by low glucose levels, such as diabetes, glucose-6-phosphate dehydrogenase deficiency, are positively correlated with crime rates and violent killings in the region. At last, individuals with lower glucose levels tend to prefer present resources more than future resources, since the urgent energy need assigns higher survival value to immediate rewards (Wang & Dvorak, 2010; Wang & Huangfu, 2017). And there is evidence that hunger also increases delay discounting for non-food commodities (Skrynka, & Vincent, 2019). In summary, the heightened survival motivations triggered by food deprivation help people to be mentally prepared for hardships and challenges in harsh environments.

The frequent co-occurrence of bitter taste experiences and food shortage caused by environmental factors in human evolutionary history forms an association between the bitter sensation and the mental preparedness to survive hard times (Chen & Chang, 2012). The authors in question demonstrated the association between bitter sensation and survival motivation using the lexical decision task in two laboratory experiments. They found that compared to people who drink plain water, individuals who consume a bitter drink react more quickly to survival-related words. The effect was successfully replicated using a cross-cultural sample including participants from America, Australia, Europe, and Asia. They also found that compared to participants who consumed sweet food, participants who consumed bitter food performed better in retrieving words encoded in a survival context, supporting the bitter-survival association. Moreover, since bitter sensation and hunger caused by low glucose levels are both physiological responses in extreme environments where food is scarce, they may similarly activate evolved psychological adaptations meant to increase survival or reproductive prospects. The effects of bitter taste on people's cognitions and behaviours are similar to the effects of food deprivation in many ways. For example, bitter taste, rather than plain taste or sour taste, increases future discounting rate, leading to higher preference for small but immediate rewards (Chen & Chang, 2012). And similar to food deprivation, bitter taste induces negative moods, increases negative evaluations and aggressive behaivours toward others (Ding, Ji, & Chen, 2014; Dubovski, Ert, & Niv, 2017; Sagioglou, & Greitemeyer, 2014).

Chapter 4 reviewed evidence from multiple disciplines to demonstrate that bitter taste serves as an indicator of a toxic compound and a cue of harsh environments. The literatures are summarized in the following Table 4.1. The understanding of the evolutionary functions of bitter taste provides a foundation for developing novel hypotheses on how bitter taste affects consumer behaviours. In the next chapter, four posited hypotheses stemming from the association between bitter sensation and mental preparedness for surviving harsh environments are presented.

Table 4.1 Summary of Findings Related to the Evolutionary Functions of Bitter Taste

Argument	Author(s)	Findings
Bitter Taste is an Indicator of Toxic Compounds	Scott and Mark (1987)	Gustatory neural responses to chemicals in the rat's hindbrain is organized along a physiological dimension related to stimulus toxicity.
	Glendinning (1994)	Among mammals, the sensitivity to bitterness is determined by the relative occurrence of possibly toxic compounds in the species' diets. Animals with a higher occurrence of toxic compounds in their diet tend to have a higher bitter taste threshold.
	Zald, Hargen, and Pardo (2002)	Compared to tasting water or a sucrose solution, tasting a concentrated bitter quinine hydrochloride solution activates the left amygdala, the left inferior frontal pole, and the anterior orbitofrontal cortex. Both sucrose and quinine solutions activate the right posterior orbitofrontal cortex relative to water.
	Keller and Adise (2016)	Children who are more sensitive to bitter taste due to genetic factors are more likely to dislike and reject bitter-tasting fruits and vegetables.
	Duffy et al. (1998)	During the first trimester of pregnancy, women perceived stronger bitterness from quinine hydrochloride, compared to during non-pregnancy and during the second and third trimesters.
	Nordin et al. (2004)	Pregnant women often reported increased bitter sensitivity in their early stage of pregnancy. The abnormal taste sensitivity declines in prevalence at the late pregnancy stage.
	Sipiora et al. (2000)	Pregnant women who report severe nausea and vomiting during pregnancy tend to be more sensitive to bitter stimuli than those who report low levels of nausea and vomiting.
	Enoch, Harris, and Goldman (2001)	Individuals who are more sensitive to bitter stimuli (defined by being able to perceive phenylthiocarbamide as bitter) are less likely to become heavy smokers.
	Mangold et al. (2008)	Individuals who have a genotype which leads to a higher bitter taste sensitivity are less likely to be nicotine dependent.
	Wang et al. (2007)	Individuals who have a genotype that reduces the sensitivity of bitter taste receptors report lower alcohol consumption and have lower risk for alcohol dependence.
Bitter Taste is a Cue of Harsh Environment	Chen and Chang (2012)	Compared to people who drink plain water, individuals who consume a bitter drink react more quickly to survival-related words. Compared to participants who consume sweet food, individuals who consume bitter food perform better in retrieving words encoded in a survival context. Compared to plain or sour taste, bitter taste increases people's future discounting rate, leading to higher preference for immediate rewards.
	Christiansen (1997)	The seed in narrow-leafed lupin contains more quinolizidine alkaloids if it is affected by drought stress during the vegetative growth phase.
	Cho, Lightfoot, and Wood (1999)	Soybean produces a higher level of trigonelline in response to drought.
	Cho et al. (2003)	Soybean produces a higher level of trigonelline during salt treatment.
	Inagaki, Panse, and Anderson (2014)	During starvation, fruit flies have significantly lower sensitivity to bitter tastants and exhibit enhanced sugar sensitivity.
	Ocho et al. (2012)	To cope with recurrent food stress due to frequent and recurrent droughts, semi-pastoralist people in Ethiopia gather and consume specific wild food plants, crop parts, and crop residues which are not normally consumed because of their unpleasant tastes.
	Zhou and Tse (2020)	Among all the tastes, bitter taste is mostly associated with negative experience and predicament in Chinese language.
	Dubovski, Ert, and Niv (2017)	Oral exposure to bitter taste significantly lowers PANAS mood score.

CHAPTER 5:
RESEARCH CONTEXT AND HYPOTHESES

Previous chapters explained the reason for adopting an evolutionary theoretical framework and demonstrated that a bitter taste experience could activate mental preparedness for surviving harsh environments. In this chapter, four testable hypotheses are posited based on the understanding of bitter taste via an evolutionary perspective. From an evolutionary psychology perspective, our brain, designed by natural selection (including sexual selection), is devoted to extracting, processing, and using environmental information for improving our evolutionary fitness (Tooby, & Cosmides, 2005). It is equipped with a toolbox of various psychological adaptations which are selected to solve specific problems frequently encountered in the ancestral environments and to maximize the chance of passing our genes to the next generation (Confer et al., 2010). We naturally have an excellent cognitive ability of detecting cheaters (Cosmides, 1989) and dangerous animals (LoBue, & DeLoache, 2008). We unconsciously adopt appropriate mating strategies which can maximize our reproductive fitness in specific contexts (Buss & Schmitt, 1993, 2019). And our memory system has been demonstrated to function better when processing fitness-related information (Nairne, Thompson, & Pandeirada, 2007; Nairne et al., 2009), especially when the context is close to those we faced in ancestral environments (Nairne, & Pandeirada, 2010). Bitter taste, as a cue of harsh environments and food shortage, may provide a context facilitating the activation of psychological mechanisms that prepare individuals for retaining and obtaining resources (e.g., value high-calorie foods, more prepared for fierce competition), to increase the chance of surviving the harsh environment. This thesis will investigate the effects of bitter taste in a marketing context.

5.1 Bitter Taste Promotes High-Calorie Food Consumption

According to the insurance hypothesis, individuals tend to store more fat as a buffer against the risk of food shortage indicated by harsh environment cues (Nettle, Andrews, & Bateson, 2017). Harsh environment cues can promote unhealthy eating and induce people's desire for high-calorie foods (Laran, & Salerno, 2013; Swaffield, & Roberts, 2015). As a cue of harsh environments, bitter taste is therefore expected to lead individuals to consume larger amounts of high-calorie food and report higher preference for the high-calorie food.

H1a: Bitter taste, compared to neutral taste, increases the amount of high-calorie food consumed.

H1b: Bitter taste, compared to neutral taste, increases the liking rating for high-calorie foods.

5.2 Bitter Taste Enhances Competitive Orientation

When essential resources, such as food, water, and shelter, become scarce, people will allocate more time and effort competing with each other to obtain and retain resources (Grossman & Mendoza, 2003). The link between resource scarcity and intensified competition has been widely documented in literatures across different academic areas. For example, ecologists found that food depletion results in more aggressive intraspecific competition in the Apennine chamois (Fattorini et al., 2018). Anthropologists documented that as the stress of famine increases, people become animalistic and aggressively compete for food sources as social

norms and values are nonexistent (Dirks et al., 1980). In laboratory settings, Roux, Goldsmith, and Bonezzi (2015) found that resource scarcity prime leads participants to make more self-benefit decisions and report a heightened competitive orientation. Also, participants affected by hunger tend to induce others to share by supporting social welfare and signaling cooperative intentions, but do not actually perform altruistic behaviours themselves (Aarøe & Petersen, 2013; Petersen et al., 2014). And low blood glucose levels are also found to be linked with more aggressive behaviours (Denson et al., 2010; Gailliot, & Baumeister, 2007). Therefore, as an environmental cue of food scarcity, bitter taste should lead individuals to be more mentally prepared for competition and to be more competitive oriented.

Besides, in order to deal with numerous competitors in harsh environments, individuals should prepare themselves by obtaining objects that could possibly grant them advantages in competitions. In the modern marketing context, many products are advertised to boost people's physical fitness (e.g., vitamin/mineral supplement, energy drink) or cognitive performance (fish oil, self-help book). The marketing campaigns of these products often try to convince people that they could become stronger or smarter and excel in the competitions after consuming or using the products. We define this type of products as self-enhancing products in this thesis. If bitter taste serves as a cue of harsh environment, then bitter taste should elicit an urge for people to be both physically and cognitively prepared for fierce competitions, therefore increasing consumers' preference toward self-enhancing products which are advertised to boost physical fitness or cognitive performance.

H2a: Bitter taste, compared to neutral taste, enhances people's self-report competitive orientation.

H2b: Bitter taste, compared to neutral taste, increases the utility of self-enhancing products which are advertised to boost physical fitness or cognitive performance.

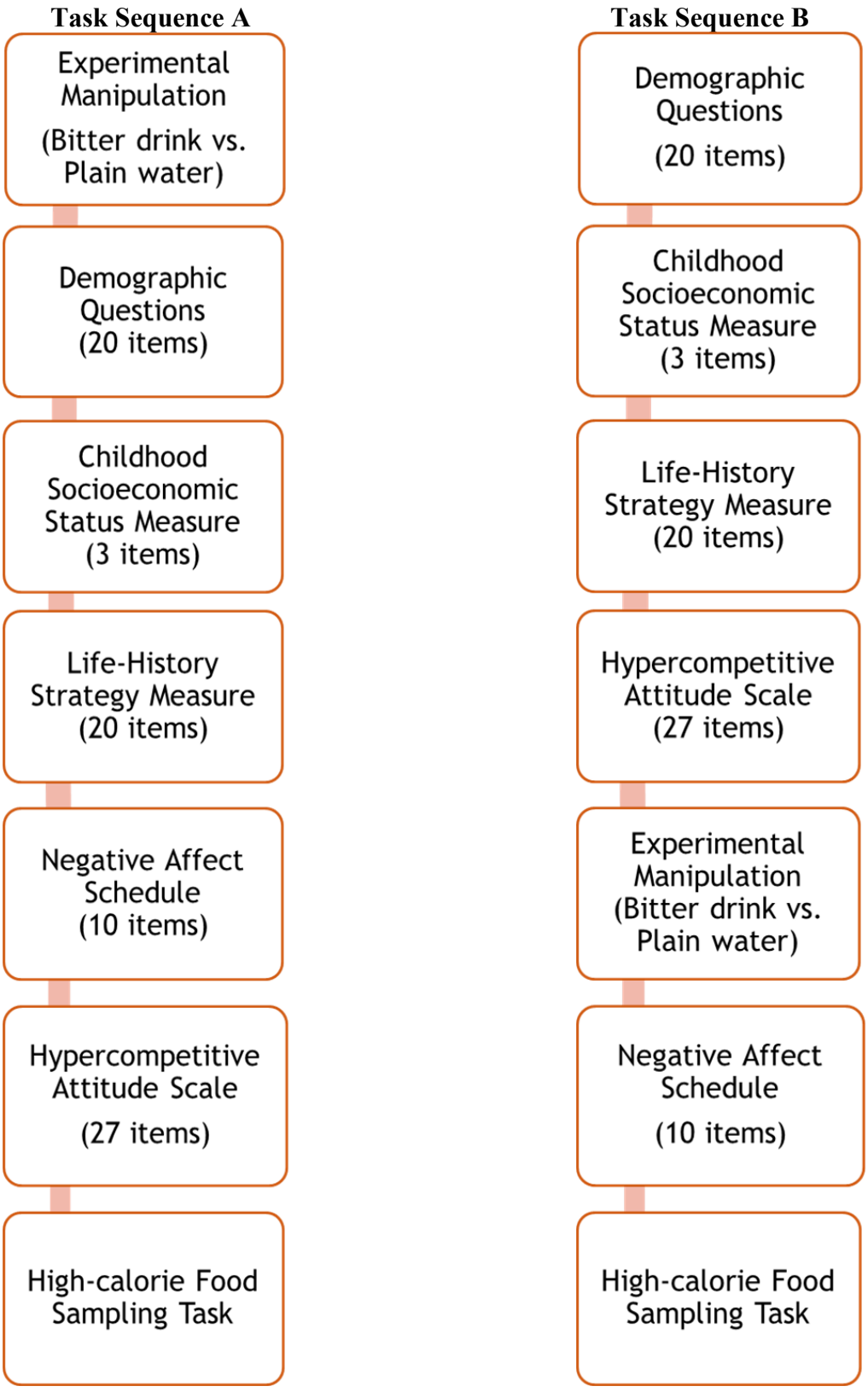
CHAPTER 6:
STUDY 1

The main goal of Study 1 was to examine whether a bitter taste experience increases high-calorie food consumption and enhances high-calorie food preference (i.e., H1a and H1b). Besides, this study provided preliminary data for testing whether a bitter taste experience promotes self-report competitive orientation (H2a). In addition, childhood socioeconomic status, life-history strategy, taste preferences, and negative affect were measured and investigated as covariates, considering these variables may determine people's preference toward high-calorie foods (Hill et al., 2016; Laran & Salerno, 2013).

6.1 Method

Eighty Chinese undergraduate students (45% male; M_{age} = 20.33; SD = 1.36) from a medical college located in North China participated in this study in exchange for 5 Chinese Yuan (about 1 Canadian Dollar) or a small gift of equivalent value. Participants completed the experiment in a laboratory session lasting about 20 minutes. The questionnaire and instructions were all given in Chinese. The questionnaires were created on and hosted by a professional Chinese survey website, Wenjuanxing (www.wjx.cn). Participants completed the questionnaires using a computer connected to the Internet and all experiment instructions were presented on the screen. One trained instructor provided the food/drink for participants to sample only in the sampling experiment session. All the participants were firstly asked to read the information and consent form carefully and to sign the form if they agreed to participate. Then they were randomly assigned to either the bitter or control conditions. Participants in the bitter condition were provided 50 ml quinine-sulfate water solution at a concentration of 0.40 mM which was used to elicit strong bitter sensation in previous research (Dubovski, Ert, & Niv, 2017). Participants in the control condition were provided 50 ml plain water in the sampling session. Then participants in each condition were equally divided into two groups in which the same tasks were given in different orders (Task Sequence A & B, see Figure 6.1 for comparison). Data from both the sequences were used for testing H1a and H1b. Participants in the Task Sequence A received experimental manipulations at the beginning of the experiment and completed the high-calorie food sampling task, which measured the dependent variables for testing H1a and H1b, at the end of the experiment. Because it might take a long time for participants to finish all the other items placed in the middle of the session, the effects of a bitter taste experience might not be as strong when participants finally reached the end of the experiment, or the other items in the questionnaire might affect how participants behaved in the high-calorie food sampling task at the end of the session. Therefore, the Task Sequence B was designed for investigating the potential sequence effects in testing H1a and H1b. In the Task Sequence B, participants received the experimental manipulation shortly before the high-calorie food sampling task. Hence, the time interval between the taste cue and the high-calorie food sampling task was largely reduced, and the influences of other items on the participants' behaviours were decreased. However, since the competitive orientation measure was placed before the experimental manipulation in the Task Sequence B, only data from the Task Sequence A were used for testing H2a. In summary, Study 1 used a 2 × 2 (Condition: Bitter vs. Control; Order: Sequence A vs. B) design for testing H1a and H1b; and Study 1 included only one independent variable (Condition: Bitter vs. Control) for testing H2a. Considering female and male participants may differ greatly in the weight of food consumed, the sex ratio of participants in each group was controlled to be the same.

Figure 6.1: Two Task Orders in Study 1



In Task Sequence A, participants were firstly asked to consume a drink and to answer a few questions regarding their gustatory experience (for example, “To what extent have you experienced bitterness?” “How much do you like the drink?”; see complete questionnaire in Appendix A & B). Participants were provided either a bitter drink or plain water depending on which condition they were in. Then they were instructed to answer twenty demographic questions, such as gender, age, education, household income, taste preferences, and the number of hours since the last meal. Next, they were presented with three items measuring childhood socioeconomic status (SES). Participants were asked to think about their childhood before 12 years old and to answer to what extent they agree or disagree with following statements on 6-point rating scales (i.e., *strongly disagree, disagree, slightly disagree, slightly agree, agree, strongly agree*): “My family usually had enough money for things when I was growing up,” “I grew up in a relatively wealthy neighborhood,” and “I felt relatively wealthy compared to the other kids in my school.” (Griskevicius et al., 2011, p. 1018). The items were translated into Chinese by one native speaker and translated back into English by another Chinese native speaker. The two translators discussed and reconciled differences to finalize the translation. The same back-translation method was used for all other measures in this study. Following the childhood SES measure, the 20-item Mini-K was presented to measure the human life history strategy (Figueredo et al., 2006). Participants answered to what extent they agree or disagree with the statements on 7-point rating scales (i.e., *strongly disagree, disagree, slightly disagree, don’t know/not applicable, slightly agree, agree, strongly agree*). Then the 10 items that measure negative affect in the Positive and Negative Affect Schedule (PANAS) were presented (Watson, Clark, & Tellegen, 1988). Participants answered the strength of each negative affect they were experiencing on 5-point rating scales (i.e., *very slightly or not at all, a little, moderately, quite a bit, extremely*). The negative affective states are expected to be influenced by drinking a bitter liquid (Dubovski, Ert, & Niv, 2017). To control for the potential confounding effect of negative emotions on the effect of bitter taste experiences, the Negative Affect Schedule was placed here to capture participants’ negative affective states right before they reported the dependent variables. Then participants were instructed to complete the Chinese version of the Hypercompetitive Attitude Scale, which measures competitive tendencies with a focus on the attendant orientation of aggressiveness (Ryckman et al., 1990). The scale was translated and edited into a 27-item version by Chinese researchers to make it more compatible with the Chinese cultural context (Chen, Li, & Lu, 2003). Participants answered to what extent they agree or disagree with the statements on 5-point rating scales (i.e., *totally disagree, disagree, neither agree nor disagree, agree, totally agree*). Finally, participants were provided with a bowl of marshmallows that weighed around 100 grams. They were instructed to sample the marshmallows and to rate the product. The instruction clearly informed participants that they can eat whatever amounts of marshmallows they want. The bowl and the marshmallows were weighed both before and after the sampling task to calculate the weight of food consumed by the participants. Participants rated their liking for the marshmallows on five items, such as “how do you like the product” and “to what extent do you like the flavor of this product”. The scores of the five items were added up to get the final liking score. Participants were asked to report whether they were on a diet before leaving the laboratory, as it might influence the weight of food that they were willing to eat in the experiment.

In the Task Sequence B, all the questions, scales, and sampling tasks were the same as those used in the Task Sequence A, except that the task order is different. Participants in the

Task Sequence B were firstly asked to answer demographic questions. Then they completed childhood SES, the Mini-K, and the Chinese version of Hypercompetitive Attitude Scale. After that, they were provided with either a bitter drink or plain water, depending on which experimental condition they were in, to elicit gustatory sensations. Then participants were instructed to report their negative affective states right before taking the food sampling task. At last, they were provided with a bowl of marshmallows to sample and rate.

6.2 Data Analyses and Results

Two participants in the bitter taste condition refused to drink the quinine-sulfate water solution and their data were therefore excluded from analyses. Participants who sampled quinine-sulfate water solution reported significantly stronger perceived bitter taste intensity than those sampled plain water ($\beta = 4.01$; $SE = 0.29$; $t(76) = 13.92$; $p < .001$; $M_{bitter} = 5.13$; $M_{control} = 1.13$), suggesting the experimental manipulation was successful. The reliabilities of the Mini-K (Cronbach's $\alpha = .712$), childhood SES (Cronbach's $\alpha = .850$), and the Hypercompetitive Attitude Scale (Cronbach's $\alpha = .779$) were satisfactory. The Kolmogorov-Smirnov Test and the Shapiro-Wilk Test were conducted to verify the normality of data distribution of the weight of food consumed by participants in each group (Table 6.1). The null hypothesis for both tests is that the data are normally distributed. The Kolmogorov-Smirnov test yielded significant results ($p < .05$) in two out of four groups and the Shapiro-Wilk test found significant results ($p < .05$) in three out of four groups. Therefore, the data of the dependent variable is unlikely to be drawn from a normally distributed population.

Table 6.1 Tests of normality on the weight of marshmallows consumed

		Kolmogorov-Smirnov			Shapiro-Wilk		
	Manipulation	Statistic	*df*	*p*	Statistic	*df*	*p*
Sequence A	Plain water	.255	20	.001	.694	20	.000
	Bitter drink	.183	18	.112	.815	18	.002
Sequence B	Plain water	.253	20	.002	.648	20	.000
	Bitter drink	.172	20	.121	.922	20	.106

Since the assumption of normality is not met, the Mann-Whitney U Test is firstly adopted to test the effects of manipulation and task order on the weight of marshmallows consumed. Results show that participants in Sequence A ($Mdn = 3.55$) did not consume significantly different amounts of marshmallows than those in Sequence B ($Mdn = 2.76$), $U = 718.5$, $Z = 0.42$, $p = .678$, $r = .047$, suggesting no sequence effect. Participants who experienced the bitter liquid ($Mdn = 4.98$) consumed significantly higher amounts of marshmallows ($Mdn = 2.35$) than those who sampled plain water in the manipulation section ($U = 510.0$, $Z = 2.50$; $p = .012$, $r = .283$), supporting H1a. An alternative to using non-parametric procedure for non-normally distributed data is to log-transform the data to correct for the non-normality. Therefore, the data of weight of marshmallows was log-transformed for further analyses. ANOVA yielded no significant interaction effect between experimental condition and task order on the log-transformed weight of food consumed ($F(1, 74) = 1.08$; $p = .303$; $\eta^2 = .014$; Table 6.2). Bitter taste manipulation significantly increases the weight of marshmallows consumed by the participants ($F(1, 74) =$

6.05; p = .016; η^2 = .076), supporting H1a. Task order again shows no effect on the dependent variable (F(1, 74) = 0.039; p= .536; η^2 = .005). Since tests of normality on liking scores do not show a violation of normality assumption, ANOVA is adopted to test the effects of bitter taste and task order on consumer liking rating for the marshmallows. Results show that no interaction effect of experimental condition and task order on participants' liking ratings (F(1, 74) = 0.89; p = .349; η^2 = .012; Table 6.3). And bitter taste does not significantly affect participants liking rating for the marshmallows (F(1, 74) = 1.02; p = .315; η^2 = .014), not supporting H1b. The task order also has no significant effect on participants' liking rating for the marshmallows (F(1, 74) = 0.57; p = .452; η^2 = .008).

Table 6.2 Effect of bitter taste and task order on log-transformed weight of food consumed

Dependent Variable: log-transformed weight of marshmallow consumed

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	1.104[a]	3	0.368	2.538	.063	.093
Intercept	19.366	1	19.366	133.572	.000	.643
Task Order	0.056	1	0.056	0.386	.536	.005
Condition	0.877	1	0.877	6.052	.016	.076
Task Order * Condition	0.156	1	0.156	1.077	.303	.014
Error	10.729	74	0.145			
Total	31.063	78				
Corrected Total	11.833	77				

a. R Squared = .093 (Adjusted R Squared = .057)

Table 6.3 Effect of bitter taste and task order on liking ratings for the marshmallows

Dependent Variable: Liking Score

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	128.459[a]	3	42.820	0.848	.472	.033
Intercept	39986.451	1	39986.451	791.487	.000	.914
Task Order	28.937	1	28.937	0.573	.452	.008
Condition	51.737	1	51.737	1.024	.315	.014
Task Order * Condition	44.926	1	44.926	0.889	.349	.012
Error	3738.528	74	50.521			
Total	43987.000	78				
Corrected Total	3866.987	77				

a. R Squared = .033 (Adjusted R Squared = -.006)

Since task order does not significantly influence the dependent variables, it is no longer taken into consideration in further analyses. A multiple regression analysis with three steps was performed to investigate whether drinking a bitter liquid increases the high-calorie food consumption (H1a) while controlling for confounding variables. In the first step, the dependent variable (i.e., log-transformed weight of marshmallows consumed) was regressed on all the control variables (i.e., childhood SES, life-history strategy, whether or not being on a diet, hours since last meal, preference toward sweet food, frequency of bitter food consumption in the past year, negative affect, and sex). In the second step, an independent variable, experimental manipulation condition (tasteless vs. bitter taste, dummy-coded), was added to the model. By comparing the R-Squared of the model before and after adding the independent variable, we can conclude how much the experimental manipulation affects the dependent variable, with all the confounding variables taken into account. In the third step, to explore whether there is a sex difference in the effect of bitter taste, the interaction term between sex (male vs. female) and experimental manipulation condition (tasteless vs. bitter taste) is added in the regression model. We could conclude that men and women were differently affected by the bitter taste experience if adding the interaction term significantly improved the model (i.e., R-Squared change is significant). The analysis reveals that bitter taste manipulation significantly increases marshmallow consumption, with all the confounding variables taken into consideration ($\beta = .212$; $t(68)= 2.01$; $p = .048$; $R^2_{change} = .039$; Table 6.6). By including the interaction term (sex × condition) in the third step of the regression analysis, we discover that sex significantly moderates the effect of bitter taste manipulation on the marshmallow consumption ($\beta = -.551$; $t(67)= -3.35$; $p = .001$; $R^2_{change} = .095$). Results show that female participants consumed significantly higher amounts of marshmallows after tasting the bitter drink (compared to after tasting plain water) whereas male participants were not much affected (Table 6.4 and 6.5 for descriptive statistics; Figure 6.2 for the boxplot comparison).

Table 6.4 Descriptive Statistics of Study 1 (Prior to Log-Transformation)

Dependent Variable: weight of marshmallow consumed

Sex	Condition	Mean	Std. Deviation	*N*
Female	plain water	1.957	1.583	22
	bitter drink	5.541	4.068	20
	Total	3.664	3.498	42
Male	plain water	6.379	6.040	18
	bitter drink	5.152	3.848	18
	Total	5.765	5.030	36
Total	plain water	3.947	4.713	40
	bitter drink	5.357	3.917	38
	Total	4.634	4.373	78

Table 6.5 Descriptive Statistics of Study 1 (Log-Transformed)

Dependent Variable: log-transformed weight of marshmallow consumed

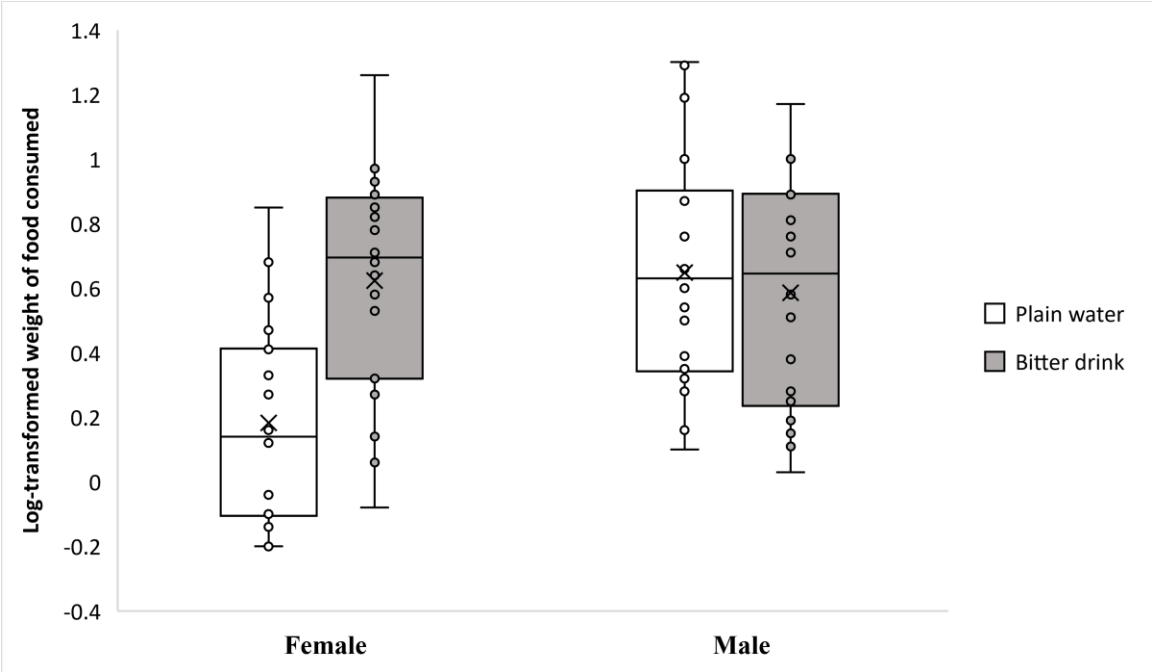
Sex	Condition	Mean	Std. Deviation	*N*
Female	plain water	0.183	0.306	22
	bitter drink	0.625	0.351	20
	Total	0.393	0.394	42
Male	plain water	0.649	0.368	18
	bitter drink	0.585	0.357	18
	Total	0.617	0.359	36
Total	plain water	0.393	0.406	40
	bitter drink	0.606	0.350	38
	Total	0.497	0.392	78

Table 6.6 Summary of Multiple Regression Analyses on variables predicting the weight of marshmallows consumed

		Step 1 β (*t*)	Step 2 β (*t*)	Step 3 β (*t*)
Control Variables	Childhood SES	-.157 (-1.534)	-.166 (-1.660)	-.097 (-1.008)
	Life History Strategy	.079 (0.762)	.058 (0.569)	.036 (0.378)
	On a diet (0= *No*; 1= *Yes*)	-.303** (-2.830)	-.244* (-2.241)	-.227* (-2.231)
	Hours since last meal	.100 (0.923)	.146 (1.345)	.147 (1.461)
	Preference to sweet food	-.054 (-0.504)	-.047 (-0.444)	.017 (0.170)
	Frequency of bitter food consumption	.105 (0.938)	.098 (0.893)	.131 (1.275)
	Negative Affect	.305** (2.862)	.277* (2.636)	.308** (3.124)
	Sex (0= *Female*; 1= *Male*)	.315** (2.894)	.305** (2.864)	.620*** (4.532)
Independent Variable	Condition (0= *Tasteless*; 1= *Bitter*)		.212* (2.010)	.516*** (3.856)
Interaction Effect	Sex × Condition			-.551** (-3.348)
		Model 1	Model 2	Model 3
R^2		.296**	.336**	.431***
R^2 change			.039*	.095**

Note. *p < .05; **p < .01; ***p < .001

Figure 6.2 Interaction effect between sex and condition on weight of food consumed



Data from Sequence A were analyzed to provide a preliminary test of H2a, i.e., consuming a bitter drink enhances participants' competitive orientation. In Sequence A, participants received either a bitter drink or plain water before completing the Hypercompetitive Attitude Scale. ANOVA is employed to examine the effects of the bitter drink consumption on participants' self-reported hypercompetitive attitudes. Men and women differ greatly in the ways that they respond to competition-related contexts and in their overall competitive orientation (Niederle & Vesterlund, 2011). Therefore, we included sex as the other independent variable in the ANOVA and investigated the potential interaction effect. However, results show no significant interaction effect ($F(1, 34) = 0.352$; $p = .557$; $\eta^2 = .010$; Table 6.7). The sex difference on hypercompetitive attitude is marginally significant. Men reported relatively higher hypercompetitive attitude than women ($F(1, 34) = 3.84$, $p = .058$, $\eta^2 = .101$), in line with previous studies. The effect of bitter taste on self-reported hypercompetitive attitude showed a promising tendency ($M_{bitter}= 87.44$; $SD_{bitter}= 13.01$; $M_{tasteless}= 81.65$; $SD_{tasteless}= 8.50$), but it does not reach significant levels ($F(1, 34) = 2.80$; $p = .104$; $\eta^2 = .076$). Although the results are not significant enough to support H2a, the data pattern is promising. A larger sample size is necessary for conducting more meaningful analyses. Moreover, the current data suggest men and women are different in hypercompetitive attitudes, suggesting the sex difference needs to be taken into consideration in further research.

Table 6.7 Effect of sex and bitter taste on hypercompetitive attitude

Dependent Variable: Hypercompetitive Attitude

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	776.454[a]	3	258.818	2.320	.093	.170
Intercept	266965.421	1	266965.421	2393.283	.000	.986
Sex (0= *Female*; 1= *Male*)	428.401	1	428.401	3.841	.058	.101
Condition (0= *Tasteless*; 1= *Bitter*)	311.863	1	311.863	2.796	.104	.076
Sex × Condition	39.267	1	39.267	0.352	.557	.010
Error	3792.625	34	111.548			
Total	275223.000	38				
Corrected Total	4569.079	37				

a. R Squared = .170 (Adjusted R Squared = .097)

6.3 Discussion

The results of Study 1 provide partial support for the first hypothesis. Participants who sampled a bitter drink consume more high-calorie snack food than those who sampled tasteless water (H1a). However, participants across the two experimental conditions did not have yield significant differences in their liking ratings for the snack food consumed (H1b). It appears that a bitter taste experience leads participants to want more high-calorie food but not to like high-calorie food more. *Wanting* food rewards, referring to the heightened incentive or appetite towards food consumption, is different than *liking*, which refers to the hedonic impact of food, in

various psychological and neurobiological literatures (Berridge, 1996; Berridge, Robinson, & Aldridge, 2009). As an environmental cue of food scarcity, a bitter taste experience could make the functional components of food rewards, i.e., providing energy to sustain metabolism, more salient, thereby enhancing craving for high-calorie food without improving liking ratings.

Moreover, interestingly, the exploratory analysis finds that the effect of bitter taste on food consumption is largely determined by participants' sex: women tend to consume more high-calorie food after a bitter taste experience, whereas men's eating behaviours are barely affected. A possible explanation is that men and women use different coping strategies in responding to harsh environment and food scarcity. Having a heavier body size may contribute to both survival and reproductive success in women when resources are scarce in the environment (Hill et al., 2014). Women are also more vulnerable to eating and weight regulation problems when affected by stressful events (Udo, Grilo, & Mckee, 2014).

In addition, the sequence effects are not observed in the testing of H1a and H1b. Although participants in Sequence A spent an average of 12.11 minutes (SD_{min} = 4.43) completing the questionnaire between the manipulation and the food sampling task, whereas participants in Sequence B sampled the marshmallows almost immediately after experimental manipulation, they consumed similar amounts of marshmallows and reported similar liking ratings in the experiment. This suggests that the effect of bitter taste on food craving is somewhat long lasting.

At last, Study 1 also provided preliminary data for investigating the effect of a bitter taste experience on consumers' competitive orientation, as a secondary goal of the study. Although consuming a bitter drink slightly increases the average hypercompetitive attitude reported after the manipulation, the effect is not significant enough to draw a conclusion. Since only half of the participants in the experiment are included in the data analyses for testing H2a, the statistical power is largely constrained by the small sample size, unable to provide sufficient evidence for the hypothesis testing. In the next two studies, we employed a much larger sample size and adopted a different paradigm for testing the effect of bitter taste on consumers' competitive orientation (H2a & H2b).

CHAPTER 7:
STUDY 2 – PRETEST

Study 1 primarily tested H1, but only provided preliminary data for the testing of H2. The main goal of Study 2 is to further examine whether bitterness enhances competitive orientation and increases preference toward body-enhancing product attributes (i.e., H2a and H2b). Also, considering individuals' aversion toward and perception of bitter taste can be influenced by cultural factors (Beckett et al., 2014; Mennella, 2005), Study 2 employed participants in Canada to examine the effects of bitter taste in a different cultural background. Because of the limitation of research resources, Study 2 employed a priming paradigm, rather than the actual tasting manipulation, to investigate the effects of bitter taste. Same as Study 1, the competitive orientation, as the dependent variable for testing H2a, was measured using a self-report method. Additionally, Study 2 employed a two-alternative forced choice task paradigm to collect behavioural data as the dependent variable for testing H2b. It is assumed that participants are more likely to choose the product which has more body-enhancing attributes if they have a higher preference toward body-enhancing product attributes. We hypothesized that participants would place more weight on body-enhancing attributes in decision-making in the forced choice task after being primed with a bitter drink rather than water (H2b). This chapter discusses the pretest of Study 2. The main purpose of the pretest is to check the validity of the priming manipulation, the reliability of scales, and to collect preliminary data for testing H2b. Besides, the behavioural data collected in the pretest are also used to test whether participants would place more weight on high-calorie attributes after being primed with a bitter drink than water (H1a).

7.1 Method

74 students (45.9% male; M_{age}= 23.66; *SD*= 5.40) from Concordia University participated in the pretest during a laboratory session in exchange for course credits. The pretest lasted about five minutes and was presented after an unrelated study in the same laboratory session. All the participants were briefed about the basic information of the study at the beginning of the session. They read and signed the information and consent form as an agreement to participate. The cover story did not mention any hypothesis of the study and simply told participants that the study was about product information and product choices. The questionnaire and instructions were in English, and they were created on and hosted by a professional survey website, Qualtrics (www.qualtrics.com). Participants completed the study using a computer connected to the Internet. All instructions were presented on the screen.

We used a taste priming paradigm documented in the literature to provoke an imagined bitter taste experience (Cai et al., 2017). The pretest started by letting participants imagine a scenario – "Imagine that you have been given a beverage without knowing what it is". The instruction was presented together with a picture of neutral white mug. After they clicked the "next" button, participants were then randomly assigned to one of the two conditions (bitter vs. control): participants in the bitter condition were presented a picture of dark black coffee with an instruction saying "after tasting it, you found it to be dark black coffee without any sugar or milk"; participants in the control condition were presented a picture of plain water with an instruction saying "after tasting it, you found it to be plain water" (see Appendix C for details). Both groups answered a manipulation check item asking the likelihood they would describe the taste of the drink as "bitter" (from 1= not so much to 10= very much so).

Priming paradigms have provoked debate and skepticism in social psychology because of the exposure of fraudulent researchers and the questionable replicability of salient results (Kahneman, 2012). Most criticism is targeted at priming effects on social behaviour and goal-directed behaviour, as the effects are easily influenced by a variety of individual difference and experimental context factors, resulting in replication failures (Cesario, 2014). The effects in question are usually labelled as "social priming" which commonly involve "some stimulation of people's mental representations of social targets, events, or situations that then influences subsequent evaluations, judgments, or actions" (Molden, 2014, p. 4). The priming paradigm used in this study serves as an alternative to the real tasting task when it is inconvenient or costly to ask participants to drink a flavored liquid. Participants were asked to imagine a physical taste of bitterness, which is concrete and invariant, rather than a social concept, which is abstract and could vary greatly depending on the personal imagination. In fact, taste imagination and actual taste perception activate the same brain regions (Levy et al., 1999). Moreover, the taste priming methods have been repeatedly used in previous literature and have been reported to reliably generate different imagined tastes (Ahn & Min, 2020; Cai et al., 2017; Frankort et al., 2012). In addition, this project includes Study 3 as a replication of Study 2, to lower the chance of Type I error.

Taurine food additive was used as a body-enhancing product attribute because of its proven beneficial effects in energy metabolism (Wen, et al., 2019). However, participants in the study may not be familiar with taurine and its functions in the body. To make sure that participants have basic knowledge of taurine and its body-enhancing functions, all the participants were then instructed to read an article introducing taurine with a focus on its benefits for helping people become stronger and more competitive. The article was a combination of paragraphs from two online sources (Collier, 2016; Mawer, 2018). One question was presented after the article – "According to the article above, is this statement true or false? – 'Consuming drinks which have an appropriate amount of taurine in it will help improve competitiveness.'" Participants who selected the "false" option will be re-directed to the article and instructed to read it again for the correct answer.

Next, participants were presented with a pair of beverage pictures (see Figure 6.1 for an example). The pictures were carefully edited to remove all the product information and to make beverage bottles similar in color and shape. Labels of two attributes – amounts of calories and whether or not taurine was added – were placed right below each of the pictures. In each choice trial, participants were instructed to choose the beverage they preferred between the two alternatives. The choice data of each trial were coded as a vector. It is coded as [1,0] if the first option is chosen, and it is coded as [0,1] if the second option is chosen. In the pretest, each attribute had two levels (70 calories vs. 270 calories; taurine added vs. no taurine added). To cover all possible attributes combinations, each participant was asked to make decisions for six choice sets in total, one choice set in each trial (The choice task is accessible via the following link: http://jmsbconcordia.ca1.qualtrics.com/jfe/form/SV_cHA94nc2gDf25AW). After completing the six choice trials, participants were instructed to complete a short version of the Competitiveness Index (Houston et al., 2002). Six items were taken out from the 14-item original scale because either they were not closely related to the concept of competitive orientation (e.g., "I try to avoid arguments.") or they were not easily comprehensible to non-native English-speaking students (e.g., "I dread

competing against other people"). At last, participants answered 10 demographic questions regarding their gender, age, ethnicity, country of origin, language fluency, and dieting behaviours.

Figure 7.1 A choice set example in Study 2 – pretest

7.2 Results and Discussion

Firstly, we conducted a manipulation check to find out whether participants perceived the bitter beverage that they imagined drinking as bitter. Participants in the bitter prime condition reported a higher likelihood that they would describe the taste of the drink as "bitter" (M = 5.05, SD = 1.83) than those in the water prime condition (M= 2.83, SD = 2.64), β = 2.22, SE = 0.53, $t(72)$= 4.23, $p < .001$, d = 0.98. Next, we tested whether imagining drink a bitter beverage could increase self-reported competitive orientation (H2a). The Competitiveness Index (Cronbach's α = .820) yielded good internal consistency. Although participants in this study were students at Concordia University, the standard deviation of participants' age is unexpectedly large (5.40). It has been documented that people in different age groups may vary greatly in their competitive orientation and competitive activities (Toda et al., 1978; Van Lange et al., 1997). Therefore, ANCOVA was employed with age included as a covariate. Also, same as in Study 1, the sex difference effect was investigated by including an interaction term between sex and prime manipulation in the model. Results show no interaction effect between gender and prime condition on the self-reported Competitiveness Index score ($F(1, 69) = 1.346$; $p = .250$; $\eta^2 = .019$; Table 7.1). Male participants reported significantly higher competitiveness than female

participants ($F(1, 69) = 7.504$; $p = .008$; $\eta^2 = .098$), consistent with previous findings (as reported in Study 1). Age, as a covariate, is also significant in the model ($F(1, 69) = 3.346$; $p = .072$; $\eta^2 = .046$), suggesting participants' age is also a factor needed to be taken into account in further studies. Results show that bitter taste has a marginally significant effect on self-reported competitive orientation. Participants in the bitter condition scored higher on the Competitiveness Index than participants in the control condition ($F(1, 69) = 2.816$; $p = .098$; $\eta^2 = .039$). Therefore, H2a is supported by the preliminary data from the pretest.

We used behavioural data collected in the two-alternative forced choice task to test whether a bitter taste experience increases participants preference toward high-calorie products (H1a) and whether a bitter taste experience increases participants preference toward body-enhancing products (H2b). Specifically, we hypothesized that participants would place more weight on high-calorie and body-enhancing attributes in decision-making in the forced choice task after being primed with a bitter drink rather than water. Conditional logit model (McFadden, 1973) was employed to examine how product attributes (i.e., calories and taurine labels) and taste prime affect participants' choices. Since the two alternatives in choice sets are matched in visual design and have no product or brand information on them, the probability of an alternative being chosen by a participant is assumed to be only affected by the calories and taurine labels presented under the pictures. We hypothesized that the taste prime affects participants' choices indirectly by altering the weight of each attribute in decision-making. Therefore, the interaction terms between each attribute and taste prime conditions are included in the model.

$$\begin{aligned} U_{nit} &= \beta_1 Taurine_{nit} + \beta_2 Calories_{nit} + \beta_3 Taurine_{nit} \times Prime_n \\ &\quad + \beta_4 Calories_{nit} \times Prime_n + \epsilon_{nit} \\ Y_{nit} &= 1 \text{ if } U_{nit} \geq \max(U_{n1t}, U_{n2t}) \\ &= 0 \text{ otherwise} \end{aligned}$$

U_{nit} is the utility that participant n obtains from choosing the alternative i in the choice set t (t= 1, …6). Y_{nit} is the decision made by individual n for alternative i in the choice set t. β_1 is the coefficient of taurine label (1= taurine-added; 0= no taurine-added) for the alternative i. β_2 is the coefficient of calories label (1= high-calorie; 0= low-calorie) for the alternative i. β_3 and β_4 are coefficients for the interaction terms. ϵ_{nit} captures the effects of all unobserved factors that influence the participant n's choice for alternative i in the choice set t.

The coefficient of the interaction term indicates how strong the taste prime conditions affect people's preference toward the attribute. The model's parameters were estimated in SAS 9.4 (SAS Institute, Cary NC) using the MDC procedure for a conditional logit model. Based on the pretest data, the estimation yields that the taurine-added (β= 0.73; SE= 0.20; $t(439)$= 3.66; p< .001; Table 7.2) and low-calorie (β=-1.60; SE= 0.23; $t(439)$= -7.08; p< .001) options are favored by participants. However, the interaction terms did not yield significant coefficients (for taurine × prime: β= 0.20; SE= 0.28; t(439)= 0.72; p= .47; for calorie × prime: β=0.07; SE = 0.31, $t(439)$= 0.21, p= .83), suggesting the bitter or tasteless prime did not significantly affect people's preferences toward the calorie or taurine attribute in the pretest.

In summary, results of the pretest provide partial support for the hypothesis 2: bitter taste enhanced self-reported competitive orientation (H2a) but did not increase the probability of

choosing products with a body-enhancing component (taurine) added (H2b). Also, the results did not support the hypothesis that a bitter taste experience increases peoples' preference toward high-calorie food (H1a). Study 2 improves the pretest design by using a much larger sample size, more real-world choice trials, attributes that consumers are more familiar with, and different products.

Table 7.1 Effect of gender and prime conditions on self-reported competitive orientation

Dependent Variable: The Competitiveness Index score

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	1052.856[a]	4	263.214	4.169	.004	.195
Intercept	7965.952	1	7965.952	126.174	.000	.646
Age	211.249	1	211.249	3.346	.072	.046
Condition (0= *tasteless*; 1= *bitter*)	177.785	1	177.785	2.816	.098	.039
Gender (0= *Female*; 1= *Male*)	473.738	1	473.738	7.504	.008	.098
Condition × Gender	84.955	1	84.955	1.346	.250	.019
Error	4356.279	69	63.134			
Total	124450.000	74				
Corrected Total	5409.135	73				

a. R Squared = .195 (Adjusted R Squared = .148)

Table 7.2 Taurine levels, calorie levels, and prime conditions predict participants' choice

Dependent Variable: choice between two alternatives

		df	β Estimate	Standard Error	*t* Value	*p*
Predictors	Taurine label (0= *not added*; 1= *added*)	1	0.73	0.20	3.66	<.001
	Calorie label (0= *70 calories*; 1= *270 calories*)	1	-1.60	0.23	-7.08	<.001
Interaction Effects	Taurine × Prime	1	0.20	0.28	0.72	.47
	Calorie × Prime	1	0.07	0.31	0.21	.83
Log Likelihood				-226.82		
Log Likelihood Null (LogL(0))				-307.76		
McFadden's LRI				0.263		

CHAPTER 8:
STUDY 2

Competitions are fiercer in harsh environments, as limited resources create inequitable realities across individuals. As a cue of harsh environment, bitter taste should lead individuals to be more mentally prepared for competition (higher competitive orientation, H2a) and to obtain objects that grant them advantages in competition (products that boost physical or cognitive performance, H2b). Study 2 aimed to test H2a and H2b by examining whether a bitter taste experience enhances self-reported competitive orientation and increases the probability that a participant chooses a product with body-enhancing attributes in a three-alternative forced choice task. The current study improves the pretest by collecting data from a much larger sample and by including three alternatives in each choice set, as opposed to the presented choice pairs in the pretest reported in the previous chapter. Also, to improve the ecological validity of the study and to facilitate implementing research findings into marketing practices, Study 2 included real-world brand names and product package designs in the choice task to better simulate an actual shopping scenario. In the realistic shopping scenario, differences in participants' personal preferences towards certain brands or product attributes could greatly affect their choices. Also, consumers are largely different in their attitudes towards food additives (Wilcock et al., 2004). Some participants might avoid choosing the product with body-enhancing attributes because they were averse to any kind of food additives. Hence, the probability that a participant chooses a product with a body-enhancing attribute might be influenced by the person's dispositional factors, although these factors are not objects of interest in this study. The data collected in this study were therefore hierarchical in nature, as each choice made by a participant was determined by both between-group experimental manipulation (group-level) and the specific person's dispositional factors (individual-level). To take the aforementioned individual-level heterogeneity into account, a mixed logit model including both individual-level random effects and group-level fixed effects was employed for the analysis of discrete choice modelling.

8.1 Method

256 students (46.1% male; M_{age}= 21.12; *SD*= 2.86) from Concordia University completed Study 2 during a laboratory session in exchange for course credits. The experiment lasted about seven minutes and was presented after an unrelated study in the same laboratory session. Same as the pretest, participants read instructions and signed the consent form at the beginning of the session. The experiment was conducted using a professional survey website Qualtrics (www.qualtrics.com). Participants completed the study on a computer with all experimental instructions and questions presented on the screen.

Participants were firstly instructed to take a 20-second break before starting the experiment, to reduce the possible influence of any previous laboratory session completed by the participants. Then they were randomly assigned to one of the two taste prime conditions – bitter vs. control. The priming paradigm and manipulation check item were the same as the ones used in the pretest (see Appendix C). Subsequently, participants from both conditions were instructed to read several paragraphs from an article introducing the importance of vitamin D and calcium to the human body (Jin, 2018). Different from the pretest, the reading material did not include any information directly related to the concept of competition, to avoid influencing participants' self-reported competitive orientation (see Appendix D). The reading material ended with a

highlighted bottom line "supplementing with an appropriate amount of vitamin D and calcium per day is known to be effective for enhancing your body in general", mimicking an advertising key message. One question was presented after the article as an attention check – "According to the article above, is this statement true or false? – 'Consuming drinks which have an appropriate amount of vitamin D and calcium in it will help enhance people's body.'" Participants selected the "false" option were re-directed to the article and instructed to read it again and were expected to now enter the correct answer. Participants who selected the "false" option twice were dropped from the experiment. 290 students in total participated in the laboratory session and 34 of them were dropped because of the attention check failure, leaving 256 participants who completed the study.

Next, participants were instructed to imagine that they were going to purchase a bottle of orange juice, and they were asked to read the product attribute information carefully before making a decision. Different from the pretest, study 2 included choice sets with three alternatives. To simulate an actual shopping scenario, real-world brand names and product package designs were used in the choice task. Participants were presented with three pictures of orange juice bottles which have similar visual designs but have different brand logos – Minute Maid, Tropicana, and Simply Orange (see Figure 8.1). The order of the three brands in choice sets stayed the same across all choice trials, as shown in Figure 8.1. Therefore, the brand effects are equivalent to the order effects and can be taken into account in the data analyses. Two product attributes labels, "Vitamin D Added" and "Calcium Added", could be presented under the brand logos. The two attributes each has two levels – label presented vs. not presented. The price of each alternative was presented right under the picture of each products. The price has six levels – from $2.49 to $4.99 with $0.5 fixed interval between two adjacent levels. A 24-choice-set fractional factorial design was obtained by using AlgDesign package for R software (Wheeler, 2008). To lower the fatigue effect, the choice design was broken up into two blocks of size 12. Participants in each prime condition were randomly assigned to either block A (choice sets No.1-12) or block B (choice sets No.13-24). Same as the pretest, after completing the choice tasks, participants were provided with the Competitiveness Index (Houston et al., 2002) and the demographic questions (see Appendix E). Participants were briefed and thanked at the end of the laboratory session.

Figure 8.1 A choice set example in Study 2

8.2 Data Analyses and Results

Firstly, we conducted a manipulation check and found that participants in the bitter prime condition reported a higher likelihood that they would describe the taste of the drink as "bitter" (M = 5.28, SD = 1.74), compared to those in the water prime condition (M= 2.86, SD = 2.21), β = 2.43, SE = 0.25, $t(254)$= 9.72, $p < .001$, d = 1.22. The Competitiveness Index (Cronbach's α = .888) exhibited good internal consistency. Since the pretest found that participants' age was significantly related to the Competitiveness Index score, age is again included as a covariate in the ANCOVA. Data of two participants were not used in this analysis because either gender or age was not reported. ANCOVA yielded a marginally significant interaction effect between gender and prime condition on the self-reported Competitiveness Index score ($F(1, 249) = 3.071$; $p = .081$; $\eta^2 = .012$; Table 8.1). A further test of simple effects shows that, compared to tasteless water prime, bitter taste prime can slightly increase female participants' competitive orientation ($F(1, 249) = 2.793$; $p = .096$; $\eta^2 = .011$; Table 8.2) whereas the prime conditions have no effect on male participants ($F(1, 249) = 0.708$; $p = .401$; $\eta^2 = .003$). Therefore, H2a is partially supported, as the effect of bitter taste on competitive orientation is dependent on a participant's sex. Age does not have a significant effect as a covariate ($F(1, 249) = 0.94$; $p = .333$; $\eta^2 = .004$).

Table 8.1 Effect of gender and prime conditions on the Competitiveness Index score

Dependent Variable: The Competitiveness Index score

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	3947.625[a]	4	986.906	11.723	.000	.158
Intercept	8160.087	1	8160.087	96.932	.000	.280
Age	79.131	1	79.131	0.940	.333	.004
Condition (0= *control*; 1= *bitter*)	22.735	1	22.735	0.270	.604	.001
Gender (0= *female*; 1= *male*)	3515.006	1	3515.006	41.754	.000	.144
Condition × Gender	258.486	1	258.486	3.071	.081	.012
Error	20961.714	249	84.184			
Total	389712.000	254				
Corrected Total	24909.339	253				

a. R Squared = .158 (Adjusted R Squared = .145)

Table 8.2 Effects of taste prime conditions depending on gender

Dependent Variable: The Competitiveness Index score

Gender	Prime Condition	Mean	Mean Difference	*SE*	*p*
Female	Bitter	35.828	2.630	1.574	.096
	Control	33.198			
Male	Bitter	41.289	-1.428	1.698	.401
	Control	42.716			

We used behavioural data collected in the three-alternative forced choice task to test whether a bitter taste experience increases participants' preference toward body-enhancing product attributes (H2b). Specifically, we hypothesized that participants in the bitter condition are more likely to choose products with "vitamin D added" label and "calcium added" label presented, compared to those in the control condition. Because the dependent variable is participants' choices in the forced choice task, a mixed logit model is used for the analyses.

$$U_{ijt} = X_{ijt}\beta + Z_{ijt}\gamma_i + \epsilon_{ijt}$$
$$Y_{ijt} = 1 \text{ if } U_{ijt} \geq \max(U_{i1t}, U_{i2t}, U_{i3t})$$
$$= 0 \text{ otherwise}$$

U_{ijt} is the utility that individual *i* obtains from choosing the alternative *j* in the choice set *t* (*t* = 1, …, 12). Y_{ijt} is the decision made by individual *i* for alternative *j* in the choice set *t*; X_{ijt} is the fixed design vector for individual *i* for alternative *j* in the choice set *t*; β is the vector of fixed

coefficients; Z_{ijt} is the random design vector for individual *i* in the choice set *t*; γ_i is the vector of random coefficients for individual *i* corresponding to Z_{ijt}.

Both fixed effects and random effects are included in the model to capture heterogeneity among individuals. Two product attributes of interest ("vitamin D added" label presented vs. not, "calcium added" label presented vs. not) are included in the fixed effects because the attribute labels are expected to have a consistent impact on choice-making across all participants: Options with the labels are more likely to be chosen because vitamin D and calcium are considered as being beneficial to health. The two product attributes are also included in the random effects since individuals are expected to be different in their preferences toward or responses to the two attributes labels. Price is included in the fixed effects, as it is expected to have a consistent effect on all participants' choices: Options with lower price are more likely to be chosen. Price is also included in the random effects because individuals might vary greatly in their price sensitivity. The taste prime conditions are manipulated at the group level, and therefore the interaction terms (taste × vitamin D, taste × calcium, taste × price) are only included in the estimation of fixed effects. Significant results of the interaction term taste × vitamin D and taste × calcium would suggest that the taste manipulation affects participants' preferences toward "vitamin D added" label and "calcium added" label, therefore providing evidence for H2b. At last, because preferences toward certain brands may vary greatly among individuals, two dummy variables for the three brands are created and included in the random effects. A hierarchical Bayes approach was employed for the model estimation (Allenby & Ginter, 1995). The Markov chain Monte Carlo estimation method for the Bayesian analysis was performed in SAS 9.4 (SAS Institute, Cary NC) using the BCHOICE procedure (see Appendix F). To reach chain convergence for the model parameters, an initial burn-in of 10,000 draws, 80,000 additional iterations were conducted, and one of every five samples were kept for computing the posterior summary statistics.

Considering that men and women usually respond to competition differently, as documented in the literature review (Niederle & Vesterlund, 2011), and results from the previous two studies in this thesis show sex difference in the effect of bitter taste on competitive orientation, data from the two gender groups are analyzed and reported separately in this study to better capture possible gender differences (Table 8.3 for female participants; Table 8.4 for male participants). Results show that, for both male and female participants, the average part-worths, which indicate utility values of product attributes, for "vitamin D label" and "calcium label" are positive, and the 95% highest posterior density (HPD) intervals do not include zero, indicating that all participants in general favor the two attributes. For both male and female participants, the average part-worth for "price" is negative, and the 95% HPD intervals do not include zero, indicating that all participants favor lower price. For female participants, no significant effect of bitter prime is found on participants' preference toward the two product attributes and price, as the 90% HPD intervals all include zero, not supporting H2b. However, for male participants, the interaction term "calcium label × taste prime" has a positive part-worth (*mean*= 1.23; *SD*= 0.54), and the 95% HPD interval is [0.17, 2.27], indicating that bitter taste prime significantly increases male participants' preference toward products which have calcium labels on them in the choice task, supporting H2b. Therefore, H2b is partially supported, as bitter taste prime only increases men's, but not women's, preference toward calcium, but not vitamin D, although both calcium and vitamin D are body-enhancing attributes.

Table 8.3 Posterior summary statistics in Study 2 for female participants

Dependent Variable: Utility

		ESS	*Mean*	*SD*	95% HPD Interval	90% HPD Interval
Fixed Effects	Vitamin D label (0= *not presented*; 1= *presented*)	381.9	4.87	0.62	[3.70, 6.12]	[3.91, 5.94]
	Calcium label (0= *not presented*; 1= *presented*)	419.7	3.93	0.53	[2.86, 4.96]	[3.09, 4.83]
	Price	460.7	-3.61	0.38	[-4.36, -2.89]	[-4.23, -3.00]
	Vitamin D label × Taste prime[a]	588.1	-0.80	0.79	[-2.37, 0.74]	[-2.04, 0.55]
	Calcium label × Taste prime	627.4	-0.16	0.69	[-1.51, 1.16]	[-1.28, 0.97]
	Price × Taste prime	1015.6	0.09	0.46	[-0.78, 1.04]	[-0.69, 0.83]

[a] Taste prime conditions: 0= *control*; 1= *bitter*

Table 8.4 Posterior summary statistics in Study 2 for male participants

Dependent Variable: Utility

		ESS	*Mean*	*SD*	95% HPD Interval	90% HPD Interval
Fixed Effects	Vitamin D label (0= *not presented*; 1= *presented*)	716.1	3.63	0.50	[2.66, 4.59]	[2.80, 4.43]
	Calcium label (0= *not presented*; 1= *presented*)	821.8	2.55	0.41	[1.75, 3.36]	[1.89, 3.22]
	Price	473.7	-2.99	0.43	[-3.86, -2.17]	[-3.67, -2.26]
	Vitamin D label × Taste prime[a]	1852.0	0.54	0.62	[-0.68, 1.76]	[-0.51, 1.53]
	Calcium label × Taste prime	1937.2	1.23	0.54	[0.17, 2.27]	[0.31, 2.07]
	Price × Taste prime	1002.4	-0.42	0.54	[-1.47, 0.66]	[-1.29, 0.48]

[a] Taste prime conditions: 0= *control*; 1= *bitter*

Although we did not have a specific hypothesis regarding the random effects in the model, a full structured covariance matrix for random effects was computed for each gender group to explore individual heterogeneity in decision-making (Table 8.5 & 8.6). For both female and male participants, the diagonal elements of covariance matrix are all very large, indicating substantial individual differences in response to the variables included in estimating the random effects. Participants in Study 2 are highly different in their price sensitivity and personal preferences towards brands, vitamin D label, and calcium label. The covariances between "vitamin label" and "calcium label" are significantly positive in both gender groups, suggesting that participants who chose options with a vitamin D label also tend to choose those with a calcium label. The covariances between price and the other two product attributes (i.e., vitamin and calcium) are negative and relatively large for both genders, suggesting participants who prefer vitamin and calcium added are those who are unwilling to pay high price.

Table 8.5 The covariance matrix of random coefficients in Study 2 for female participants

	Minute Maid	Tropicana	Vitamin D	Calcium	Price
Minute Maid	3.69[a]	.	.	.	.
(relative to Simply Orange)	[2.02, 5.56][b]				
Tropicana	2.74	10.93	.	.	.
(relative to Simply Orange)	[0.39, 5.25]	[6.28, 15.70]			
Vitamin D label	-0.90	-3.59	6.63	.	.
(0= *not presented*; 1= *presented*)	[-2.63, 0.74]	[-6.86, -0.41]	[3.02, 10.47]		
Calcium label	-0.37	-3.74	5.08	5.56	.
(0= *not presented*; 1= *presented*)	[-1.96, 1.22]	[-6.47, -1.13]	[2.37, 7.99]	[2.85, 8.61]	
Price	-1.19	2.21	-1.99	-2.62	6.70
	[-2.74, 0.26]	[-0.19, 4.86]	[-4.53, 0.23]	[-4.75, -0.66]	[3.45, 10.11]

a. the mean covariance of the random coefficients

b. 95% HPD Interval

Table 8.6 The covariance matrix of random coefficients in Study 2 for male participants

	Minute Maid	Tropicana	Vitamin D	Calcium	Price
Minute Maid	11.45[a]	.	.	.	.
(relative to Simply Orange)	[6.91, 16.61][b]				
Tropicana	6.27	18.54	.	.	.
(relative to Simply Orange)	[1.71, 11.33]	[11.10, 26.95]			
Vitamin D label	0.87	-2.45	14.22	.	.
(0= *not presented*; 1= *presented*)	[-2.51, 4.61]	[-7.09, 2.09]	[8.16, 21.11]		
Calcium label	0.22	-2.74	11.50	10.97	.
(0= *not presented*; 1= *presented*)	[-2.91, 3.53]	[-6.85, 1.39]	[6.88, 17.00]	[6.48, 16.26]	
Price	-2.20	3.40	-2.73	-2.10	4.86
	[-4.49, 0.06]	[0.70, 6.29]	[-5.48, -0.08]	[-4.39, 0.14]	[2.48, 7.37]

a. the mean covariance of the random coefficients

b. 95% HPD Interval

8.3 Discussion

Study 2 included both a self-report measure of competitive orientation and a behavioural measure of individual preference for body-enhancing product attributes, to provide convergent evidence for testing the second hypothesis, namely that bitter taste enhances competitive orientation. Analyses of the self-reported data demonstrate that bitter taste prime slightly enhances female participants' competitive orientation, but has no significant effect on male participants, thus providing partial support for H2a. The sex difference in the effect of bitter taste prime on the Competitive Index score might be a result of ceiling effect. Male participants generally have very high baseline scores on the Competitive Index and on average reported a 5.3 on each item on the 7-point scale. The bitter taste prime might not be able to further enhance the self-report measure of competitive orientation, as many male participants would report maximum scores on the items regardless of the manipulation conditions. The choice data we collected for testing H2b are behaviour-based and are not vulnerable to the ceiling effect. Analyses of the behavioural data demonstrate that the bitter taste prime significantly increases the part-worths of calcium, a body-enhancing food additive, in male participants' decision-making, but has no effect on female participants, thus partially supporting H2b. However, the bitter taste prime does not have significant effect on consumers' preference toward the other body-enhancing food additive, namely vitamin D, for both male and female participants. Considering the large individual heterogeneity found in participants' preferences towards the product attributes, the inconsistency in effects of bitter taste may be caused by gender differences in needs or individual differences in how the advertising message was interpreted. A possible explanation for the results is that, compared to vitamin D, calcium is better known for its role in building physical strength, which is valued more in men than in women because males are more likely to be involved in physical competitions than women (Niederle & Vesterlund, 2011). At last, the analysis of covariance found that participants who prefer vitamin D added in the drink also tend to prefer calcium added, but they are not willing to pay higher price for the product, suggesting it is possible to identify the group of people who are open to body-enhancing food additives but sensitive to price changes.

To provide greater ecological validity, Study 3 replicates the experiment using a slightly different design for simulating a more real-world shopping scenario. In Study 3, the article that introduces the functions of calcium and vitamin D was removed, as such information is rarely available when consumers shop in a grocery store. Also, Study 3 uses real photos of milk cartons rather than edited pictures of juice bottle in the choice task.

CHAPTER 9:
STUDY 3

Study 3 is a conceptual replication of Study 2. Study 3 tests H2a and H2b by examining whether bitter taste prime leads participants to report higher competitive orientation and increases the part-worth utilities of body-enhancing attributes in participants' decision-making. Study 3 are different from Study 2 in three aspects: First, participants were asked to shop for milk rather than juice, and the two body-enhancing attributes used in the study are calcium and omega-3. By using a new product category and a different product attribute in study design, Study 3 attempted to generalize the findings from Study 2 to other shopping contexts. Second, participants were not asked to read an article introducing body-enhancing attributes before the choice task, as the information of product attributes is rarely available in a real-world shopping scenario. Third, photos of milk cartons, rather than edited pictures of juice bottles, were presented as options, to make the choice task more realistic for the respondents.

9.1 Method

203 students (48.3% male; M_{age}= 21.21; *SD*= 2.92) from Concordia University completed this study in exchange for course credits. The experiment lasted about five minutes and was presented after a 20-second break from an unrelated study in the same laboratory session. Participants signed the consent form as an agreement to participate. They completed the study on Qualtrics (www.qualtrics.com) by using a computer in the lab. To begin with, participants were randomly assigned to either the "bitter black coffee" prime condition or the "tasteless plain water" prime condition. The priming paradigm and manipulation check item were the same as those used in Study 2 and the pretest. Different from the previous two studies, participants in Study 3 were not asked to read any article introducing body-enhancing components, to simulate a real-world situation where participants casually shop for drinks after an exposure to bitter or neutral stimuli. Participants were instructed to imagine that they were shopping for a carton of milk. Study 3 used the same conjoint choice design as that of Study 2. In each trial, participants chose among three alternative milk brands (Lactantia, Natrel, and Beatrice) which were available in most local markets. Different from Study 2, real photos of two-liter whole milk products from the three brands were used as choice set stimuli in this study (see Figure 9.1). The pictures were slightly edited to remove all promotional information. The order of three brands in choice sets stayed the same in the experiment. Study 2 found that bitter taste prime increases men's preference toward calcium rather than vitamin D. Study 3 attempted to replicate the finding by using calcium again as one of the body-enhancing attributes in the experiment, and to generalize the finding by including a new well-known body-enhancing attribute, omega-3, in the experiment. Two product attributes labels, "Calcium" and "Omega-3", could be presented on the body of the carton. Each of the two attributes had two levels – label presented vs. not presented. The price was presented right under the product picture. The price had six levels – from $3.49 to $5.99 with $0.5 fixed interval between two adjacent levels. Except for the three manipulated attributes, other nutrition labels (3.25% milk fat, homogenized, and vitamin D added) were the same across the three alternatives. To lower the fatigue effect, participants in each prime condition were randomly assigned to either block A (choice sets No.1-12) or block B (choice sets No.13-24). After that, participants completed the Competitiveness Index (Houston et al., 2002) and the demographic questions. At last, participants were briefed and thanks before leaving the lab.

Figure 9.1 A choice set example in Study 3

9.2 Data Analyses and Results

The experimental manipulation worked as expected, as participants in the bitter prime condition reported a higher likelihood that they would describe the taste of the drink as "bitter" (M = 5.58, SD = 1.52) than those in the water prime condition (M= 2.43, SD = 1.92), β = 3.14, SE = 0.24, t(201)= 12.87, p < .001, d = 1.82. The Competitiveness Index (Cronbach's α = .844) exhibited good internal consistency. To maintain consistency across Studies 2 and 3, ANCOVA was employed for data analyses with age included as a covariate. Data of three participants were not used in the ANCOVA because either gender or age was not reported. ANCOVA yielded no significant interaction effect between gender and prime condition on the self-reported Competitiveness Index score (F(1, 195) = 0.828; p = .364; η^2 = .004; see Table 9.1 for the descriptive statistics). Results show the bitter taste prime significantly increases both male and female participants' competitive orientation (F(1, 195) = 4.195; p = .042; η^2 = .021; Table 9.2). Therefore, H2a is supported. Gender also has a significant main effect. Male participants reported higher competitive orientation than their female counterparts (F(1, 195) = 22.552; p < .001; η^2 = .104). Age does not have a significant effect as a covariate (F(1, 195) = 0.094; p = .759).

Table 9.1 Descriptive statistics of the effect of bitter taste prime on competitive orientation

Dependent Variable: The Competitiveness Index score

Gender	Prime Condition	*Mean*	*SD*	*N*
Female	Bitter	37.46	7.31	48
	Control	34.02	9.31	55
Male	Bitter	41.96	7.89	49
	Control	40.63	7.86	48

Table 9.2 Effect of gender and prime conditions on the Competitiveness Index score

Dependent Variable: The Competitiveness Index score

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*-value	Partial η^2
Corrected Model	1963.137[a]	4	490.784	7.321	.000	.131
Intercept	5093.238	1	5093.238	75.979	.000	.280
Age	6.329	1	6.329	0.094	.759	.000
Condition (0= *control*; 1= *bitter*)	281.214	1	281.214	4.195	.042	.021
Gender (0= *female*; 1= *male*)	1511.784	1	1511.784	22.552	.000	.104
Condition × Gender	55.533	1	55.533	0.828	.364	.004
Error	13071.738	195	67.035			
Total	309563.000	200				
Corrected Total	15034.875	199				

a. R Squared = .131 (Adjusted R Squared = .113)

Same as for Study 2, behavioural data collected in the three-alternative forced choice task were used to test whether bitter taste prime increases participants' preference toward body-enhancing product attributes (H2b). Specifically, we hypothesized that the importance (part-worth utility) of "calcium" label and "omega-3" label in choice-making is higher for participants in the bitter prime condition than for those in the control condition. Same as Study 2, the mixed logit model with both fixed effects and random effects was used to take individual heterogeneity into consideration (see Appendix G). The two product attributes ("omega-3" label presented vs. not; "calcium" label presented vs. not) and price are included in the fixed effects because they are expected to have effects on choice-making across all participants: Options with "omega-3" and "calcium" labels are more likely to be chosen because the two attributes are generally considered beneficial to health; And options with lower price are more likely to be chosen. The two product attributes and price are also included in the random effects, as individuals may have different personal preferences toward the attributes and may vary greatly in their price sensitivity. The interaction terms (taste × omega, taste × calcium, taste × price) are included in

fixed effects only. Significant results of interaction term taste × omega and taste × calcium would suggest that the taste manipulation affects participants' preferences toward the "omega-3" label and "calcium" label, therefore providing evidence for H2b. Two dummy variables for the three brands (Lactantia, Natrel, and Beatrice) are included in the random effects to capture the brand effects. A hierarchical Bayes approach was employed for the model estimation (Allenby & Ginter, 1995). The Markov chain Monte Carlo estimation method for the Bayesian analysis was performed in SAS 9.4 (SAS Institute, Cary NC) using the BCHOICE procedure. To reach chain convergence for the model parameters, an initial burn-in of 10,000 draws, 80,000 additional iterations were conducted, and one of every five samples were kept for computing the posterior summary statistics.

Same as Study 2, to investigate potential sex differences, posterior summary statistics for the two gender groups are reported separately (Tables 9.3 and 9.4). Results show that for participants from both gender groups, the average part-worths, which indicate utility values of product attributes, for "omega label" and "calcium label" are positive, with 95% highest posterior density (HPD) intervals not including zero, indicating that all participants in general favor the two attributes. The average part-worths for "price" are negative in both gender groups, and the 95% highest posterior density (HPD) intervals do not include zero, indicating that all participants in general favor lower price. For male participants, the interaction term "calcium label × taste prime" has a positive 90% HPD interval [0.00, 1.47], indicating bitter taste prime has a marginally significant effect on male participants' preference toward products which have calcium labels on them in the choice task, supporting H2b. However, no significant effect of bitter prime is found on female participants' preference toward "calcium label", as the 90% HPD intervals all include zero, not supporting H2b. And bitter taste prime does not have significant effect on preference toward "omega-3" label for participants from both gender groups, as the 90% HPD intervals all include zero, not supporting H2b. Therefore, H2b is partially supported, as bitter taste prime only increases men's, but not women's, preference toward calcium, but not omega-3, although both calcium and omega-3 are body-enhancing attributes.

The full structured covariance matrix (Tables 9.5 and 9.6) was computed for male and female participants separately to explore individual heterogeneity in participants' decision-making. Although we do not have specific hypotheses regarding the random effects, the results help to understand and interpret participants' behavioural patterns. The matrix has large diagonal elements for both gender groups, indicating substantial individual differences in response to the variables included in random effects. Covariances between "omega label" and "calcium label" are significant in both gender groups, suggesting the participants who tend to choose Omega-3 labeled options also prefer options with a calcium label. Different from the results in Study 2, the covariances between price and the other two product attributes (i.e., omega and calcium) are not significant, suggesting participants who prefer omega and calcium are not different from those who do not prefer the two attributes in term of price sensitivity.

Table 9.3 Posterior summary statistics in Study 3 for female participants

Dependent Variable: Utility

		ESS	*Mean*	*SD*	95% HPD Interval	90% HPD Interval
Fixed Effects	Omega label (0= *not presented*; 1= *presented*)	1738.7	1.96	0.36	[1.27, 2.69]	[1.38, 2.56]
	Calcium label (0= *not presented*; 1= *presented*)	1543.1	2.56	0.35	[1.88, 3.26]	[1.96, 3.12]
	Price	822.8	-2.91	0.34	[-3.60, -2.26]	[-3.50, -2.39]
	Omega label × Taste prime[a]	3904.0	-0.73	0.47	[-1.63, 0.21]	[-1.53, 0.02]
	Calcium label × Taste prime	4571.9	0.33	0.47	[-0.57, 1.24]	[-0.42, 1.10]
	Price × Taste prime	2323.2	-0.44	0.40	[-1.27, 0.33]	[-1.08, 0.25]

[a] Taste prime conditions: 0= *control*; 1= *bitter*

Table 9.4 Posterior summary statistics in Study 3 for male participants

Dependent Variable: Utility

		ESS	*Mean*	*SD*	95% HPD Interval	90% HPD Interval
Fixed Effects	Omega label (0= *not presented*; 1= *presented*)	3096.4	0.96	0.36	[0.27, 1.66]	[0.38, 1.55]
	Calcium label (0= *not presented*; 1= *presented*)	3120.2	1.77	0.33	[1.12, 2.42]	[1.22, 2.31]
	Price	975.4	-2.74	0.36	[-3.50, -2.07]	[-3.31, -2.12]
	Omega label × Taste prime[a]	3518.5	0.56	0.48	[-0.40, 1.51]	[-0.25, 1.34]
	Calcium label × Taste prime	4029.2	0.72	0.45	[-0.16, 1.61]	[0.00, 1.47]
	Price × Taste prime	1066.6	0.55	0.45	[-0.33, 1.44]	[-0.15, 1.32]

[a] Taste prime conditions: 0= *control*; 1= *bitter*

Table 9.5 The covariance matrix of random coefficients in Study 3 for female participants

	Lactantia	Natrel	Omega	Calcium	Price
Lactantia	8.47[a]	.	.	.	.
(relative to Beatrice)	[4.89, 12.48][b]				
Natrel	5.95	7.93	.	.	.
(relative to Beatrice)	[2.97, 9.38]	[4.50, 11.89]			
Omega label	-1.36	-1.81	2.70	.	.
(0= *not presented*; 1= *presented*)	[-3.27, 0.45]	[-3.65, -0.10]	[1.09, 4.51]		
Calcium label	-2.15	-1.80	1.69	2.87	.
(0= *not presented*; 1= *presented*)	[-4.16, -0.34]	[-3.59, -0.10]	[0.35, 3.13]	[1.13, 4.80]	
Price	1.48	-0.23	-0.23	-0.24	3.33
	[-0.11, 3.23]	[-1.72, 1.25]	[-1.38, 0.91]	[-1.36, 0.90]	[1.72, 5.17]

a. the mean covariance of the random coefficients
b. 95% HPD Interval

Table 9.6 The covariance matrix of random coefficients in Study 3 for male participants

	Lactantia	Natrel	Omega	Calcium	Price
Lactantia	6.56[a]	.	.	.	.
(relative to Beatrice)	[3.75, 9.86][b]				
Natrel	2.56	6.11	.	.	.
(relative to Beatrice)	[0.60, 4.83]	[3.40, 9.07]			
Omega label	2.68	0.64	3.45	.	.
(0= *not presented*; 1= *presented*)	[0.92, 4.69]	[-1.05, 2.44]	[1.42, 5.66]		
Calcium label	0.39	-0.27	1.62	2.20	.
(0= *not presented*; 1= *presented*)	[-1.10, 1.94]	[-1.79, 1.26]	[0.36, 3.03]	[0.95, 3.71]	
Price	-1.22	-1.52	-0.36	-0.18	3.74
	[-2.79, 0.20]	[-3.07, -0.05]	[-1.69, 0.91]	[-1.28, 0.92]	[1.86, 5.70]

a. the mean covariance of the random coefficients
b. 95% HPD Interval

9.3 Discussion

Study 3 finds that bitter taste prime significantly increases self-reported competitive orientation for participants in both gender groups, providing additional support for H2a. The effect size is relatively larger for female participants, but the interaction effect between gender and prime condition is not significant. Consistent with Study 2, analyses of behavioural data show that bitter taste prime has a marginally significant effect on male participants' preference toward calcium, providing partial support for H2b. However, bitter taste prime has no significant effect on omega-3 for both gender groups, suggesting some unobserved factors may moderate the bitter taste effect. At last, participants who prefer calcium labels also tend to like omega-3 labels. Different from Study 2, participants who like the two attributes do not have significantly different price sensitivity than those who do not like. A possible explanation is that most milk products in the market have labeled themselves as sources of additional nutrition, such as vitamin D and calcium. Consumers do not expect to pay extra money for the additional nutrition. Therefore, consumers' attitudes towards the two attributes are unrelated to their willingness to pay.

CHAPTER 10:
GENERAL DISCUSSION

The current research contributes to understanding the effects of bitter taste on consumer behaviour and decision-making. Specifically, we demonstrate that bitter taste, compared to neutral taste, can increase high-calorie food consumption, promote the probability of choosing body-enhancing products, and enhance self-reported competitive orientation in cross-cultural samples. Study 1 shows that exposure to bitter gustatory stimuli increases the amount of high-calorie food consumed by Chinese participants in a following sampling task, and the effect is stronger for female participants than for males. Next, study 2 demonstrates that, in the Canadian cultural context, products with certain body-enhancing functions are more likely to be chosen by participants who have been presented with bitter taste prime than tasteless prime. The effect is significant in male participants but not in females. Study 3 re-confirms the effect using a more real-world choice task. Finally, the three studies together provide cross-cultural evidence in support of the hypothesis that people tend to report higher competitive orientation after being affected by bitter stimuli. The following sections will further discuss the contributions of the current research, limitations of the experiments, future research directions, and managerial implications of the findings.

10.1 Contributions of The Studies

First, this thesis provides theoretical contributions by infusing Darwinian principles within the field of sensory marketing. Although both proximate and ultimate-based theories are required for a complete and accurate understanding of any consumer behaviour (Saad, 2008), prior research in the sensory marketing field has been primarily exploring phenomena at the proximate level. By applying an evolutionary theoretical framework, the current research highlights an ultimate explanation for the effects of sensory factors on consumer behaviour: human gustatory sensations are evolved adaptations providing us with environmental information critical to our survival and reproductive success (Breslin, 2013). Building on literature from multiple disciplines, including marketing, psychology, physiology, anthropology, and ecology, we propose that the bitter taste experience serves as a warning of harsh environment and food shortage, and therefore leads consumers to allocate more efforts in obtaining and retaining essential resources. The adoption of evolutionary thinking also contributes to methodological pluralism. The current research uses a multi-method approach and cross-cultural samples to provide convergent evidence for testing the hypotheses. Thus, this thesis examines the effects of sensory factors at ultimate levels and contributes to a more comprehensive understanding of consumer behaviour and decision-making.

Second, this thesis adds to the existing literature on the effects of tastes on consumer behaviour. Previous research in sensory marketing primarily focuses on how external influences, such as packaging, brand names, and marketing communications, affect consumers' taste perceptions (Krishna, 2012). Despite the prevalence of bitter-tasting products and the importance of sensory factors in marketing efforts, less is known about the direct effects of tastes on consumer behaviour. A few psychological and physiological studies have investigated how different tastes may influence people's interpersonal behaviour, moral judgement, sensation-seeking, and risk-taking (Bègue et al., 2015; Byrnes, & Hayes, 2016; Chen, & Chang, 2012; Fetterman, Meier, & Robinson, 2017; Hellmann, Thoben, & Echterhoff, 2013; Wang & Chen, 2019). However, the effects of gustatory experience of bitterness on consumer behaviour are still under-researched in

the marketing discipline. The current research is the first to our knowledge to examine the direct effects of bitter taste in the marketing context. In summary (see Table 10.1 for the summary of the tested hypotheses), Study 1 provides evidence that the consumption of bitter drink can lead participants to consume more high-calorie food. The effect is significant only in female participants but not in males, suggesting sex differences in behavioral responses to bitter stimuli. Study 2 and 3 demonstrate that the reminder of bitter taste can alter participants' choice preference for certain body-enhancing product attributes. Specifically, male, but not female, participants are more likely to choose drinks with the "calcium added" label after being primed with a bitter stimulus. At last, the three studies together provide cross-cultural evidence in support of the hypothesis that bitter taste can increase self-reported competitive orientation.

Thirdly, in addition to testing our proposed hypotheses, the current research explores the role of sex in moderating the effects of bitter taste on consumer behaviour and decision-making. Men and women are likely to have different responses to bitter stimuli. First, Study 1 finds the effect of bitter taste on high-calorie food consumption is significant only in females whereas study 2 and 3 find the effect of bitter taste on preferences toward body-enhancing product attribute is significant only in males. One possible explanation to the seemingly contradicting findings is that females and males tend to adopt different coping strategies when facing challenges (Tamres, Janicki, & Helgeson, 2002). Men are more likely to adopt outwardly aggressive strategies whereas women use more internalizing defenses (Diehl, Coyle, & Labouvie-Vief, 1996). In response to bitterness, which is the cue of harsh environment and food shortage, men may put more efforts in preparing themselves for aggressive competitions for limited essential resources. Therefore, men, rather than women, are more likely to choose products that boost their physical performance (milk or juice with calcium added) after experiencing bitter taste, as the results of Study 2 and 3 showed. Different from men, women have no advantage in physical competition and may store more energy inside the body as defenses to food shortage. Having a heavier body contributes to a woman's survival and reproductive success in harsh environments. In fact, it has been documented that hungry men find heavier women more attractive, as an adaptive psychological mechanism to an impoverished environment (Nelson & Morrison, 2005). Therefore, women, rather than men, are more likely to consume high-calorie food after experiencing bitter taste, as the results of Study 1 showed. Second, Study 2 found that bitter stimuli have a stronger effect on self-reported competitive orientation for female participants than for male participants. One possible explanation for the sex difference is that male participants generally have high base-line levels of competitive orientation and the effect may not be fully captured by the self-report measures because of the ceiling effect.

Finally, this thesis provides interesting findings that challenge people's taken-for-granted beliefs. Bitter taste, a gustatory sensation, and competitive orientation, an attitude toward competitions, are rarely discussed together in marketing science as they were presumed to be uncorrelated. The adoption of evolutionary thinking helps us to propose and investigate the link between these two seemly unrelated phenomena in this thesis, therefore passing the "Co-relation" criteria suggested by Davis (1971). Additionally, the findings of sex differences in bitter taste effects are also likely to be considered interesting, as the discrepancy between men's and women's responses to bitter taste denies the routinely taken-for-granted proposition that men and women are not different in their responses to gustatory stimuli.

Table 10.1 Summary of the Tested Hypotheses Across the Three Studies

Hypothesis	Study	Support	Finding
H1a	1	Partially**	Female, but not male, participants who drank a bitter quinine-sulfate solution consumed higher amounts of marshmallows (high-calorie food), compared to those who drank tasteless water.
	2-pretest	No	Participants who imagined drinking a bitter black coffee did not show a different preference toward drinks with a high-calorie label in a forced choice task, compared to those who imagined drinking plain water.
H1b	1	No	Participants who drank a bitter quinine-sulfate solution did not give different liking ratings to marshmallows (high-calorie food), compared to those who drank tasteless water.
H2a	1	No	Participants who drank a bitter quinine-sulfate solution did not report different levels of hypercompetitive attitudes, compared to those who drank tasteless water.
	2-pretest	Marginally	Participants who imagined drinking a bitter black coffee reported higher scores on the Competitiveness Index, compared to those who imagined drinking plain water.
	2	Partially, Marginally	Female, but not male, participants who imagined drinking a bitter black coffee reported higher scores on the Competitiveness Index, compared to those who imagined drinking plain water.
	3	Yes*	Participants who imagined drinking a bitter black coffee reported higher scores on the Competitiveness Index, compared to those who imagined drinking plain water.
H2b	2-pretest	No	Participants who imagined drinking a bitter black coffee did not show a different preference toward drinks with a taurine label (body-enhancing attribute) in a forced choice task, compared to those who imagined drinking plain water.
	2	Partially, with 95% probability	Male, but not female, participants who imagined drinking a bitter black coffee showed a higher preference toward juice with a "calcium added" label (body-enhancing attribute), but not "vitamin D added" label, in a forced choice task, compared to those who imagined drinking plain water.
	3	Partially, with 90% probability	Male, but not female, participants who imagined drinking a bitter black coffee showed a higher preference toward milk with a "calcium" label (body-enhancing attribute), but not "omega-3" label, in a forced choice task, compared to those who imagined drinking plain water.

Note. *$p < .05$; **$p < .01$; ***$p < .001$

10.2 Limitations and Future Research

First, results of Study 1 show no evidence in support of the H1b (i.e., bitter taste increases the liking rating for high-calorie food). One possible explanation is that "wanting" and "liking" are dissociable concepts. Individuals may show heightened incentive or appetite towards food consumption (wanting), but at the same time do not enjoy the hedonic impact of the food (liking). The discrepancy between wanting and liking has been well documented in various psychological and neurobiological literatures (Berridge, 1996; Berridge, Robinson, & Aldridge, 2009). Bitter taste might increase high-calorie food consumption by making people value the functional components of food rewards, i.e., providing energy to sustain metabolism. Future research might examine the psychological and neurobiological mechanism for the phenomenon and provide proximate explanation as to how and why bitter taste could enhance craving for high-calorie food without improving liking for the food. A second possible explanation is that the aversive gustatory experience of bitterness might still be in effect when participants rated the food in the sampling task, therefore offsetting its positive effect on the liking rating. Bitter taste lingers longer in our mouth than other tastes (Drewnowski, & Gomez-Carneros, 2000). And people tend to give negative evaluations to objects and people after tasting something bitter (Ding, Ji, & Chen, 2014). This account seems reasonable but is not supported by the data in Study 1. Half of the participants completed the food sampling task more than twelve minutes on average after experiencing the bitter taste, and the other half completed the food sampling task immediately after they drink the bitter beverage. The results of study 1 show no evidence that the task order could influence participants' liking ratings, suggesting a ten-minute time interval might not be long enough to make a difference. Further investigation on the duration of bitter effects is needed.

Second, this thesis only tested hypotheses in Chinese and Canadian cultural backgrounds and included limited investigations on potential moderators of bitter taste effects. The association between bitter taste and mental preparedness to survive harsh environment is formed due to frequent co-occurrence of bitter taste experience and food shortage in human evolutionary history. Therefore, it is presumed to be a global phenomenon that could be observed in all cultural backgrounds. However, in different cultures, people may vary greatly in the specific ways they prepare themselves for potential harsh environments and food shortage, depending on local social norms, cultural values, and languages. For example, individuals who speak different languages may differ in their responses to the same bitter taste experience as the metaphorical meaning of bitter taste may vary. In the English language, "bitter" can be used to describe a negative experience linked to unfair treatment or injustice. However, "bitter" does not have the same metaphorical meaning in the Chinese language. Such discrepancy was found to moderate bitter taste effects (Xu, Wan, & Schwarz, 2020). Also, the exposure to bitter food may vary greatly across cultures, depending on local cuisine culture and local food sources. This may result in different preference or sensitivity to bitter taste. For example, in Chinese culture, bitterness is not always aversive and sometimes even favored by people. In traditional Chinese medicine, which is still widely practiced in mainland China, it is believed that bitter-tasting plants are beneficial to health. There is a possibility that such cultural factors could moderate bitter taste effects. Moreover, the findings of the current research suggest high individual heterogeneity in people's responses to bitter taste. All three studies show sex differences in the effects of bitter taste on consumer behaviour. And Study 2 and 3 find that unobserved individual factors account for a big part of the differences in participants' decision-making in the choice

tasks. Also, it has been documented that people's perception and preference toward bitter taste are largely determined by genetic factors, cultural factors, and personal experiences (Beckett et al., 2014; Behrens et al., 2004; Mennella, 2005; Xu, Wan, & Schwarz, 2020). Bitter taste experience may have very different effects on consumer behaviour and decision-making depending on individual-level factors. Future research might explore possible moderators of bitter effects. For example, people vary greatly in their ability to taste the bitter compound PROP (6-*n*-pro-pylthiouracil) and the tasters of PROP have lower liking and consumptions of bitter foods (Keller, & Adise, 2016). Future research might explore how individuals' sensitivity to PROP moderate the effects of bitter taste on high-calorie consumption and competitive orientation.

Third, future research might test the posited hypotheses using different methods for eliciting bitter taste or activating the imagined bitter taste experience. In the current research, participants in Study 1 were asked to drink quinine-sulfate water solution which is not familiar to most people. Participants may worry about the safety of the bitter drink and experience greater negative affect because of drinking something they have no knowledge of. Future research might replicate the study using different bitter drinks and food, such as decaffeinated coffee and bitter melon, which are more common in real life. Moreover, in Study 2 and 3, the imagined bitter taste experience was activated using a documented priming paradigm (Cai et al., 2017). Priming paradigms have provoked debate and skepticism in social psychology, as the effects are often easily influenced by a variety of individual difference and experimental context factors, resulting in replication failures (Cesario, 2014; Kahneman, 2012). Although random effects have been included in the model in Study 2 and 3 for capturing and investigating individual heterogeneity, it is still important to conduct conceptual replication studies in which participants are asked to consume real bitter food or drink rather than to imagine doing so. In addition, the current research only includes student samples from Chinese and Canadian cultural backgrounds. Most participants are young adults who live in an industrialized society and have received many years of formal education. The findings may not be generalized to other populations, as even the most basic psychological processes could vary dramatically across populations (Henrich, Heine, & Norenzayan, 2010). Multi-cultural samples of people from a variety of backgrounds are needed to further test the hypotheses.

Fourth, Study 2 and 3 did not rule out alternative explanations to the effect of bitter taste on preference to self-enhancing products. Study 2 and 3 found that male participants who imagined drinking a bitter drink showed higher preference to calcium added products than those who imagined drinking plain water. We proposed that bitter taste increased preference to calcium additive because people become more competitive orientated after tasting something bitter. However, the study design cannot rule out the alternative explanation that bitter taste increased preference to calcium additive because bitter taste enhances participants' health consciousness. Future research could measure participants' general desire for better health and investigate if this factor could mediate the effect of bitter taste. Moreover, future research could use extreme sour taste and extreme salty taste as comparison groups in the experiment to rule out the possibility that people prefer calcium additive because of the bad taste experience rather than bitter taste experience.

Fifth, we did not find any significant effect of bitter taste on price sensitivity in Study 2 and 3. It would be interesting to examine how bitter taste might affect the amounts of money people would like to pay for certain survival related products. It is possible that people will become less price sensitive to high-calorie foods after tasting something bitter. Alternatively, it is possible that people will become more price sensitive to any product after tasting a bitter drink because money might be regarded as an essentially resource for survival. Future research could investigate how bitter taste affects participants' price sensitivity in different marketing contexts.

Finally, future research might extend this work by examine the effects of bitter taste on other high-level cognitions, such as memory. Our memory system is sculpted in ancestral environments to process items pertinent to our survival and reproductive success. In a harsh environment where essential resources are scarce, events or items critical to our survival are more likely to be elaborately encoded and stored in long-term memory in case we need to use them in the future, whereas trivial items are soon forgotten (Nairne, 2010). Chen and Chang (2012) demonstrate that bitter taste makes participants respond more quickly to survival-related words in the lexical decision task. It would be interesting to examine whether bitter taste could also facilitate the encoding and retention of advertising campaigns of brands and products which are associated with the concept of survival, such as medicine, energy, and outdoor gears and equipment.

10.3 Managerial Implications

The current research reveals that people, especially females, may want more high-calorie food after experiencing bitter taste without necessarily exhibiting a correspondingly increased liking of the food in question. Wanting is often associated with problematic eating but liking is not (Polk et al., 2017). The results have important practical implications for governments and policy makers who intend to lower public high-calorie food consumption and to promote healthy diet in service of the greater good. For instance, in contexts where bitter foods or drinks are frequently consumed or bitterness cues are present, consumers should be reminded of the risks of high-calorie intake and be informed of the benefits of keeping a healthy diet. Moreover, many dietary phytonutrients in vegetables and fruits, which can lower the risk of cancer and cardiovascular diseases, have a bitter taste (Drewnowski, & Gomez-Carneros, 2000). Results of the current research suggest that the health benefits of these foods could be offset by the harmful effects of bitter taste on promoting high-calorie consumption. Policy makers might consider offering financial assistance to programs devoted to reducing the bitter taste from such foods by removing bitter-tasting molecules or adding bitter masking compounds (Ley, 2008).

Results of this thesis also suggest that, after experiencing bitter taste or being primed with bitterness cues, people may become more competitive oriented and put more efforts in preparing themselves for competition. Thus, marketing campaigns of self-enhancing or body-enhancing products (e.g., self-help books, protein powder, energy drink) may be more effective if distributed in places, such as cafés, lounges, and coffee shelves in a grocery store, where people are frequently exposed to bitter taste or bitterness cues. In such contexts, marketers could improve marketing communications by highlighting how the products could be helpful for competitions. For example, the owner of a café could set up a bookshelf filled with self-help books, which help people become more competitive, and place these near the café counter or the entrance to make some extra money. As another example, grocery stores could set up a product

display near coffee shelves for selling health products to men. The products should be advertised as being beneficial to men's physical strength and athletic performance. In addition, our results also suggest that individuals may differ greatly in the ways they prepare for competitions and challenges. Advertising companies may predict the different coping strategies of their consumers basing on demographic information and recommend appropriate products accordingly. For example, women may prefer either appearance-enhancing products or foods in different phases of their menstrual cycle (Saad & Stenstrom, 2012). Thus, the heightened competitive orientation triggered by bitterness may result in different desire for the two product categories, both of which could be useful in a harsh environment (Hudders et al., 2014), depending on consumers' hormonal profile. Such individual factors should be taken into consideration.

10.4 Conclusion

The current research uses three experimental studies to demonstrate the effects of bitter taste on consumer behaviour and decision-making. The first study finds that consuming a bitter drink significantly increases the amount of high-calorie food eaten by female, but not male, participants. The second and third studies find that participants who imagine drinking a bitter beverage report higher competitive orientation, compared to those who are primed with drinking plain water. Male, but not female, participants place more weight on certain body-enhancing product attributes in the choice task after being primed with bitterness than those in the control group. This thesis contributes to introducing Darwinian theory into sensory marketing and advancing our understanding of the effects of bitter taste on consumer behavior.

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APPENDICES

Appendix A: Questionnaire Originally Used in Study 1 (Chinese)

Manipulation Check (No. 3 – 13)

请先尝第一小口，然后回答以下问题。

*3. 总体来讲，你刚才体验到的味觉感受有多强烈?

无味道	1	2	3	4	5	6	7	非常强烈

*4. 你多大程度上感觉到了“甜味”?

无味道	1	2	3	4	5	6	7	非常强烈

*5. 你多大程度上感觉到了“酸味”?

无味道	1	2	3	4	5	6	7	非常强烈

*6. 你多大程度上感觉到了“苦味”?

无味道	1	2	3	4	5	6	7	非常强烈

*7. 你多大程度上感觉到了“咸味”?

无味道	1	2	3	4	5	6	7	非常强烈

*8. 你多大程度上感觉到了“鲜味”?

无味道	1	2	3	4	5	6	7	非常强烈

请品尝第二小口，然后回答以下问题。

*9. 你有多喜欢喝这款饮料?

非常不喜欢 1 2 3 4 5 6 7 非常喜欢

*10. 总体来讲，你觉得这款饮料味道怎样?

非常难喝 1 2 3 4 5 6 7 非常好喝

*11. 你会如何评价这款饮料的味道?

非常令人讨厌 1 2 3 4 5 6 7 非常令人愉悦

请喝完剩余饮料，然后回答以下问题。

*12. 你觉得以下哪些味道的食物与这款饮料的味道搭配最好? 【多选题】

- [ ] 甜味
- [ ] 苦味
- [ ] 辣味
- [ ] 咸味
- [ ] 鲜味
- [ ] 酸味
- [ ] 其他

*13. 你觉得加入以下哪些味道最能提高饮料的受欢迎程度? 【多选题】

- [ ] 甜味
- [ ] 苦味
- [ ] 辣味
- [ ] 咸味
- [ ] 鲜味
- [ ] 酸味
- [ ] 其他

Demographic Questions (No. 15 - 34)

*15. 你的性别：

○男　　○女

*16. 你的年龄：　(从18到60)

请输入数字，如您今年19岁请输入"19"

*17. 请填写你的民族

*18. 你所接受的最高教育程度是?

○初中或以下
○中专或职中
○高中
○大专
○大学本科
○硕士
○博士

*19. 从小学入学算起，到目前为止，你接受了多少年的正式教育（请填写整数）？

如7岁入小学，目前19岁，则接受了12年正式教育，填写整数"12"

*20. 你目前的家庭人均月收入是多少（家庭每月总收入除以家庭总人数）？

家庭所有成员（父母兄弟姐妹）每月总收入/家庭总人数

- ○500元或以下
- ○501~1000元
- ○1001~2000元
- ○2001~3000元
- ○3001~4000元
- ○4001~5000元
- ○5001~7000元
- ○7001~10000元
- ○10001~15000元
- ○15001元或以上

*21. 你上次用餐距离现在有多长时间?

- ○1小时以内
- ○1~2小时
- ○2~3小时
- ○3~4小时
- ○4~5小时
- ○5~6小时
- ○6~7小时
- ○7小时或以上

*22. 与你周围的其他人相比较而言，你有多经常食用或饮用甜味的食品或饮品（例如：奶茶，牛奶巧克力，甜点等）？

与别人相比非常少	1	2	3	4	5	6	7	8	9	与别人相比非常多

*23. 与你周围的其他人相比较而言，你有多经常食用或饮用酸味的食品或饮品（例如：酸奶，山楂片，酸枣糕等）？

与别人相比非常少	1	2	3	4	5	6	7	8	9	与别人相比非常多

*24. 与你周围的其他人相比较而言，你有多经常食用或饮用苦味的食品或饮品（例如：茶叶饮料/凉茶，苦瓜，柚子等）？

与别人相比非常少	1	2	3	4	5	6	7	8	9	与别人相比非常多

*25. 与你周围的其他人相比较而言，你有多经常食用或饮用辣味的食品或饮品（例如：酸辣汤，各类川菜，泡椒凤爪等）？

与别人相比非常少	1	2	3	4	5	6	7	8	9	与别人相比非常多

*26. 请问在过去的一年内，你有多经常食用或饮用甜味的食品或饮品（例如：奶茶，牛奶巧克力，甜点等）

- ○平均每天食用/饮用3次或以上
- ○平均每天食用/饮用1次~2次
- ○平均每周食用/饮用4次~6次
- ○平均每周食用/饮用1次~3次
- ○平均每半个月食用/饮用1次
- ○平均每个月食用/饮用1次
- ○平均每个季度食用/饮用1次~2次
- ○平均每半年食用1次
- ○平均每半年食用/饮用不到1次或从未食用/饮用过

*27. 请问在过去的一年内，你有多经常食用或饮用酸味的食品或饮品（例如：酸奶，山楂片，酸枣糕等）

- ○平均每天食用/饮用3次或以上
- ○平均每天食用/饮用1次~2次
- ○平均每周食用/饮用4次~6次
- ○平均每周食用/饮用1次~3次
- ○平均每半个月食用/饮用1次
- ○平均每个月食用/饮用1次
- ○平均每个季度食用/饮用1次~2次
- ○平均每半年食用1次
- ○平均每半年食用/饮用不到1次或从未食用/饮用过

*28. 请问在过去的一年内，你有多经常食用或饮用苦味的食品或饮品（例如：茶叶饮料/凉茶，苦瓜，柚子等）

- ○平均每天食用/饮用3次或以上
- ○平均每天食用/饮用1次~2次
- ○平均每周食用/饮用4次~6次
- ○平均每周食用/饮用1次~3次
- ○平均每半个月食用/饮用1次
- ○平均每个月食用/饮用1次
- ○平均每个季度食用/饮用1次~2次
- ○平均每半年食用1次
- ○平均每半年食用/饮用不到1次或从未食用/饮用过

*29. 请问在过去的一年内，你有多经常食用或饮用辣味的食品或饮品（例如：酸辣汤，各类川菜，泡椒鸡爪等）

- ○平均每天食用/饮用3次或以上
- ○平均每天食用/饮用1次~2次
- ○平均每周食用/饮用4次~6次
- ○平均每周食用/饮用1次~3次
- ○平均每半个月食用/饮用1次
- ○平均每个月食用/饮用1次
- ○平均每个季度食用/饮用1次~2次
- ○平均每半年食用1次
- ○平均每半年食用/饮用不到1次或从未食用/饮用过

*30. 总体来说，你在多大程度上喜欢甜味的食品或饮品?

非常不喜欢 ♥♥♥♥♥♥♥ 非常喜欢

*31. 总体来说，你在多大程度上喜欢酸味的食品或饮品?

非常不喜欢 ♥♥♥♥♥♥♥ 非常喜欢

*32. 总体来说，你在多大程度上喜欢苦味的食品或饮品?

非常不喜欢 ♥♥♥♥♥♥♥ 非常喜欢

*33. 总体来说，你在多大程度上喜欢辣味的食品或饮品?

非常不喜欢 ♥♥♥♥♥♥♥ 非常喜欢

*34. 比较你自己与你认识的同龄人的经济状况，你觉得你在经济状况上相对而言处于一个怎样的位置?
（最左端表示你觉得自己经济状况比其他人都差，最右端表示你觉得自己经济状况比其他人都好）

滑动游标到你觉得你所处的位置

Childhood Socioeconomic Status Measure (No. 35 – No. 37):

接下来，请回想一下你在12岁之前的生活状况，然后仔细阅读以下描述，并选择每一项描述在多大程度上符合你自己童年的真实情况。

*35. 在我长大的过程中，我的家庭通常有足够的钱来买各种东西。

○非常不符合 ○有些不符合 ○略微不符合 ○略微符合 ○有些符合 ○非常符合

*36. 我从小长大的社区相对来说比较富裕。

○非常不符合 ○有些不符合 ○略微不符合 ○略微符合 ○有些符合 ○非常符合

*37. 我感觉自己小时候比学校里的其他同学富裕些。

○非常不符合 ○有些不符合 ○略微不符合 ○略微符合 ○有些符合 ○非常符合

Mini-K (No. 38, 20 items):

请继续回答以下问题，请注意，**各个选项无正确与错误之分**，请选择**最符合你的观点和你的现状的选项**

*38. 请选择多大程度上您同意或者不同意以下陈述（如该陈述不适用于你，请选择“不知道/不适用”）：

	非常不同意	有些不同意	稍微不同意	不知道/不适用	稍微同意	有些同意	非常同意
我经常能够知道各种事情在将来会如何发展。	○	○	○	○	○	○	○
我会尝试思考我是如何陷入某种状况的，并以此来弄明白如何处理这种状况。	○	○	○	○	○	○	○
我经常发现糟糕状况的好的一面。	○	○	○	○	○	○	○
没有解决问题之前我是不会放弃的。	○	○	○	○	○	○	○
我经常提前制定计划。	○	○	○	○	○	○	○
我避免冒险。	○	○	○	○	○	○	○
在长大过程中，我和我的亲生母亲关系紧密且融洽。	○	○	○	○	○	○	○
在长大过程中，我和我的亲生父亲关系紧密且融洽。	○	○	○	○	○	○	○
我和我自己的孩子们有着紧密且融洽的关系。	○	○	○	○	○	○	○
我和我的性伴侣间有着紧密且融洽的恋爱关系。	○	○	○	○	○	○	○
我更喜欢保持一段单一的性关系，而非同时和几个人保持性关系。	○	○	○	○	○	○	○
我一定要先和某人有亲密的关系，然后才会接受发生性关系。	○	○	○	○	○	○	○
我经常和我的亲戚有联系。	○	○	○	○	○	○	○
我经常从我的亲戚那里得到一些情感上的支持和实际的帮助。	○	○	○	○	○	○	○
我经常在情感上支持我的亲戚，也经常会实际帮助我的亲戚。	○	○	○	○	○	○	○
我经常与我朋友们有联系。	○	○	○	○	○	○	○
我经常从我的朋友那里得到一些情感上的支持和实际的帮助。	○	○	○	○	○	○	○
我经常在情感上支持我的朋友，也经常会实际帮助我的朋友。	○	○	○	○	○	○	○
我与我所在的社区有紧密的联系，我能融入我所在的社区。	○	○	○	○	○	○	○
我与我信仰的宗教有紧密的联系，我能融入我信仰的宗教。	○	○	○	○	○	○	○

Negative Affect Schedule (No. 39, 10 items):

*39. 下面的表格中，左边一列中是各种用来描述感觉和情绪的形容词。请仔细阅读每一个词语，并依照你当前的情绪状态，选择每种感觉或情绪的强度

	轻微或没有	有点	适中	很强	极强
坐立不安的	○	○	○	○	○
心烦的	○	○	○	○	○
内疚的	○	○	○	○	○
羞愧的	○	○	○	○	○
怀有敌意的	○	○	○	○	○
易怒的	○	○	○	○	○
紧张的	○	○	○	○	○
心神不宁的	○	○	○	○	○
惊恐的	○	○	○	○	○
害怕的	○	○	○	○	○

Hypercompetitive Attitude Scale (No. 40, 27 items):

*40. 请仔细阅读以下题目，然后根据自己的想法作出回答：

	完全不符合	不符合	不置可否	符合	完全符合
我喜欢竞争，因为它给了我发现自己能力的机会。	○	○	○	○	○
竞争能促成人与人之间的友谊。	○	○	○	○	○
我相信你能成为一个好人，同时在竞争中获胜并成功。	○	○	○	○	○
我在竞争中并不把自己的对手看成敌人。	○	○	○	○	○
没有竞争的挑战，我可能永远也不会发现自己有某些潜力和才能。	○	○	○	○	○
我欣赏竞争，因为它使得我与竞争对手作为平等的人来讲更加接近。	○	○	○	○	○
对我而言，对自己在竞争中的表现完全满意并不困难。	○	○	○	○	○
竞争的失败使我感到作为一个人的价值的降低。	○	○	○	○	○
竞争激励我变得杰出。	○	○	○	○	○

	完全不符合	不符合	不置可否	符合	完全符合
如果有办法能扰乱对手，使我在竞争中胜出，我愿意这么做。	○	○	○	○	○
即使那些人竞争不过我，我也和他们竞争。	○	○	○	○	○
我不介意给某些人奖励，即使他们做的事我也能做或做的更好。	○	○	○	○	○
我发现自己会把友善的游戏和活动变成一系列的角逐与冲突。	○	○	○	○	○
这是一个人吃人的世界，如果你不胜过别人，别人一定会把你击败。	○	○	○	○	○
竞技运动的失利，真的会使我沮丧。	○	○	○	○	○
为了得到他人的赞扬并不是我参与竞争的一个重要原因。	○	○	○	○	○
我喜欢挑战，赢得早已与别人有亲密关系的人的喜欢。	○	○	○	○	○
我不在竞争中考虑友谊。	○	○	○	○	○
我喜欢竞争，因为它使我更多地了解自己。	○	○	○	○	○

	完全不符合	不符合	不置可否	符合	完全符合
我不能忍受输掉一场辩论。	○	○	○	○	○
竞争让我表现自己的潜力与才能，因此我感到它使我快乐。	○	○	○	○	○
对于那些批评自己或使自己在众人面前出丑的人，我认为没有报复的必要。	○	○	○	○	○
我重视竞争，因为它有助于我充分地展现自己。	○	○	○	○	○
我欣赏竞争，并不仅仅因为它是使自己做的比别人好的一种方法，更主要的是因为竞争使我进入比较高的动机水平，从而最好地发挥自己。	○	○	○	○	○
我喜欢竞争，因为它能够使我发挥最大的潜力，而不是因为它使我自己感觉比别人好。	○	○	○	○	○
我喜欢竞争，因为与独自一人从事一些活动相比，竞争可以帮我更全面地发挥自己的潜力。	○	○	○	○	○
由于竞争，我感觉到自己对他人的健康与幸福出了一份力。	○	○	○	○	○

Appendix B: Questionnaire in Study 1 (Translated into English)

(Keywords were highlighted in red for attention.)

Manipulation Check (No. 3 – 13)

Please take a sip and answer the following questions.

3. Generally speaking, how strong was the taste sensation you just experienced?

Tasteless	1	2	3	4	5	6	7	Very Strong

4. To what extent have you experienced "sweet taste"?

Tasteless	1	2	3	4	5	6	7	Very Strong

5. To what extent have you experienced "sour taste"?

Tasteless	1	2	3	4	5	6	7	Very Strong

6. To what extent have you experienced "bitter taste"?

Tasteless	1	2	3	4	5	6	7	Very Strong

7. To what extent have you experienced "salty taste"?

Tasteless	1	2	3	4	5	6	7	Very Strong

8. To what extent have you experienced "umami taste"?

Tasteless	1	2	3	4	5	6	7	Very Strong

Please take a second sip and answer the following questions.

9. How much do you like drinking the beverage?

Dislike Very Much	1	2	3	4	5	6	7	Like Very Much

10. Generally speaking, how much do you like the taste of the beverage?

Very Bad	1	2	3	4	5	6	7	Very Tasty

11. How would you like to rate the taste of the beverage?

Very Annoying	1	2	3	4	5	6	7	Very Pleasant

Please finish the beverage and answer the following questions.

12. Foods with which of the following tastes taste better together with the beverage?

□Sweet

□Bitter

□Spicy

□Salty

□Umami

□Sour

□Others

13. Which of the following tastes should be added to make the beverage more popular?

□Sweet

□Bitter

□Spicy

□Salty

□Umami

□Sour

□Others

Demographic Questions (No. 15 – 34)

15. Your gender:

○Male ○Female

16. Your age: (from 18 to 60)

Please input the number, for example, input "19" if you are 19 years old

17. Please fill in your ethnicity

18. The highest level of education you have received?

○Middle school or lower

○Technical secondary school or vocational high school

○High school

○Junior college

○Undergraduate

○Postgraduate - Master

○Postgraduate - Doctorate

19. From elementary school until now, how many years of formal education have you received (please fill in an integer)?

Please fill in "12" if you are 19 years old and entered elementary school when you were 7.

20. How much is your household monthly income per person (household monthly income divided by number of family members)?

All family members (parents, brothers, & sisters) total monthly income/number of family members

○ 500 CNY or lower

○ 501–1000 CNY

○ 1001–2000 CNY

○ 2001–3000 CNY

○ 3001–4000 CNY

○ 4001–5000 CNY

○ 5001–7000 CNY

○ 7001–10000 CNY

○ 10001–15000 CNY

○ 15001 CNY or higher

21. How long it has been since the last time you ate something?

○ 1 hour or less

○ 1–2 hours

○ 2–3 hours

○ 3–4 hours

○ 4–5 hours

○ 5–6 hours

○ 6–7 hours

○ 7 hours or more

22. Compared to other people you know, how often do you eat or drink sweet food or drink (for example, milk tea, milk chocolate, dessert)?

Rarely	1	2	3	4	5	6	7	Very often

23. Compared to other people you know, how often do you eat or drink sour food or drink (for example, yogurt, hawthorn candies, jujube cake)?

Rarely	1	2	3	4	5	6	7	Very often

24. Compared to other people you know, how often do you eat or drink bitter food or drink (for example, bitter herbal tea, bitter melon, grapefruit)?

Rarely	1	2	3	4	5	6	7	Very often

25. Compared to other people you know, how often do you eat or drink spicy food or drink (for example, hot and sour soup, Sichuan cuisine, chicken feet with pickled peppers)?

Rarely	1	2	3	4	5	6	7	Very often

26. In the past year, how often do you eat or drink sweet food or drink (for example: milk tea, milk chocolate, dessert)?

○ On average 3 or more times per day

○ On average 1–2 times per day

○ On average 4–6 times per week

○ On average 1–3 times per week

○ On average once per half month

○ On average once per month

○ On average 1–2 times per season

○ On average once per half a year

○ On average less than once per half a year or never

27. In the past year, how often do you eat or drink sour food or drink (for example: yogurt, hawthorn candies, jujube cake)?

○ On average 3 or more times per day

○ On average 1–2 times per day

○ On average 4–6 times per week

○ On average 1–3 times per week

○ On average once per half month

○ On average once per month

○ On average 1–2 times per season

○ On average once per half a year

○ On average less than once per half a year or never

28. In the past year, how often do you eat or drink bitter food or drink (for example: bitter herbal tea, bitter melon, grapefruit)?

○ On average 3 or more times per day

○ On average 1–2 times per day

○ On average 4–6 times per week

○ On average 1–3 times per week

○ On average once per half month

○ On average once per month

○ On average 1–2 times per season

○ On average once per half a year

○ On average less than once per half a year or never

29. In the past year, how often do you eat or drink spicy food or drink (for example: hot and sour soup, Sichuan cuisine, chicken feet with pickled peppers)?

○ On average 3 or more times per day

○ On average 1–2 times per day

○ On average 4–6 times per week

○ On average 1–3 times per week

○ On average once per half month

○ On average once per month

○ On average 1–2 times per season

○ On average once per half a year

○ On average less than once per half a year or never

30. Generally speaking, to what extent do you like sweet food or drink?

Dislike very much ♡ ♡ ♡ ♡ ♡ ♡ ♡ Like very much

31. Generally speaking, to what extent do you like sour food or drink?

Dislike very much ♡ ♡ ♡ ♡ ♡ ♡ ♡ Like very much

32. Generally speaking, to what extent do you like bitter food or drink?

Dislike very much ♡ ♡ ♡ ♡ ♡ ♡ ♡ Like very much

33. Generally speaking, to what extent do you like spicy food or drink?

Dislike very much ♡ ♡ ♡ ♡ ♡ ♡ ♡ Like very much

34. Compared to your peers, what is your relative socioeconomic status?

(The left end represents that you have worse economic status than all other peers, the right end represents that you have better economic status than all other peers)

Move the cursor to the place that you think you are at

Poorest (0) Richest (100)

Childhood Socioeconomic Status Measure (No. 35 – 37)

Next, please think about your childhood before age 12, read the following statements, and indicate to what extent you agree or disagree with the following statements.

35. My family usually had enough money for things when I was growing up:

○Strongly disagree ○Somewhat disagree ○Slightly disagree ○Slightly agree ○Somewhat agree ○Strongly agree

36. I grew up in a relatively wealthy neighborhood:

○Strongly disagree ○Somewhat disagree ○Slightly disagree ○Slightly agree ○Somewhat agree ○Strongly agree

37. I felt relatively wealthy compared to the other kids in my school:

○Strongly disagree ○Somewhat disagree ○Slightly disagree ○Slightly agree ○Somewhat agree ○Strongly agree

Mini-K (No. 38, 20 items):

Please answer the following questions and please be aware that there is no right or wrong answer to these questions. Please select the option that you agree with most or the option that best describes your current situation.

38. Please answer to what extent you agree or disagree with the following statements (please select "don't know/not applicable" if the statement does not apply to you).

	Strongly disagree	Somewhat disagree	Slightly disagree	Don't know/not applicable	Slightly agree	Somewhat agree	Strongly agree
I can often tell how things will turn out.	○	○	○	○	○	○	○
I try to understand how I got into a situation to figure out how to handle it.	○	○	○	○	○	○	○
I often find the bright side to a bad situation.	○	○	○	○	○	○	○
I don't give up until I solve my problems.	○	○	○	○	○	○	○
I often make plans in advance.	○	○	○	○	○	○	○
I avoid taking risks.	○	○	○	○	○	○	○
While growing up, I had a close and warm relationship with my biological mother.	○	○	○	○	○	○	○
While growing up, I had a close and warm relationship with my biological father.	○	○	○	○	○	○	○
I have a close and warm relationship with my own children.	○	○	○	○	○	○	○
I have a close and warm romantic relationship with my sexual partner.	○	○	○	○	○	○	○

I would rather have one than several sexual relationships at a time.	○	○	○	○	○	○	○
I have to be closely attached to someone before I am comfortable having sex with them.	○	○	○	○	○	○	○
I am often in social contact with my blood relatives.	○	○	○	○	○	○	○
I often get emotional support and practical help from my blood relatives.	○	○	○	○	○	○	○
I often give emotional support and practical help to my blood relatives.	○	○	○	○	○	○	○
I am often in social contact with my friends.	○	○	○	○	○	○	○
I often get emotional support and practical help from my friends.	○	○	○	○	○	○	○
I often give emotional support and practical help to my friends.	○	○	○	○	○	○	○
I am closely connected to and involved in my community.	○	○	○	○	○	○	○
I am closely connected to and involved in my religion.	○	○	○	○	○	○	○

Negative Affect Schedule (No. 39, 10 items):

39. The following table consists of a number of words that describe different feelings and emotions. Please read each item carefully and then choose the option that best describes the strength of your current feelings and emotions.

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
jittery	○	○	○	○	○
upset	○	○	○	○	○
guilty	○	○	○	○	○
ashamed	○	○	○	○	○
hostile	○	○	○	○	○
irritable	○	○	○	○	○
nervous	○	○	○	○	○
distressed	○	○	○	○	○
scared	○	○	○	○	○
afraid	○	○	○	○	○

Hypercompetitive Attitude Scale (No. 40, 27 items):

40. Please read the following statements and answer to what extent you agree or disagree with each statement:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I like competition because it gives me a chance to find out what I am good at.	○	○	○	○	○
Competition promotes friendships between people.	○	○	○	○	○
I believe that you can be a nice guy and still win or be successful in competition.	○	○	○	○	○
I do not see my opponents in competition as my enemies.	○	○	○	○	○
Without the challenge of competition, I may never find out some potentials and talents that I have.	○	○	○	○	○
I appreciate competition because it brings me and my opponents closer as equal people.	○	○	○	○	○
I do not find it difficult to be fully satisfied with my performance in a competitive situation.	○	○	○	○	○
Failure or loss in competition makes me feel less worthy as a person.	○	○	○	○	○
Competition inspires me to excel.	○	○	○	○	○
If I can disturb my opponent in some way in order to get the edge in competition, I will do so.	○	○	○	○	○

I compete with others even if they cannot compete with me.	○	○	○	○	○
I do not mind giving credit to someone for doing something that I could have done just as well or better.	○	○	○	○	○
I find myself turning a friendly game or activity into a serious contest or conflict.	○	○	○	○	○
It's a dog-eat-dog world. If you don't get the better of others, they will surely get the better of you.	○	○	○	○	○
I really feel down when I lose in athletic competition.	○	○	○	○	○
Gaining praise from others is not an important reason why I enter competitive situations.	○	○	○	○	○
I like the challenge of getting someone to like me who is already going with someone else.	○	○	○	○	○
I do not view my relationships in competitive terms.	○	○	○	○	○
I like competition because it helps me know more about myself.	○	○	○	○	○
I can't stand to lose an argument.	○	○	○	○	○
Competition allows me to show my potentials and talents. Therefore, I think it makes me happy.	○	○	○	○	○
I feel no need to get even with a person who criticizes or makes me	○	○	○	○	○

look bad in front of others.					
I care about competition because it helps me to fully show who I am.	○	○	○	○	○
I appreciate competition not only because it helps me do things better than others but also because competition gives me stronger motivations to perform better.	○	○	○	○	○
I like competition because it helps me to live up to my potentials rather than because it makes me feel superior to others.	○	○	○	○	○
I like competition because, compared to things that I can do alone, competition helps me to live up to my potentials.	○	○	○	○	○
Because of participating in competitions, I think I contribute to improving other people's health and happiness.	○	○	○	○	○

Appendix C: Taste Priming Materials Used in Study 2 and Study 3

Please imagine the following scenario and answer a few questions:

Imagine that you have been given a beverage without knowing what it is.

→

For bitter taste prime condition:

After tasting it, you found it to be dark black decaffeinated coffee without any sugar or milk.

For tasteless prime condition:

After tasting it, you found it to be plain water.

Manipulation Check Item:

Please indicate the likelihood that you would describe the taste of the drink as "**bitter**" along with a scale from 1 (not so much) to 7 (very much so).

	1: Not so much	2	3	4	5	6	7	8	9	10: Very much so
Bitter Taste	○	○	○	○	○	○	○	○	○	○

Appendix D: Article Used for Introducing Vitamin D and Calcium in Study 2

Please read the following article and answer a few questions:

The Role of Vitamin D and Calcium in Health

Calcium is an essential mineral for many body functions. Your bones, heart, muscles, and nerves all need calcium to function properly. Calcium regulates muscle contraction, including the beating of the heart muscle. Also, calcium plays a key role in normal blood coagulation (clotting). Moreover, calcium is required for the full activity of many important enzymes in our body.

Vitamin D is also essential for your health. Your body must have vitamin D to absorb calcium. Vitamin D helps regulate the immune system and the neuromuscular system. And vitamin D plays major roles in the life cycle of human cells. Vitamin D deficiency has now been linked to breast cancer, colon cancer, prostate cancer, heart disease, depression, weight gain, and other maladies.

Experts recommended that all Canadian adults take calcium and vitamin D supplements year-round. Some studies suggest that supplementing with appropriate amounts of calcium, along with vitamin D, may have benefits beyond bone health: perhaps protecting against cancer, diabetes, and high blood pressure; and enhancing your body in general.

BOTTOM LINE

Supplementing with an appropriate amount of vitamin D and calcium per day is known to be effective for enhancing your body in general.

Attention Check Item:

According to the article above, is this statement true or false?

"Consuming drinks which have an appropriate amount of vitamin D and calcium in it will help enhance people's body."

True

False

Appendix E: Questionnaire in Study 2 and Study 3

The Competitiveness Index (8 items)

Please answer how much do you disagree/agree with each statement.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
I like competition.	○	○	○	○	○	○	○
I am a competitive individual.	○	○	○	○	○	○	○
I enjoy competing against an opponent.	○	○	○	○	○	○	○
I get satisfaction from competing with others.	○	○	○	○	○	○	○
I find competitive situations unpleasant.	○	○	○	○	○	○	○
I often try to outperform others.	○	○	○	○	○	○	○
I don't enjoy challenging others even when I think they are wrong.	○	○	○	○	○	○	○
In general, I will go along with the group rather than create conflict.	○	○	○	○	○	○	○

Demographic Questions (9 items)

DEMOGRAPHIC INFORMATION

To what extent do you watch what you eat?

Not at all						Very much

Are you currently on a diet?

Not at all						Very much

Do you have any dietary restrictions?
(Click all that apply)

- I do not have any dietary restriction
- Vegetarian or vegan
- Gluten intolerance or celiac
- Lactose intolerance
- Food allergy (e.g., peanuts, shellfish, etc.)
- Other:

What is your gender?

- Male
- Female
- Other/Do not want to answer

What year were you born? (Please use numbers only)

What is your race or ethnicity?

- White/Caucasian
- African American
- Hispanic
- Asian
- Indian
- Native American
- Other

What country were you born in?

- Canada
- United States
- Other (please describe)

Is English your first language?

- Yes
- No (if no, enter first language below)

What is your level of knowledge of English?

Very basic					Native or Bilingual

Appendix F: Multinomial Discrete Choice Model in Study 2

The choice model that have random effects can be retrieved from SAS/STAT User's Guide (https://support.sas.com/documentation/onlinedoc/stat/131/bchoice.pdf, page 1011)

$$U_{ijt} = X_{ijt}\beta + Z_{ijt}\gamma_i + \epsilon_{ijt}$$
$$Y_{ijt} = 1 \text{ if } U_{ijt} \geq \max(U_{i1t}, U_{i2t}, U_{i3t})$$
$$= 0 \text{ otherwise}$$

U_{ijt} is the utility that individual i obtains from choosing the alternative j in the choice set t (t = 1, …, 12). Y_{ijt} is the decision made by individual i for alternative j in the choice set t; X_{ijt} is the fixed design vector for individual i for alternative j in the choice set t; β is the vector of fixed coefficients; Z_{ijt} is the random design vector for individual i in the choice set t; γ_i is the vector of random coefficients for individual i corresponding to Z_{ijt}.

The SAS code used for analysis is as follows:

```
proc bchoice data=dataset seed=123 nbi=10000 nmc=80000 thin=5 nthreads=4
statistics(ALPHA=(0.05 0.1)) diagnostics=all;

    class ID trial;
    model decision = vitamin_D calcium price interVC interCC interPC/ choiceset=(ID trial);
    random brand_1 brand_2 vitamin_D calcium price / subject=ID type=un;

run;
```

Each individual was assigned an "ID" number and completed twelve "trial"s. The terms "interVC" "interCC" "interPC" refer to the interaction terms between vitamin_D and condition, calcium and condition, and price and condition.

Appendix G: Multinomial Discrete Choice Model in Study 3

The choice model that have random effects can be retrieved from SAS/STAT User's Guide (https://support.sas.com/documentation/onlinedoc/stat/131/bchoice.pdf, page 1011)

$$U_{ijt} = X_{ijt}\beta + Z_{ijt}\gamma_i + \epsilon_{ijt}$$
$$Y_{ijt} = 1 \text{ if } U_{ijt} \geq \max(U_{i1t}, U_{i2t}, U_{i3t})$$
$$= 0 \text{ otherwise}$$

U_{ijt} is the utility that individual i obtains from choosing the alternative j in the choice set t (t = 1, …, 12). Y_{ijt} is the decision made by individual i for alternative j in the choice set t; X_{ijt} is the fixed design vector for individual i for alternative j in the choice set t; β is the vector of fixed coefficients; Z_{ijt} is the random design vector for individual i in the choice set t; γ_i is the vector of random coefficients for individual i corresponding to Z_{ijt}.

The SAS code used for analysis is as follows:

```
proc bchoice data=dataset seed=123 nbi=10000 nmc=80000 thin=5 nthreads=4
statistics(ALPHA=(0.05 0.1)) diagnostics=all;

    class ID trial;
    model decision = omega calcium price interOC interCC interPC/ choiceset=(ID trial);
    random brand_1 brand_2 omega calcium price / subject=ID type=un;

run;
```

Each individual was assigned an "ID" number and completed twelve "trial"s. The terms "interOC" "interCC" "interPC" refer to the interaction terms between omega and condition, calcium and condition, and price and condition.