MSc Thesis in Management of Technology

THE IMPACT OF NUDGING AND SELF-CONTROL ON FOOD PREFERENCES

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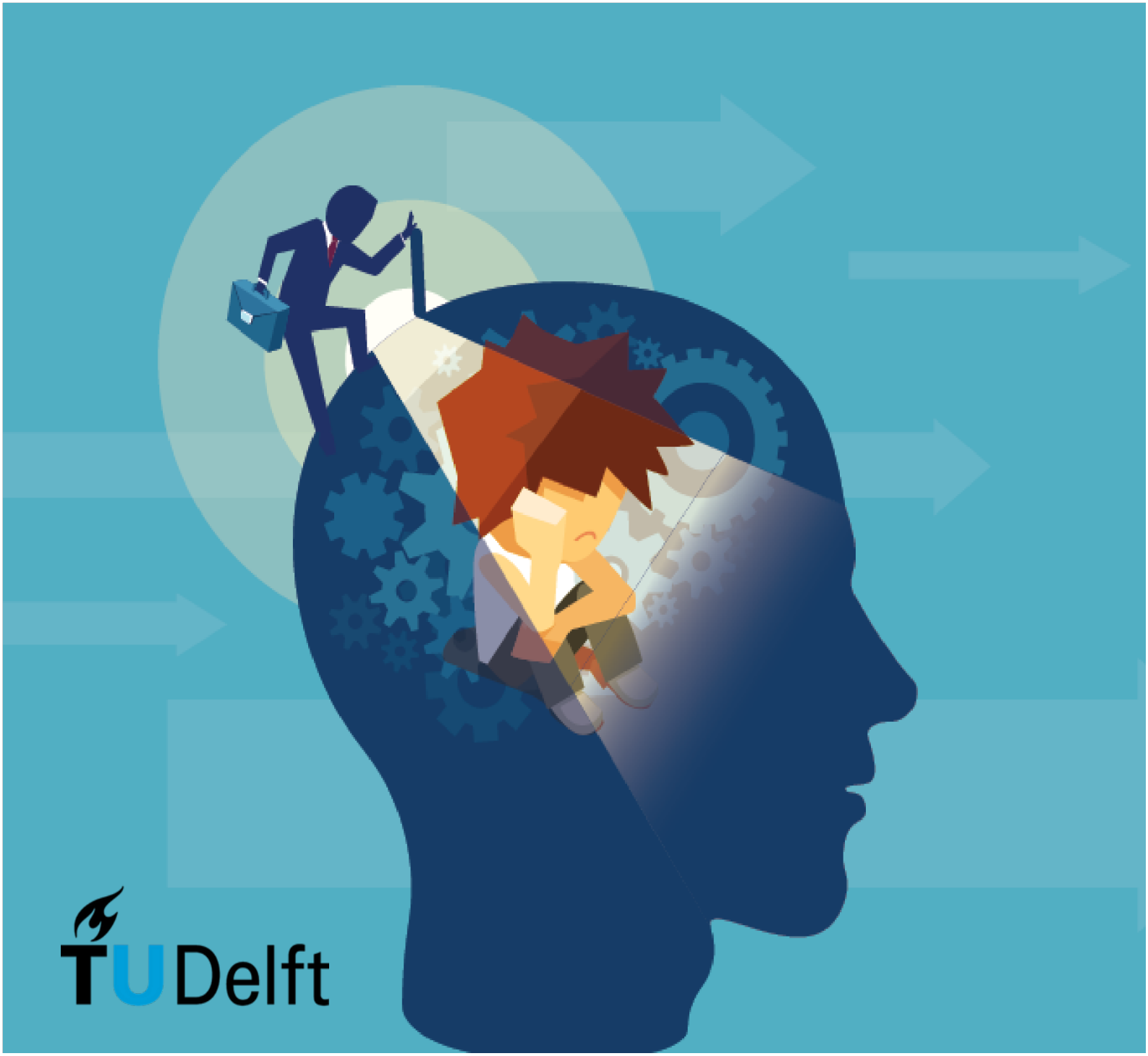

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The Impact of Nudging and Self-Control on Food Choices

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Preface

Dear reader,

With this master's thesis report, I am concluding my academic journey after years of dedicated effort, marked by both delightful and challenging moments that have shaped my adult persona. I am immensely grateful for my decision and for the support of those who aided me in writing this thesis, since this journey could not have a better finale. The feeling of excitement while ordering the book "Nudge" after the introduction of the nudge theory on the last day of one of my master classes will hardly be erased from my memory. I am expressing those feelings because it was the first time I could unite my deep-rooted interest in the complex function of the human mind with my engineering studies. Hence, this research was not merely seen as another obligatory assignment to complete my studies, but rather as a research to fulfill my personal thirst for more knowledge about the psychology behind self-control and food behaviors.

So, first and foremost I would like to thank Dr. Laurens Rook for giving me the opportunity to work on this project and for his support and inspiration. Laurens Rook was one of the most supportive professors I ever had. I will never forget his quick replies to emails even during the weekend, and his insightful meetings that gave me the needed direction and confidence to accomplish this research. Also, I would like to express my sincere gratitude to Prof. Frances Brazier and Dr. Iulia Lefter for their inspiring feedback that undeniably determined the results of this project. Finally, I owe much to my family, and friends for their encouragement, compassion, and emotional support over the past months. Their faith in me helped me maintain my confidence and motivation high during this journey.

I would like to conclude with an inspirational saying of mine,

" Live each day like it's a movie. You are the protagonist of your story."

Sofia Stavrou,
Delft, June 2023

Abstract

Maintaining a healthy eating behavior can be challenging, especially under stressful situations. Self-control plays a pivotal role in this struggle, since it allows one to resist immediate desires in pursuit of higher-level goals. The level of self-control can differ among individuals, with varying degrees of "strength". This strength can be likened to a "muscle", which has specific power and endurance and enables the exertion of self-control at a certain time. Power is linked to the individual situation-invariant levels of trait self-control, which enables the initial exercise of self-control at a particular moment. However, the maintenance of self-control over time is attributed to "muscle endurance", which is represented by individual depletion sensitivity. Like a muscle that can become depleted after exertion, the exercise of self-control can deplete available cognitive resources, leading to ego depletion, decreased self-control capacity, and thus unhealthy food choices. Food recommender systems are considered effective tools for promoting healthier choices and may be seen as nudges that make healthier options more salient. Many studies have demonstrated the effectiveness of recommender systems and digital nudging in influencing users' food choices in the direction of healthier ones. Attribute frames, including positive and negative types, are popular information nudges in the health field. Nonetheless, their impact on eating behaviors remains a controversial issue. Evidence has shown that dispositional factors, such as self-control levels, may moderate the effectiveness of attribute frames.

This study aimed to examine to what extent attribute frames steer human food choices toward healthy ones, and in what way self-control levels influence that relationship. An online experiment was conducted, utilizing attribute frames as the independent variable, food choices as the dependent variable, and depletion sensitivity and trait self-control as moderating variables. Participants were randomly provided seven different food options, each of which came with an attribute framing message, to evaluate the effects of positive and negative attribute frames on healthy food choices. The Depletion Sensitivity Scale (DSS), and Brief Self-Control Scale (BSCC) were used to assess the individuals' levels of depletion sensitivity and trait self-control, in respect. The findings revealed that positive attribute frames effectively encouraged healthy food choices, while negative frames had a relatively lower impact. Depletion sensitivity moderated the relationship between attribute frames and healthy food choices, suggesting that individuals with low depletion sensitivity were more likely to select healthy options under positive framing conditions. However, no significant moderating effect of trait self-control was observed. Lastly, the relationship between attribute frames and food preference was found to be significantly moderated by gender differences. In conclusion, this study provided evidence supporting the influence of attribute frames on healthy food choices and the moderating role of depletion sensitivity on this relationship. The significance of considering gender differences in the analysis of the effect of attribute frames on food preferences was also illustrated.

Executive summary

Many people struggle to maintain healthy eating habits due to stress. Self-control plays a major role in this struggle, as the ability to suppress a behavioral tendency towards a "lower-level" desire in pursuit of a "higher-level" goal. The level of self-control can differ among individuals, with varying degrees of "strength". This strength can be likened to a "muscle", possessing specific power and endurance. However, similar to a muscle that can become depleted after exertion, the exercise of self-control can deplete available cognitive resources, limiting the capacity for self-control in subsequent tasks. This condition is known as "ego depletion", or the limited strength model of self-control (Baumeister et al., 1998). To exert self-control at a certain time, individuals need both muscle power and endurance. Power is linked to the individual situation-invariant levels of trait self-control, which enables the initial exercise of self-control at a particular moment (Baumeister & Alquist, 2009). On the other hand, the maintenance of self-control over time is attributed to "muscle endurance", which is represented by individual depletion sensitivity.

External factors also have a significant role in influencing dietary behaviors. To encourage healthier food choices, food recommender systems can be utilized. Also, recommender systems can be regarded as a nudge that increases the salience of healthy alternatives (Kamsteeg et al., 2011). Numerous studies have demonstrated the effectiveness of recommender systems and digital nudging in influencing users' food choices in the direction of healthier ones (Abhari et al., 2019; Marcano-Olivier et al., 2020; Musto et al., 2020; Trang Tran et al., 2018). Attribute frames, which consist of both positive and negative variations, are a popular information nudge category in the health field. However, their effect on eating behaviors remains a topic of debate due to inconsistent findings observed in different studies for the positive and negative types of frames. Additionally, in previous research, it has been argued that the effect of attribute frames is moderated by dispositional factors, that influence the way people perceive and respond to nudges (Covey, 2014; Dolgopolova et al., 2021). Examples of such factors are personal characteristics (individual moderators), such as self-control levels (Bermúdez, 2020).

Considering the above, the main research question of this thesis was: *To what extent can attribute framing messages steer human food choices toward healthy ones, and in what way do self-control levels influence that relationship?* To answer these questions, an online experiment was designed, in which the attribute frames were the independent variable, the food choices the dependent variable, and depletion sensitivity and trait self-control the moderating variables.

To evaluate the impact of positive versus negative attribute framing nudge for healthy food choices, participants were randomly assigned to seven food choices, including attribute framing messages. Then, Depletion Sensitivity Scale (DSS) (Salmon, Adriaanse, et al., 2014) and Brief Self-Control Scale (BSCC) (Tangney et al., 2004), were used to assess the individuals' levels of depletion sensitivity and

trait self-control, respectively. Moreover, questions regarding food preferences, restrictions, Body Mass Index, and demographics were also included. To test the generated hypotheses, statistical analysis was done.

First, the findings show that positive attribute frames successfully encourage participants to choose healthy food options. Although negative attribute frames also contributed to the promotion of healthy food choices, their efficacy was less than that of the positive frames. Those findings do not refute the notion that positive attribute frames are more effective in encouraging healthy food choices. However, they offer more nuanced insights. Moreover, depletion sensitivity moderated the relationship between attribute frames and healthy food choices. Specifically, participants with low levels of depletion sensitivity chose a healthy food option more frequently than participants with high levels of depletion sensitivity under positive framing conditions. Nonetheless, no significant findings were observed regarding the moderating effect of trait self-control. Interestingly, a significant gender-related moderating effect on the relationship between attribute frames and food preferences was found. Specifically, females more often selected a healthy food choice under the positive framing conditions than under the negative ones. The same effect was observed for males. However, females made overall more healthy food choices than males.

Apart from providing answers to the research question, this research identified different potential directions for future research. Future research could focus on exploring the moderating effects of depletion sensitivity and trait self-control under real ego-depletion conditions. This can be accomplished through on-site, laboratory experiments utilizing the dual-task paradigm (Baumeister et al., 1998; Finkel et al., 2006; Muraven et al., 1999). Physiological metrics of self-control, such as the heart rate variability (HRV), and skin conductance, or electrodermal activity (EDA) could also be considered. By investigating how individuals with different levels of depletion sensitivity and trait self-control perform in tasks that induce ego depletion, researchers can gain a deeper understanding of how these factors interact and influence the effectiveness of nudge interventions. Research on state self-control, which represents situational fluctuations in self-control through time and under various situations, may also be taken into consideration.

In conclusion, the findings and knowledge obtained from this research have the potential to assist researchers in the development of successful nudging interventions and enhance the design of food recommender systems. These advancements can contribute to supporting individuals in making healthier food choices.

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1. Introduction

1.1. Background

Despite having a "fitness fanatic" lifestyle, or promising to follow a healthier diet, many people might have encountered the following situation: Reaching the nearest snack machine, stopping at the drive-through, or ordering the tempting fast food being advertised, all seem familiar impulsive decisions after a stressful and exhausting day of work. Those choices are attributed to the pleasure, stress alleviation, or reward to oneself that the unhealthy food cravings would provide. In such circumstances, people tend to succumb to unhealthy food choices and increased food consumption. In the book of Nicomachean Ethics, Aristotle described this condition as "akrasia"(Ward, 2014). Chronic stress is found to be linked to the consumption of sugary and high-fat food. Over the years this unhealthy diet leads to health issues, such as obesity, and diabetes (Dutt et al., 2019; Friedman & Mozaffarian, 2016). By 2025, the World Health Organization (WHO) predicts that 167 million adults and children will be overweight or obese (WHO, 2022). So, although the knowledge of the benefits, and the willingness to adopt a healthier diet exists, in some people this will is weak, and cannot resist tempting foods during distress. This situation describes the conflict between the force of doing what one believes is rational, and correct, and the opposite force of doing what will bring more pleasure. To overcome this conflict, self-control is needed (Hofmann et al., 2009). In other words, self-control is the suppression of a behavioral tendency toward a "lower-level" objective in the pursuit of a "higher-level" goal (Johnson et al., 2011).

The issue is that the mechanisms under which self-control influences behavior are still ambiguous (Forestier et al., 2018). It has been widely argued that self-control varies among people, by having a different level of self-control "strength". This strength is characterized as a "muscle" that has a specific power and endurance. This "muscle" can be depleted after the exercise of self-control, limiting the human resources to exert self-control in secondary tasks. This condition is known as "ego depletion", or the limited strength model of self-control (Baumeister et al., 1998). Many studies have tried to analyze and explain the phenomenon of self-control failures, with eating behaviors being a popular testing example (Baumeister & Vohs, 2004). Considering this muscle metaphor of ego depletion, people need both muscle power and endurance to be able to exert effort at a certain time. Power is linked to the individual situation-invariant levels of trait self-control, which enables the initial exercise of self-control at a particular moment (Baumeister & Alquist, 2009). On the other hand, the maintenance of self-control over time is attributed to "muscle endurance", which is represented by individual depletion sensitivity.

Although eating behaviors are influenced by personal motivations and capacities, people are also affected by the environments in which they make decisions. One example is the food recommender system that is widely being adopted by businesses and individuals these days (Weinmann et al., 2016). Those systems are regarded as tools to help decision-making processes and have the potential to promote healthy food choices (Trang Tran et al., 2018). To increase the likeliness of achieving the latter goal, digital nudging is considered a way to guide consumers toward healthier diets. Also, the choice and combination of nudging mechanisms can impact the effectiveness of the recommendation system (Jesse et al., 2021).

In parallel, recent studies examine under which conditions people are receptive to nudging mechanisms (de Ridder et al., 2022). An interesting research field is the influence of nudging mechanisms on different levels of self-control capacity (Salmon et al., 2015; Thunström, 2019). Mariotti et al. (2022) showed in their work that people have different reactions to nudges due to diversity in individual self-control levels. They also suggested that policymakers should consider the impact of self-control when designing informational nudges to discourage harmful consumption. Similar studies focus on the acceptability of nudges based on self-control levels (Van Gestel et al., 2021).

Considering the above, the success of a nudge in food recommender systems highly depends on the choice of the most appropriate nudge type for a particular field. A well-known informational nudge category in the health field is framing. It refers to how the context of a phrase affects how individuals make judgments (Gena et al., 2019). The phenomenon derives from Prospect Theory, which states that decision-making and behavior can be affected differently by message framing triggered by prospective perceived losses or perceived benefits in the provided information (Kahneman & Tversky, 1984; Yao et al., 2022). A popular sub-category of frames for eating behaviors is attribute framing. This framing type provides evaluative information about an item by highlighting its positive or negative aspects (Levin et al., 1998). In the literature, it is argued that attribute frames seem useful tools to bridge the knowledge-deficit gap of healthy eating, with positive attribute frames contributing to this goal (Bannon & Schwartz, 2006; Binder et al., 2020; Collins et al., 2019; Dolgopolova et al., 2021; Gallagher & Updegraff, 2012; Van Assema et al., 2001; Zahid & Reicks, 2018).

1.2. Problem definition

Although nudges are found to ameliorate food recommender systems toward healthier food choices, research on digital nudges in online diet behavior is still lacking (Berger et al., 2020; Jesse, Jannach, & Gula, 2021). So, there is an emerging challenge for behavioral economists to design informative digital nudges that will improve decision-making processes toward online healthier food choices.

Moreover, the effect of positive and negative attribute frames on food behaviors is a controversial issue, due to the opposite results in that research field. Although many studies have shown that positive attribute frames rather than negative ones are more effective in eating behavior changes (Bannon & Schwartz, 2006; Binder et al., 2020; Collins et al., 2019; Dolgopolova et al., 2021; Gallagher & Updegraff, 2012; Van Assema et al., 2001; Zahid & Reicks, 2018), other studies had different results. Specifically, some researchers have concluded that negative frames had a more significant effect (Eguren et al., 2021; Rosenblatt et al., 2018; Vidal et al., 2019), whereas others found no noteworthy difference between the two framing types at all (Lagerkvist et al., 2023).

The identified effects of individual factors, such as self-control, on the nudge create an interesting opportunity for further research. This research might eventually shed light on the knowledge gap regarding the effectiveness of positive versus negative attribute frames on eating behaviors. To our knowledge, there is no study examining the effect of situation-invariant levels of individual depletion sensitivity and trait self-control on attribute framing theory.

Also, previous research investigated the different effects of attribute frames between females and males (Braun et al., 1997; Koenigstorfer & Baumgartner, 2016; Maheswaran & Meyers-Levy, 1990; Putrevu, 2013; Rothman et al., 1993). Braun et al. (1997) showed that attribute frames were more salient to females. On the other hand, Putrevu (2013) found a moderating role of gender on positive and negative attribute frames. A significant effect of gender on attribute frames was also reported in the work of Koenigstorfer et al. (2016). This shows that the gender aspect gives rise to a fruitful opportunity for more study.

1.3. Research objective and research questions

Considering the above, the main research objectives of this thesis are the following. First, the main goal of this thesis project is to determine if attribute frames are efficient nudges toward healthy food choices to be implemented in food recommender systems and to promote the effort of making people adopt healthier diets. A second main objective is to investigate if there is a link between different self-control levels and the attribute framing effect. It is also intended to configure how to design concrete attribute framing messages that will provide sufficient information regarding food choices. The

composition of concrete framing messages might advance not only the digital nudge literature but also the general choice architecture research. Another research challenge is to discover if situation-invariant levels of self-control influence the effect of the nudge and whether this effect differs among individuals (in terms of depletion sensitivity, and trait self-control). Additionally, given the reported differences in the effect of attribute frames on females and males in the literature (Braun et al., 1997; Koenigstorfer & Baumgartner, 2016; Maheswaran & Meyers-Levy, 1990; Putrevu, 2013; Rothman et al., 1993), a better understanding of the relationship between attribute frames and food preferences may be achieved by analyzing the impact of gender on that relationship.

To realize the above-mentioned objectives, the main research question of this thesis is as follows:

> *To what extent can attribute framing messages steer human food choices toward healthy ones, and in what way do self-control levels influence that relationship?*

The sub-questions (SQ) required to provide more insights into the main research question and meet the research objectives are the following:

> SQ_1: *What is the impact of attribute framing messages on nudging users towards healthier food options?*
>
> SQ_2: *Does the effectiveness of the attribute framing messages differ for people depending on their depletion sensitivity?*
>
> SQ_3: *Does the effectiveness of the attribute framing messages differ for people depending on their trait self-control?*
>
> SQ_4: *Does the effectiveness of attribute framing messages differ for people depending on their gender?*

SQ_1 will contribute to the existing knowledge gap regarding the effectiveness of attribute frames in healthy food choices. SQ_2 and SQ_3 will aid the investigation of the situation-invariant levels of self-control in attribute frames. Also, the last-mentioned sub-research questions will provide a novel insight into the framing theory and help the research progress toward understanding the "black box" of the mind and the way people make decisions under uncertainty. Finally, SQ_4 will provide further insights into the role of gender differences on the effect of attribute frames on dietary choices.

1.4. Research relevance

Studying and understanding the relationship between ego depletion, situation-invariant levels of self-control, and human eating behavior under stressful conditions is critical to comprehend under which conditions people make unhealthy food decisions. This can contribute to the creation of personalized interventions toward a healthy diet, which can help deal with the disadvantageous effects associated with depletion and enhance general well-being. Moreover, human behavior is not influenced only by self-control capabilities, but also by the environment of decision-making. A popular example is the online environment, where people make complex decisions, as well as food choices under a variety of options. Tools that can substantially influence users' decisions are the food recommender systems. Those systems can affect food choices by providing individual food recommendations (Isinkaye et al., 2015), but also advice on food alternatives based on different factors, such as dietary needs and limits (Chavan et al., 2021). Thus, food recommender systems have the potential to ameliorate eating behaviors. Therefore, this research can advance the digital nudging literature, and help identify effective nudges for healthy eating behaviors.

1.5. Report structure

The thesis is organized into seven chapters as follows. The first one presents the background information, the research problem, the research objective, questions, and research relevance. Chapter 2 demonstrates the literature review around self-control and the nudge theory, and Chapter 3 delineates the conceptual framework, together with the research gap and hypotheses. The research methodology is presented in Chapter 4, and Chapter 5 explains the results of the statistical analysis. Chapter 6 deliberates on the findings of the experiment, the research consequences, as well as some limitations, and future research. Finally, in Chapter 7 a short conclusion is presented.

2. Literature review

This section will first discuss the existing literature on the relationship between stress, eating behaviors, and self-control, introducing the concepts of depletion sensitivity, and trait self-control, as promising tools to analyze and explain self-control failure regarding eating behaviors. Following that, the relevance of recommendation systems for food choices and the implementation of nudges will be presented. Finally, the framing theory and attribute frames will be reviewed.

2.1. Stress and dietary behavior

Dietary behavior is crucial for human health since foods deliver the required energy and nutrients into the body that support all physiological functions and protect against the development of chronic diseases (Tapsell et al., 2016). However, nowadays, a significant population worldwide follows suboptimal diets including vitamin deficiencies and overconsumption of macronutrients. This leads to serious health problems, such as cardiovascular disease, diabetes, and obesity (Friedman & Mozaffarian, 2016). In parallel, eating disorders (e.g., anorexia nervosa, bulimia nervosa, and binge eating disorder), which cause the above-mentioned insufficient diet, are considered common chronic health issues (Chang et al., 2015). They also create serious problems not only in people's physical condition but also in their emotional health and personal relationships (National Eating Disorders Association, 2023).

Research has proven that those diet behavioral problems are affected by different environmental, societal, personal, and behavioral factors (Friedman & Mozaffarian, 2016). Specifically, studies have shown that stress influences human health both through direct biological reactions and fluctuations in health behaviors, including food choices and appetite. Under high stress, the associated food preferences mostly include sugary, fatty foods, such as fast food, and snacks (Almogbel et al., 2019; Grunberg & Straub, 1992; Oliver et al., 2000). Other findings have shown that people exhibit either chronic or occasional episodes in response to stress, known as binge eating (Evers et al., 2010; Gluck, 2006). For example, a national survey by the American Psychological Association showed that 38% of individuals had a hyperphagic episode or ate unhealthily during a month period to cope with stress, while 49% of them mentioned that those behaviors reiterate every week (American Psychological Association, 2013).

2.2. Stress and self-control

Apart from the fact that unhealthy food consumption is a reaction to stress, research has shown that food behaviors vary among individuals, with examples of emotional eating tendencies and low levels of eating constraints (Oliver et al., 2000). Those responses to stress are attributed to individual levels of self-control, which regulate and control one's eating behaviors (Zhu et al., 2014). Regarding

Baumeister & Heatherton (2009), this indulgent eating behavior is attributed to trade-offs between long-term advantages and short-term enjoyment. Specifically, individuals who are under more stress are more likely to choose unhealthy foods to improve their mood. This can happen even when they are aware that giving up a salient food would result in longer-term health benefits. This impulsive unhealthy behavior also relates to the depletion of self-regulation resources by stress (Kim & Jang, 2017). However, the mechanisms under which self-control influences behavior are still ambiguous (Forestier et al., 2018).

In the following paragraphs, the relationship between stress and self-control is analyzed in the concept of dietary behavior, as well as the phenomenon of the depletion of self-regulation resources.

2.3. Self-control exertion under ego-depletion

Eating constraints are an example of self-monitoring (or self-control) strategies, that try to subdue immediate urges to eat to achieve long-term weight objectives. Regarding Restraint Theory (Herman & Polivy, 1975), dietary behaviors are under cognitive control, and people use self-control capabilities to restrict the levels of food intake. However, in stressful events, cognitive control can be compromised leading to binge eating in situations (Johnson et al., 2011). When people lack the ability to exercise self-control, they tend to make impulsive food choices and struggle to reject unhealthy products (Salmon, Fennis, et al., 2014). It has been proven in different studies that the ability to exercise self-control is greatly influenced by the rate at which one's self-control resources, which are restricted in amount, are depleted. This self-regulatory resource depletion (or ego depletion), which occurs when a resource is repeatedly used up, reduces the ability to successfully self-regulate in the future (Baumeister et al., 1998; Salmon et al., 2016; Salmon, Fennis, et al., 2014).

2.3.1. The “muscle” metaphor and situational invariant levels of self-control

The above-mentioned findings have shifted much research attention toward the fact that self-control can be compared to a “muscle”. Considering this muscle metaphor of ego depletion, to be able to exert effort at a certain time, people need both muscle power and endurance. Regarding the concept of ego depletion, this “muscle” can be depleted after the exercise of self-control, limiting the human resources to exert self-control in secondary tasks (Muraven & Baumeister, 2000). Baumeister et al. (1994, 1998) named this phenomenon the “limited strength model of self-control”. The latter is one of the most important theories on self-control (de Ridder et al., 2011).

First, power is linked to the individual situation-invariant levels of trait self-control, which enables the initial exercise of self-control at a particular moment. Trait self-control is regarded a consistent personality feature (Guan & He, 2018). On the other hand, the maintenance of self-control

over time is attributed to "muscle endurance", which is represented by individual depletion sensitivity. Salmon et al. (2014), proved that depletion sensitivity influences the use of self-control in situations of ego depletion. A significant link between depletion and self-control has also been found in recent studies on behavioral health (Adnan et al., 2021; Z. Zhang et al., 2021). Moreover, people with high depletion sensitivity are less likely to be able to exert self-control on secondary self-control tasks, such as unhealthy food choices (Salmon et al., 2014).

2.3.2. Physiological metrics of self-control

Apart from the Strength Model of Self-Control (Muraven & Baumeister, 2000), a different approach to measuring self-control levels is through physiological metrics, such as heart rate, sweat levels, skin temperature, and hormone release. This approach has received much research attention recently, because of technological developments and the rising popularity of applied psychophysiological measures (Pilcher et al., 2022). For example, recent studies have proved that heart rate variability (HRV) is correlated with self-control levels. Both Neurovisceral Integration Theory and Polyvagal Theory suggest that HRV demonstrated the operation of a central inhibitory network that is responsible for self-regulatory activities. Also, there exists a link between the prefrontal cortical regions of the human brain, which are responsible for self-regulation, and the nervous system that influences HRV (Zahn et al., 2016). Another example is the measure of skin conductance, or electrodermal activity (EDA), which captures changes in sweat levels during different degrees of physiological arousal (Markowitz et al., 2019). This physiological arousal could be attributed to the exertion of self-control after a specific task (Markowitz et al., 2019).

Moreover, psychological stress has been found to increase significantly human body temperature, a condition known as "stress-hyperthermia" or psychogenic fever (Imataki & Uemura, 2021; Oka, 2015; Oka & Oka, 2007; Vinkers et al., 2008, 2013). The increased levels of body temperature are linked with the facilitation of the endocrine, and autonomic responses controlled by the autonomic nervous system of humans that ensures the maintenance of the body's homeostasis (Korte et al., 2005; Ulrich-Lai & Herman, 2009). The levels of intestinal temperature (core body temperature) or skin temperature (peripheral temperature) can be used to detect changes in body temperature induced by stress (Vinkers et al., 2013). Moreover, hormonal stress responses can be captured through the measurement of cortisol, the "stress hormone". Cortisol blood levels are increased by the activation of hypothalamic–pituitary–adrenal (HPA) axis, which regulates the stress hormones, during stressful conditions (Cay et al., 2018; Hinds & Sanchez, 2022; S. M. Smith & Vale, 2006; Vinkers et al., 2008). This hormone can be diffused in different body parts, including saliva, sweat, hair, urine, and the interstitial fluid (ISF), and considered sources of sample (Kaushik et al., 2014). Stress levels can also be detected by electroencephalography (EEG), which measures electro-physiological signals in the brain, through wearable devices (Ahn et al., 2019; Perez-Valero et al., 2021; Saeed et al., 2020).

Specifically, EEG captures the brainwave activity, such as alpha wave activity, triggered by stress (Attar, 2022; Perez-Valero et al., 2021).

In the literature, numerous methods to measure self-control levels exist, which generate new operational definitions of self-control (Duckworth & Kern, 2011). A note to that is the fact that there is not a single or superior method of evaluating self-control, but rather best practices considering different limitations in each case (Pilcher et al., 2022). However, the focus of this study is the investigation of the Strength Model of Self-control.

2.4. Food Recommender Systems and Nudge Theory

The following paragraphs illustrate the emergence of food recommender systems for healthier diets and the incorporation of a digital nudge to enhance the effectiveness of the above.

2.4.1. Food Recommender Systems

Although food choices are influenced by various factors, key obstacles to a healthy diet are today's hectic schedules and/or reluctance to exert mental effort in meal preparation (Kamsteeg et al., 2011). That's why food recommender systems have been investigated as an effective way to help people adapt their dietary behavior and make healthy food choices (Trang Tran et al., 2018). Recommender systems are characterized as a method for users to make decisions in complex informational environments, by providing individual, exclusive content and service recommendations (Isinkaye et al., 2015). The widespread adoption and successful implementation of this technology can significantly influence users' choices and decisions. Therefore, it can generate significant value both for businesses and individuals (Weinmann et al., 2016). Specifically, food recommender systems can improve nutrition-based health management. This is achieved by giving people additional food alternatives based not just on their preferences, and past eating habits but also on their dietary needs and limits (Chavan et al., 2021).

2.4.2. Digital Nudging in Food Recommender Systems

The abovementioned broad adoption of recommender systems presents an opportunity to incorporate and develop nudges in the field of dietary behaviors (Piper et al., 2021). As described by Thaler et al. (2014), a nudge in behavioral economics is the concept of creating conditions that induce individuals to make better choices, without pressuring them to achieve specific results. Studied predominantly in offline health and wealth decision scenarios, choice architects have been evaluating how a choice environment can influence people to make choices they perceive to be in their best interests (Jesse & Jannach, 2021). At the same time, many scholars and practitioners promote nudges as an effective intervention to reinforce a healthy diet (van Gestel et al., 2018).

Nudge Theory is getting more attention in the digital sphere, where more and more decisions are made on screens. Specifically, because of the variety of available information on the Internet, users struggle to comprehend and evaluate it critically. As a result, they are making fast, automatic judgments, that lead to deficient decisions. Nudge Theory is considered a tool to effectively guide users' choices in the digital environment, where digital nudges are simpler, quicker, and less expensive compared to physical settings. Additionally, the Internet offers special characteristics, including user monitoring, that allow customization of nudges offered to users, potentially increasing their effectiveness (Jesse, Jannach, & Bartosz, 2021). Also, recommender systems can be regarded as a nudge that increases the salience of healthy alternatives (Kamsteeg et al., 2011). Many studies have shown that recommender systems and digital nudging are effective tools to ameliorate users' food choices toward more healthy ones (Abhari et al., 2019; Marcano-Olivier et al., 2020; Musto et al., 2020; Trang Tran et al., 2018).

2.4.3. Nudge Theory, food choices, and self-control

The impact nudges may have on food decisions is based on the idea that most daily food choices are arising from psychological factors. Daily food choices are based on biases (e.g., status quo, optimism), and heuristics (e.g., anchoring, availability), which are made in System 1 of reasoning, and can be exploited by nudges (Y. Lin et al., 2017; van der Laan & Orcholska, 2022). Specifically, Kahneman (2011) introduced the metaphor of System 1 and System 2 to analyze the two discrete cognitive systems that regulate our perception, judgments, and decision-making processes. The metaphor of the two distinct cognitive processes was originally introduced by Stanovich & West (2000). In System 1 the cognitive operations are unconscious, fast, based on heuristics, and require minimal or no endeavor at all. On the other hand, System 2 mental functions are slow, complex, and arduous, and linked to the individual's sense of agency, control, and focus (Evans & Stanovich, 2013; Kahneman, 2011). Also, the reasoning is analytical, moderate, and based on rules.

Moreover, nudge theorists (Sunstein, 2015, 2016; Thaler & Sunstein, 2008) contend that processes based on System 1 are frequently activated when individuals make inferior lifestyle decisions. So, the reconstruction of the elements in decision contexts on which the heuristics and biases of System 1 are invoked, seems a realistic strategy to produce beneficial behavioral transformations (Y. Lin et al., 2017). Salient cues and heuristics have also been proven to be impulsive decision-making strategies people exploit when being in situations of low self-control (Salmon, Fennis, et al., 2014). This implies that the above-mentioned dual-system perspective is also linked with self-control theory, by being responsible for the exertion of different self-control behaviors (Hofmann et al., 2009).

2.5. Message framing

2.5.1. Background theory

Studies have highlighted the fact that the choice and combination of nudge mechanisms can be detrimental to the effectiveness of the nudging tool (Jesse, Jannach, & Gula, 2021). In the literature, four main categories of nudging mechanisms have been identified: Decision Information, Decision Structure, Decision Assistance, and Social Decision Appeal. The Decision Information nudging technique works by altering the data that the decision-maker sees. This happens without altering the alternatives themselves, but by translating the information, increasing its salience, making it more visible, or changing its phrasing (Jesse & Jannach, 2021).

A sub-category of the Decision Information nudges is the framing one. This type refers to how the context of a phrase, which might result in a different interpretation of a sentence's meaning, affects how individuals make eventually judgments (Gena et al., 2019). This nudging category is based on the psychological phenomenon of the framing effect which is one of the most popular studied decision biases derived from System 1 (Li & Chapman, 2013). The principles of this phenomenon were derived from Prospect Theory, originated by Kahneman & Tversky in 1979. This theory states that decision-making and behavior can be affected differently by message framing, triggered by prospective perceived losses or perceived benefits in the provided information (Kahneman & Tversky, 1979; Yao et al., 2022). The foundation of Prospect Theory is the concept of "bounded rationality", which contends that people's limited rationality has an impact on the outcomes of their decision-making (Shan et al., 2019, 2022). This contradicts the Western economic theory of the "rational economic man". The latter theory argues that human behavioral choices consistently aim for the maximization of utility and have some intrinsic stability that is less susceptible to external influences. To put it another way, in "bounded rationality" judgments might be influenced by outside information and people's past experiences in similar circumstances, leading to suboptimal decisions. Due to the constraints in the information processing capacities, presenting the same information in multiple ways can alter the decision maker's cognitive frame of reference. This can in turn influence their behavior (Shan et al., 2022).

Risky choice framing is considered the standard view of framing, where options are presented in terms of their correlated risks (Levin et al., 1998). The "*Asian disease problem*" by Tversky & Kahneman (1981) is the archetypal example of this framing category. In this example, the decisions between two options—dangerous and riskless—with equal anticipated values relied on whether they were characterized in positive (i.e., lives saved) or negative terms (i.e., lives lost). The positive frame presents the end result in terms of gains, whereas the negative frame in terms of losses. In their results, Tversky and Kahneman discovered a "choice reversal" in which most individuals, who were given the task with a positive frame opted for the option with a sure result. On the other hand, most people who

were given the task with a negative frame opted for the risky alternative (Levin et al., 1998). Based on the Prospect Theory, the researchers argued that people are risk averse in the field of positive framing, but risk seeking in negative one (Kahneman & Tversky, 1979, 1984; Levin et al., 1998). This means that people will favor a risky option that can prevent them from a loss, rather than a risky choice that promises to bring gains (Gena et al., 2019). Different studies have studied replicated the authentic "Asian disease problem", while others have made relative changes to it.

However, the assessment of the effects of risky choice framing is perplexing. This is because the framing influences both the dependent measure of choice and the existence of risk. Other factors also play a role in the ultimate decision (Levin et al., 1998). Levin et al. (1998) proposed other two framing categories, the attribute, and goal-framing ones that affect how information is processed. In their typology, Levin et al. (1998) tried to shed light on the possible mechanisms behind framing and differences during the encoding of positive and negative message information. In the next chapter, attribute framing, which is the framing type utilized in this project, is presented.

2.5.2. Attribute framing

Attribute framing, the most basic example of framing, manipulates only a single property in a specific given context. In contrast to risky choice framing, choices are not independent of each other, but rather provide evaluative information (Levin et al., 1998). In other words, the choice option's attribute serves as the frame's object. Specifically, attribute framing can examine positive versus negative concepts, as well as strengths versus hazards (Levin et al., 1998). Also, in this framing type, a product's feature is chosen and described in a dichotomous manner. This opposes risky choice framing, which indicates the loss and gain associated with an anticipated outcome (Dolgopolova et al., 2021). Moreover, the ability to perceive risk is not a necessary component of attribute framing effects (Levin et al., 1998). So, this framing category complies with the argument that the evaluation of information varies depending on the way is it demonstrated (Braun et al., 1997). Evaluative information in attribute framing has been found to influence three different types of judgment: item, performance evaluations, and gambles. Item evaluations reflect performance using a labeled characteristic with a positive or negative valence. Performance evaluations compare success and failure rates to describe performance. Gambles depict the results of a single bet in terms of the likelihood of success or failure.

Linguistic differences can have an impact on how strong the effects of framing are. A difference regarding the linguistic variations of positive and negative terms is that in attribute framing, positive frames delineate an advantageous result or attribute of one choice, whereas the negative frame highlights an unpleasant result or attribute (Levin et al., 1998). Studies have shown that positive frames provide more favorable judgments than negative frames in the above-mentioned categories (Janiszewski et al., 2003). Examples of how positive versus negative attribute framing can be presented,

are the existence or lack of desirable attributes, the existence or lack of undesirable attributes, as well as the demonstration of desirable versus undesirable ones (Krishnamurthy et al., 2001).

Regarding the latter, a popular experiment was administered by Levin & Gaeth (1988), who found that item evaluations and judgments are based on how the object is labeled. Specifically, they demonstrated that whether ground beef was characterized as "75% lean" or "25% fat" influenced people's judgments of its quality. They discovered that when ground beef was labeled as positive (75% lean) as opposed to negative (25% fat), people assessed it as having a better flavor and being less oily. Most literature findings argue that people favor more a positive framing than a negative one (Krishnamurthy et al., 2001; Levin et al., 1988; Levin & Gaeth, 1988; Linville et al., 1993).

In the literature, attribute frames have been utilized in many fields, such as health care (Gamliel & Peer, 2010), medical hazards (Peng et al., 2013; Welkenhuysen et al., 2001), business progress (Janiszewski et al., 2003; Kuvaas & Selart, 2004), event satisfaction (Isaac & Poor, 2016), as well as mate selection (Saad & Gill, 2014).

2.5.3. Health message framing on food behaviors

A lot of previous research has examined the effect of message framing on health behavioral changes. Gain-framed messages have been proven more effective for preventive low-risk behaviors, such as sunscreen use (Detweiler et al., 1999; Rothman & Salovey, 1997), and exercise (Robberson & Rogers, 1988), whereas loss-framed ones for detective high-risk actions with uncertain outcomes, such as HIV tests (Apanovitch et al., 2003), and self-breast check (Meyerowitz & Chaiken, 1987). In the abovementioned examples, "risky" behavior refers to actions that involve the possibility (risk) of discovering an illness (van 't Riet et al., 2014).

Eating choices are considered behaviors with low perceived risk. In other words, food preferences are more closely tied to environmental or health-related goals than high-risk levels (Gallagher & Updegraff, 2012). In parallel, diet behavior literature mostly focuses on the positive or negative benefits and characteristics of food products (Bannon & Schwartz, 2006; Binder et al., 2020; Collins et al., 2019; Eguren et al., 2021; Gallagher & Updegraff, 2012; Rosenblatt et al., 2018; Van Assema et al., 2001; Vidal et al., 2019). Attribute framing can be utilized to communicate food's nutritional benefits, either by highlighting good traits (such as vitamins), or by demonstrating detrimental traits (such as sugar and fat; Dolgopolova et al., 2021). Moreover, in their meta-analysis, Dolgopolova et al. (2021) showed that when an object's attribute is framed positively, the effectiveness of the frame toward people's attitudes and intentions is higher.

Table 1 presents some previous studies regarding attribute frames on food preferences. Recently the literature on attribute framing for food behavior has been remarkably extended from the perspective of amount and diversity (Dolgopolova et al., 2021).

Table 1: Attribute frames for food behaviors (Retrieved by Dolgopolova et al. (2021)

Author(s) (Year)	Food Item	Attribute frame
Levin (1987)	Ground beef	Lean/fat
Levin & Gaeth (1988)	Ground beef	Lean/fat
Braun et al. (1997)	Chocolate	Fat-free/fat
van Assema et al. (2001)	Low-fat diet/fruits and vegetables	Positive/negative consequences
Orth et al. (2007)	Apples, bottled water	Positively/negatively framed advertisements
Kees (2011)	Healthy/unhealthy food	Advantages/disadvantages of healthy/unhealthy foods
Van't Riet et al. (2013)	Junk food	Nutrition information
Jin & Han (2014)	Beef tallow/cow milk	Food safety
Bosone et al. (2015)	Healthy diet	Vitamin and nutrient content
de Bruijn et al. (2015)	Fruit	Fruit intake benefits
Yan (2015)	Junk food	Advantages/disadvantages of junk food
Lundeberg et al. (2018)	Variety of food products	Healthfulness
K. Kuo et al. (2019)	Fat-free yoghurt, ice cream	Advantages/disadvantages of yoghurt/ice cream
Vidal et al. (2019)	Snack food	Nutrition information
Shan et al. (2020)	Organic food	Benefits/losses of buying organic food

The literature on eating choices primarily involves two food categories: hedonic, and utilitarian. Hedonic foods are considered unhealthy, vices, such as snacks because they give instant delight but may have negative long-term effects (Wertenbroch, 1998). On the other hand, utilitarian foods are healthy types, the virtues, such as fruits, whose consumption is more cognitively motivated, and goal-oriented, in contrast with hedonic foods (Dhar & Wertenbroch, 2018).

2.5.4. Critiques of attribute framing messages

The purpose of the following section is to present the received critiques of risky choice framing and justify the selection of attribute frames for this study. Furthermore, critiques for the attribute frames, which generate an interesting research gap, are also illustrated.

O' Keefe & Jensen (2007), in their meta-analytic studies, discovered a sizable yet tenuous benefit of gain over loss-framed, questioning the relevance of Prospect Theory. One of their arguments to support the contracting results of gain and loss-framed messages is the ambiguity of the "risk" term. In other words, although "risk" in the Prospect Theory of Kahneman & Tversky (1979) is the uncertainty between a particular activity and its outcome, many times, in a health-promotion context, is correlated with the desirability or hazard of a particular result (O'Keefe & Jensen, 2007). Van 't Riet

et al. (2014) made the same critique, arguing that thinking about risk in terms of perceived threat rather than uncertainty makes a huge difference. In previous work, Van 't Riet et al. (2014) reviewed available empirical data to investigate a relationship between perceived risk and massage framing. They found that various studies used different operationalizations of risks, making the comparisons of results difficult. The evidence in favor of the risk-framing hypothesis is mixed, with some studies showing support, others showing partial support, and others showing no support (van 't Riet et al., 2014).

Another insightful critique has been made by Gigerenzer (2018), who criticized the communication of risk and uncertainty to the public through the use of complicated language and probabilistic information. He argued that the way in which information is presented, or "framed" can have a significant impact on decision-making under uncertainty. Specifically, in his work, he contradicts the traditional beliefs of neoclassical economics, that preferences are stable and there is full knowledge of all possible future outcomes. Conversely, he advocates that people make decisions in uncertain situations, where the complete set of possible future states and their consequences is not known. His arguments comply with the work of Herbert Simon (1972), who proposed an alternative perspective on human decision-making called "bounded rationality". In "bounded rationality" people cannot have complete information and unlimited computational abilities, as the traditional view of rationality proposes. On the other hand, they have bounded cognitive abilities, limited information, and time limits.

Considering the above-mentioned studies and conflicting findings of framing messages, Gigerenzer disproves behavioral economists' belief that people have stable preferences, and full knowledge of all possible future outcomes, and are irrational while interpreting framing, and making important decisions. He also criticizes the use of rational choice theory as a universal norm, and asserts that traditional framing can convey incomplete information that is not contained in the verbatim message. As a result, people rely on heuristics and intelligent inferences to understand the provided information. In other words, heuristics are not a cause of mental biases, as Thaler & Sunstein (2008) did in their work, but as an essential tool to make decisions under uncertain situations (Gigerenzer, 2015). Gigerenzer et al. (1999) named those heuristics fast-and-frugal ones. The provision of concrete framing messages should focus on how individuals make choices in this world of uncertainty, where heuristics and framing are essential tools (Gigerenzer, 2018). Lai & Tang (2017) came to a similar conclusion, that when people have insufficient knowledge, they frequently rely on their own expertise and circumstances to draw arbitrary conclusions or make judgments.

Gallagher & Updegraff (2012) argue that diet choices are associated with health-related goals, and not linked with high-risk levels, as mentioned in 2.5.3. That could be the explanation for why most of the existing literature focuses on delineating the positive or negative attributes of food products and behavior (Bannon & Schwartz, 2006; Binder et al., 2020; Collins et al., 2019; Eguren et al., 2021; Gallagher & Updegraff, 2012; Rosenblatt et al., 2018; Van Assema et al., 2001; Vidal et al., 2019).

Taking all the above into consideration, attribute frames seem a more promising framing candidate to be utilized for nudging healthier food behaviors.

2.5.5. Dispositional factors on attribute frames

The following paragraphs illustrate a different perspective to explain the conflicting results in attribute frames. A consistent moderating role in the effect of message framing has been found in dispositional factors that influence how individuals perceive and respond to messages (Covey, 2014). Apart from the context in which a positive or negative message is applied (situational moderator), personal characteristics (individual moderators), such as differences in the motivational system, have also been proposed as factors to influence the effectiveness of attribute frames (Cesario et al., 2008; Godinho et al., 2016; Lagerkvist et al., 2023). Examples include studies that explored the effect of regulatory focus (Bosone et al., 2015; Dijkstra et al., 2011; C. Y. Lin & Yeh, 2017; Shimul et al., 2021), as well as regulatory fit (Kuo et al., 2019), self-efficacy (Bertolotti et al., 2019; Carfora et al., 2022), and intrinsic self-relevance (Krishnamurthy et al., 2001) on unhealthy food choices under positively and negatively framed messages.

Regarding attribute framing, Dolgopolova et al. (2021) argued in their meta-analysis that the effectiveness of attribute frames on food choices depends on both the category of the frame (positive versus negative) and moderators. In other words, it is the combination of the type of frame and external factors that influence positively people's attitudes and intentions toward food. For example, previous studies on attribute frames examined the relationship between those frames and individual characteristics, such as different types of personality, intelligence (Murch & Krawczyk, 2014), cognitive processing (Kuvaas & Selart, 2004; Murch & Krawczyk, 2014), regulatory focus (Bosone et al., 2015; Kees, 2011; Kuo et al., 2019), prior knowledge (Jin & Han, 2014), attitudinal ambivalence (Yan, 2015), motivational orientation (Godinho et al., 2016), as well as subjective reference scales (Janiszewski et al., 2003).

The relationship between framing and self-control is another interesting research finding. Regarding José Luis Bermúdez (2020), the successful exertion of self-control is frequently a function of how one frames oneself and one's goals, while clashes between temptation and self-control may be depicted as clashes of frames. The way an option is framed in a state of temptation should influence the decision-makers' self-control levels and behavior. In parallel, as already mentioned, Mariotti et al. (2022) proved that heterogeneous levels of self-control led to different interpretations of informational nudges and argued that this should be considered when developing nudges to prevent unhealthy consumption. Similar studies have found that nudges effectively promoted healthy food items under low self-control levels (Salmon et al., 2015). On the other hand, Thunström (2019) argued that

individuals with low levels of trait self-control tend to be less receptive to nudging in contrast to those with higher levels.

As already explained, ego depletion is found to result in mental-cognitive fatigue, which subsequently leads to low intellectual performance, such as logical reasoning (Schmeichel et al., 2003) At the same time, under low self-control levels, humans frequently use decision-making techniques like heuristics that require fewer cognitive resources (Baumeister & Vohs, 2016; Pohl et al., 2013; Salmon et al., 2015). *Depleted people are therefore more likely to act as the heuristics suggest. They are also more susceptible to external influences* (Jinghui et al., 2017). This argument is also linked with the theory of Systems 1 and 2 of thinking. Specifically, self-control, which is a higher-level mental resource of System 2, relies on a finite supply of mental resources. When those resources are exhausted due to depletion, people switch to their simpler System 1 of thinking (de Haan & van Veldhuizen, 2015). As already stated, framing messages are choice biases coming from System 1 (Li & Chapman, 2013). This means that, under an ego depletion state, individuals will be more influenced by framing messages. Therefore, by regenerating the aspects of choice contexts, in which System 1's heuristics and biases are activated, positive behavioral changes could be generated (Battaglio et al., 2019; Y. Lin et al., 2017). However, although those with a limited ability for self-regulation may leverage more from nudges, from a theoretical standpoint, the actual circumstances under which people are more receptive to nudges is an area of research that has not been well investigated (de Ridder et al., 2022).

2.6. Summary

Considering all the above, this chapter presented the issue of unhealthy diet behaviors under stress and the importance of situational invariant self-control levels for affecting those behaviors. Also, the significance of food recommender systems for helping people ameliorate their eating habits was discussed, as well as why framing messages can enhance their potency. Attribute framing messages are considered a promising candidate to influence individuals toward healthy food products. Moreover, the investigation of self-control as a dispositional moderating factor between attribute frames and food choices can provide useful insights into how people respond to these framing messages. To our knowledge, the combined impact of these variables on food behaviors has not been examined in any research yet. Studying the effect of self-control levels and attribute frames on food choices can not only progress the digital nudging literature but also help understand to what extent people with different self-control levels are influenced by these framing messages.

3. Conceptual Framework

The following section presents the research gap regarding the effectiveness of positive versus negative framing messages on food choices, the conceptual framework, as well as the hypotheses associated with the conceptual framework.

3.1. Conceptual Framework

Previous studies have shown that digital nudging, and in particular framing messages, can influence healthy food choices in the field of food recommender systems (Jesse et al., 2021). In parallel, research has proven that dispositional factors, such as self-control, that are part of an individual's personality can influence the effectiveness of the frames (Bermúdez, 2020; Covey, 2014; Mariotti et al., 2022; Thunström, 2019). Those factors might also provide an explanation for the conflicting results of positive versus negative attribute messages on eating choices, whose critiques makes it a controversial research tool for health behavioral change. Also, the role of gender differences on the effectiveness of attribute frames has also been demonstrated in past research (Braun et al., 1997; Koenigstorfer & Baumgartner, 2016; Maheswaran & Meyers-Levy, 1990; Putrevu, 2013; Rothman et al., 1993).

As mentioned in 1.1, healthy food choices in depleted states can be moderated by self-control levels. Although there is controversy over the ways in which self-control affects behavior (Forestier et al., 2018), the "muscle" metaphor of self-control seems a promising mechanism to interpret self-control failures in the field of diet behaviors (Baumeister & Vohs, 2004). It is argued that trait self-control (Guan & He, 2018), and depletion sensitivity (Salmon, Adriaanse, et al., 2014; Salmon et al., 2016) are efficient representatives of the situational invariant levels of self-control to predict human behavior during depleted states.

Based on this theoretical background, an online experiment was designed. Specifically, the experiment's first part consists of providing food options that include positive or negative attribute frame messages. The second part includes different self-control scales that will help investigate the influence of situational invariant levels of self-control on the selected nudge type on healthy food choices. The following Figure 1 illustrates the conceptual framework of this research project with the relative hypotheses, which are presented in the following chapter 3.2.

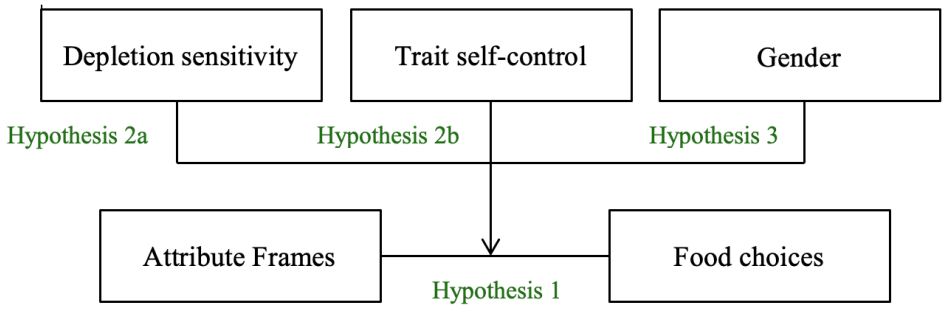

Figure 1: The identified conceptual framework

3.2. Hypothesis development

Based on the literature review, it is anticipated that attribute framing messages will affect the choice of the healthy option. Positive attribute-framing messages are expected to be more effective in promoting healthy foods. The accuracy of this argument can be supported by the meta-analysis study on attribute framing messages by Dolgopolova et al. (2021). As mentioned in 2.5.3, they concluded that when an object's attribute is framed positively, the framing messages' effectiveness in influencing people's attitudes and intentions is stronger. The following hypothesis focuses on this part of the study:

> *Hypothesis 1: Positive attribute framing messages increase healthy food choices more than negative attribute frames.*

Moreover, self-control levels are found to be a dispositional factor in the attribute framing nudges (Bermúdez, 2020). In this study, it thus is hypothesized that situation-invariant self-control levels, represented by depletion sensitivity and trait self-control, have a moderating role in the effect of the attribute-framing message:

> *Hypothesis 2a: The relationship between attribute framing and food choices is influenced by depletion sensitivity levels.*

> *Hypothesis 2b: The relationship between attribute framing and food choices is influenced by trait self-control levels.*

It is hypothesized that participants with low levels of self-control, represented by high levels of depletion sensitivity or/and low levels of trait self-control, will be more influenced by the attribute framing messages. Specifically, as a higher-level mental resource used by System 2, self-control relies on a finite supply of mental resources (de Haan & van Veldhuizen, 2015). During an ego depletion state people's cognitive resources are depleted, leading to mental-cognitive fatigue, and subsequently to lower intellectual performance (Schmeichel et al., 2003). At the same time, people tend to resort to decision-making processes linked with System 1 of reasoning, such as heuristics, which require fewer

cognitive resources (Baumeister & Vohs, 2016; Pohl et al., 2013). Therefore, depleted individuals are more likely to behave as predicted by the heuristics and are more vulnerable to external influences (Jinghui et al., 2017). The attribute framing messages are an example of such external influences in the current study. As previously mentioned, framing messages are choice biases coming from System 1 of reasoning (Li & Chapman, 2013). Daily diet choices are also based on biases and heuristics made in the same system (Y. Lin et al., 2017; van der Laan & Orcholska, 2022). Considering the above, depleted participants with low self-control levels, who switch from their System 2 to System 1 thinking, will be more vulnerable to the attribute framing messages promoting daily food choices.

Finally, a link between the effect of attribute frames and gender has been found in previous studies (Braun et al., 1997; Koenigstorfer & Baumgartner, 2016; Maheswaran & Meyers-Levy, 1990; Putrevu, 2013; Rothman et al., 1993). Specifically, a moderating role of gender on positive and negative attribute frames has been discovered in the study of Putrevu (2013). In this paper, it was found that positive attribute frames were more favorable than negative ones among females. Consequently, it is proposed in this study that positive attribute frames, and not negative ones, will be more effective in promoting healthy food choices among females:

Hypothesis 3: Positive framing messages increase healthy food choices more than negative ones among females, but not among males.

4. Research method

This chapter introduces the research design and methodology followed. An online experiment was developed to address the research questions considering the literature study and conceptual framework that was suggested above. The first part of the chapter delineates the research design, participants, and procedure, followed by the measurement part.

4.1. Ethics Approval

The Human Research and Ethics Committee (HREC) of the Technical University Delft officially reviewed and approved this study.

4.2. Participants

Participants were found via the author's personal and professional network, which included coworkers, friends, university classmates, and acquaintances. The material was utilized for educational objectives, and participation was completely voluntary. The initial sample consisted of 260 participants. However, due to missing values, 7 participants' data were excluded from the sample. The final sample size consisted of 253 complete responses (Female 130, Male 120, and Non-binary/third gender 1). The majority of the participants were from Greece (67,89%), and between 25-34 years old (59.68%) The descriptive statistics of the final sample are illustrated in Table 2, Table 3, and Table 4 below.

Table 2: Nationality of participants

Nationality	Frequency	Percent
Austria	1	0.40
Canada	2	0.79
China	1	0.40
Colombia	1	0.40
Cyprus	2	0.79
Germany	1	0.40
France	1	0.40
Greece	172	67.98
Guyana	1	0.40
India	15	5.93
Indonesia	2	0.79
Italy	6	2.37
Kosovar	1	0.40
Lithuania	1	0.40
Mexico	5	1.98
Netherlands	22	8.70
Peru	1	0.40

Poland	1	0.40
Portugal	1	0.40
Serbia	2	0.79
Spain	4	1.58
Sweden	2	0.79
Turkey	4	1.58
United Kingdom	2	0.79
USA	2	0.79
Total	253	100.00

Table 3: Age range of participants

Age Range	**Frequency**	**Percent**
18-24	64	25.30
25-34	151	59.68
35-44	11	4.35
45-54	11	4.35
55 or above	16	6.32
Total	253	100.000

Table 4: Gender of participants

Gender	**Frequency**	**Percent**
Female	130	51.38
Male	120	47.43
Non-binary/third gender	1	0.40
Prefer not to say	2	0.80
Total	253	100.000

4.3. Procedure

This research was operated as an online experiment aimed at investigating the causal relationship between the selected nudges, diet behaviors, and self-control. The experiment was designed in Qualtrics ™ and participants were provided with a Qualtrics™ facilitated URL link. The first part of the online experiment included an introductory statement that presented the purpose of the experiment. Also, the participant's rights and guidelines for taking the experiment were presented, as well as a confidentiality agreement for not collecting or disclosing any personal data. This was followed by the first part of the online experiment, in which participants were provided with a brief diet choice questionnaire to assess their food preferences. After that, questions regarding the type of diet followed, as well as significant food allergies that can affect dietary habits and food preferences (A. D. Smith et al., 2016). This part of the experiment also included questions regarding the participants' Body Mass Index. Following this, participants were given designed food choices that included nudging mechanisms. They were asked to make their food choices regarding some scenarios. Attribute framing message types (positive/negative) per scenario were randomly distributed to them. Participants then had to fill out the depletion sensitivity and trait self-control questionnaire. Finally, the closing part of the questionnaire included a demographic questionnaire. The procedural flowchart for the online experiment that participants completed is shown in Figure 2 below.

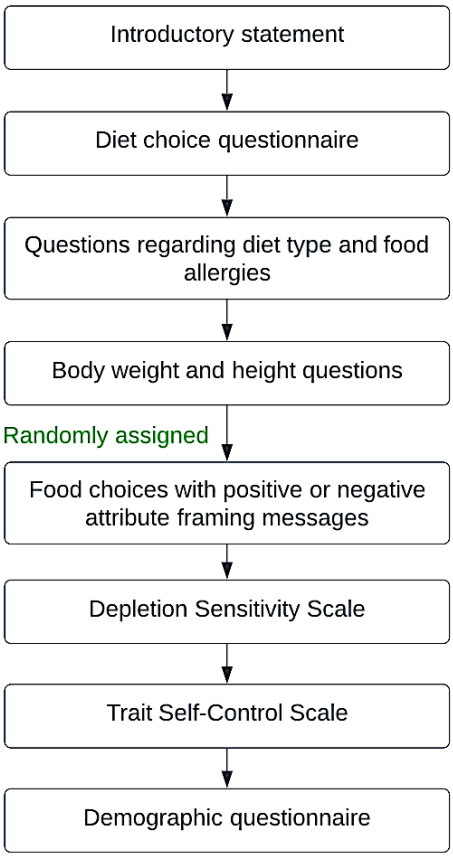

Figure 2: Procedural flowchart for the online experiment

4.4. Food nudging mechanism

Attribute framing has been highly utilized for health messages, especially for eating behaviors. Also, attribute-framing messages disclose food's nutritional benefits, including both good and detrimental traits (Dolgopolova et al., 2021). This approach was selected with the aim to provide sufficient information about the provided food choices to participants. On the other hand, risky choice attributes were not selected for this project due to the received critique regarding the chasm of interpreting the risk concept in health-promoting messages (O'Keefe & Jensen, 2007). Another important consideration was the fact that dietary choices are not linked to high-risk levels but rather to environmental or health-related objectives (Gallagher & Updegraff, 2012).

The provided food options were divided into hedonic and utilitarian choices. Hedonic food's function is mainly the gratification of the senses. On the contrary, utilitarian food's function is the fulfillment of functional purposes (Otterbring et al., 2023). Hedonic foods are mostly viewed as vices that are unhealthy. Although they provide short-term pleasure, they have harmful long-term impacts, due to their high consistency in unhealthy fats, refined carbs, or sugar (Wertenbroch, 1998). Examples are candies, cakes, cookies, fast food, and energy drinks. On the contrary, utilitarian foods are healthier types that are rich in essential body nutrients, such as vitamins, antioxidants, healthy fats, protein, and

whole carbohydrates. Some utilitarian food can be considered unhealthy, such as particular weight loss diets. Also, hedonic foods, such as smoothies, and low-fat yogurt, can indeed be healthy. So, the classification of hedonic versus utilitarian foods is not straightforward (Antonides & Cramer, 2013). However, for simplicity reasons, hedonic foods were regarded as unhealthy, whereas utilitarian as healthy.

Ideas for healthy and unhealthy food examples were derived from the adult version of the Food Preference Questionnaire (Adult-FPQ) (A. D. Smith et al., 2016). The Food Preference Questionnaire (Adult-FPQ) consists of 62 food items, which are subdivided into 6 food groups: fruits, vegetables, proteins, dairy, snacks, and starch. The utilitarian/healthy food items in this study were derived from the fruits, vegetables, proteins, and dairy food categories and were the following: strawberries, oily fish (e.g. mackerel fish), plain low-fat yogurt, eggs, porridge, cottage cheese, and grapes. The hedonic/unhealthy food items were selected from the proteins, snacks, and starch food categories and were the following: chocolate biscuits, bacon, chocolate, beef burgers, cake, sausages, and chewy gummy sweets. The above-mentioned categorization of healthy versus unhealthy food products was based on the consultation of various reliable sources in the food and healthy online literature.

In the experiment, both the positive and negative attribute frames were utilized for healthy food choices, which is the reference point of this study. The goal of this design is to investigate what is the impact of the positive and negative attribute frames on the promotion of the healthy food option.

Participants were provided with the same seven different scenarios designed for food choices with the positive and negative attribute frames. In all scenarios, the situation of feeling hungry during or after completing a rigorous task was illustrated. This was done in order to enable participants to envisage themselves in the situation in which they would have to make a food choice. Consequently, the food questions would be more relevant to them. Also, for each scenario, two versions were formulated including the positive attribute frame and the negative one, in respect. The positive and negative attribute framing messages were designed only for the case of utilitarian/healthy food items. The attribute characteristics of the healthy food items were retrieved from the food and healthy online literature (Ferris et al., 2012; Giampieri et al., 2012; Hadjimbei et al., 2022; Liu et al., 2023; M. Mengelers et al., 2017; nhs.uk, 2023; Paudel et al., 2021; Pozzobon & Pozzobon, 2023; Ruxton et al., 2010; Sri Kantha, 1987; Weerathilake et al., 2014; Xia et al., 2010). Participants were randomly assigned to the two versions of each scenario.

Figure 3 illustrates one of the seven different scenarios, which includes both the positive and negative attribute frames. The total number of the different scenarios, including the food items and attribute frames the participants were provided with, is listed in Appendix A.

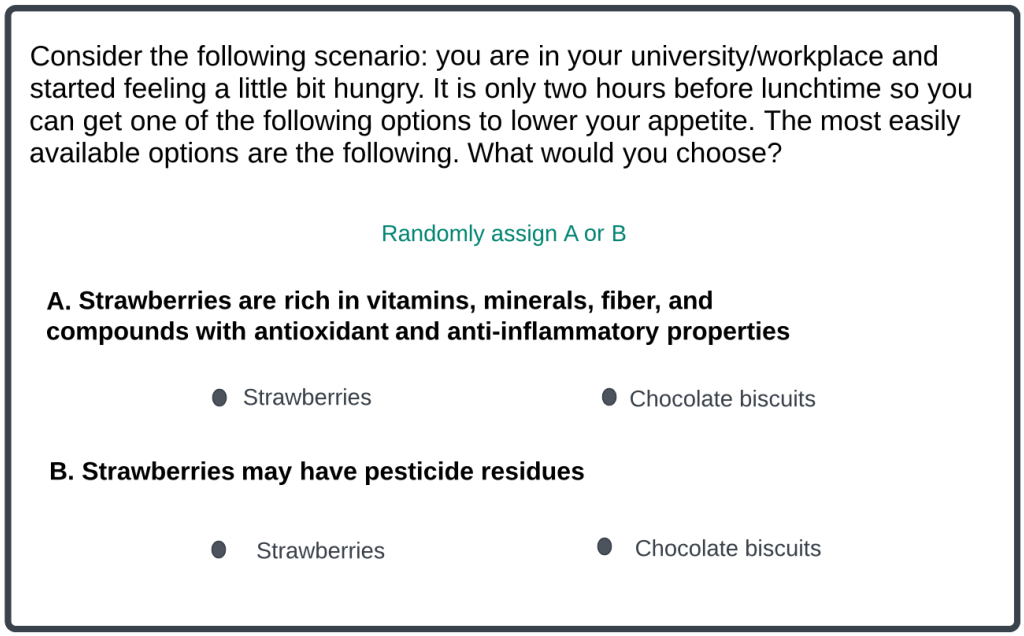

Figure 3: Example item for food choices with attribute framing messages

4.5. Measures

The following section demonstrates the measurement scales utilized for the assessment of the variables of the conceptual framework, as presented in Figure 1.

4.5.1. Independent variable

The designed food choices, which included the attribute framing messages, were used to evaluate the impact of positive versus negative attribute framing nudge for healthy food choices. Participants were provided with the same seven different scenarios, but were randomly assigned to the two versions of each scenario. This means that all participants had to select between the same food options under each scenario, although the scenario version including the positive or negative attribute frame was randomly provided to them. The order in which the scenarios were provided was the same for all participants.

4.5.2. Moderating variables

The Depletion Sensitivity Scale (DSS) (Salmon, Adriaanse, et al., 2014) and Trait Self-Control Scale (Tangney et al., 2004), were used to assess the influence of depletion sensitivity and trait self-control on the attribute framing messages for promoting healthy food choices. Following the work of (Salmon, Adriaanse, et al., 2014), depletion sensitivity was measured through the DSS, which consists of 11 items. Those items were rated on a 7-point Likert scale ranging from 1 (totally disagree) to 7 (totally agree). According to the developers of the scale, all items loaded ≥ 0.40 on one forced factor.

Also, the analysis showed a good reliability of the 11-item scale, with a Cronbach's alpha of 0.837. One example of such an item is, "*When I'm tired, I have difficulties concentrating".* It is assumed that high scores on these items will reflect significant depletion sensitivity. The Brief Self-Control Scale (BSCS), a 13-item adaptation of the Trait Self-Control Scale, was utilized for trait self-control. This scale was introduced by Tangney et al. (2004) and is widely used for measuring trait self-control levels (Kip et al., 2021). A 7-point Likert scale that determines individual variations in self-control was presented, with one item example being the following: *"I have a hard time breaking bad habits".* According to the scale's developers, all 13 items loaded ≥ 0.40 on one factor. The analysis also revealed that the 13-item scale had strong reliability, with a Cronbach's alpha of 0.807. The items from both scales are presented in Appendix B.

4.5.3. Food Restrictions and Body Mass Index

Three extra sections of questions regarding the type of diet followed and significant food allergies were included to evaluate the influence dietary habits and food preferences may have on food choices (A. D. Smith et al., 2016). Questions regarding the participants' weight and height, from which the Body Mass Index is calculated, were also provided to determine the link between gender and body weight (Vijayalakshmi et al., 2017; J. Zhang et al., 2019).

4.5.4. Dependent variable

Healthy (utilitarian), and unhealthy (hedonic) food choices were provided to examine the participant's food behavior under different everyday scenarios. The designed food choices were extracted from the adult version of the Food Preference Questionnaire (Adult-FPQ; Smith et al., 2016). Also, questions regarding the provided food choices were presented in the first section of the experiment for participants to state their liking for each presented food item. The potential answers were: (1) dislike a lot, (2) dislike a little, (3) neither like nor dislike, (4) like a little, (5) like a lot, (6) not applicable.

5. Results

The following chapter presents the results obtained from the online experiment. First, the food preferences are illustrated followed by the diet type, allergies, and the BMI of the participants. Next, the results for the effect of attribute frames on healthy food choices and the moderating role of self-control are reported, followed by the relevant hypothesis testing.

5.1. Food preferences

The following Table 5 illustrates the mean preferences scores of the 14 food items that were utilized in the designed food choices that included nudging mechanisms. Strawberries, oily fish (e.g., mackerel, kippers), eggs (boiled, scrambled, or fried), porridge, cottage cheese, plain, low-fat yogurt and grapes correspond to the utilitarian food items, whereas beef burgers, bacon, sausages, chocolate biscuits, cake, chocolate, and chewy gummy sweets (e.g., Haribo-style sweets, wine gums) to the hedonic ones. Both the mean and standard deviation were calculated for all food items. For the utilitarian food category, strawberries were the most favored food item, with a mean score of 4.61, whereas oily fish (e.g., mackerel, kippers) was the least favored with a mean score of 3.45. For the hedonic food category, chocolate was the most favorite food item, with a mean score of 4.63, whereas chewy gummy sweets (e.g., Haribo-style sweets, wine gums) were the least favorite with a mean score of 3.07.

Table 5: Food preferences

	Food items	**Mean**	**Std. Deviation**
Utilitarian	Strawberries	4.61	0.752
	Grapes	4.49	0.775
	Eggs (boiled, scrambled, or fried)	4.44	0.891
	Plain, low-fat yogurt	4.04	1.046
	Porridge	3.66	1.273
	Cottage cheese	3.62	1.246
	Oily fish (e.g., mackerel, kippers)	3.45	1.234
Hedonic	Chocolate	4.63	0.722
	Beef burgers	4.41	0.968
	Chocolate biscuits	4.33	0.910
	Cake	4.31	0.918
	Sausages	3.72	1.150
	Bacon	3.60	1.340
	Chewy gummy sweets (e.g., Haribo-style sweets, wine gums)	3.07	1.371

5.2. Diet type, allergies, and BMI

The diet followed and some food products participants are allergic to are presented in Table 6 and Table 7, respectively. Most participants (94.86%) did not follow a particular diet and were not allergic to any food product (90.12%), as illustrated in Table 6 and Table 7. Table 8 presents the BMI calculated for the participants. For adults, BMI values below 18.5 correspond to underweight weight status, values between 18.5-24.9 to healthy weight status, 25.0-29.0 to overweight status, and 30.0 or above to obesity (Bhaskaran et al., 2022). Most participants (65.22%) had a healthy weight, followed by those with overweight status (23.32%). Table 9 shows that the majority of females (63.8%) and males (49.2%) had a healthy weight status. However, the percentage of males who were overweight was higher (43.3%) than that of females (14.6%). Nonetheless, BMI can be a misleading indicator of overweight status and obesity. Specifically, the measure considers excess weight, which consists of both fat and muscle mass. So, athletic individuals, with a higher proportion of muscle rather than fat, can have a higher BMI and wrongly be classified as overweight or obese. The accuracy of BMI in assessing body fat percentage in college athletes and physically active young adults has also been criticized in previous research (Humphreys, 2010; Mazic et al., 2009; Ode et al., 2007). Moreover, men tend to have biologically more muscle tissue, and hence weight, than females (Janssen et al., 2000; Miller et al., 1993). This can explain the lower percentage of men having a healthy weight status, as reported above.

Table 6: Diet Type

Diet Type	Frequency	Percent
Vegan	-	-
Vegetarian	9	3.56
Pescetarian	4	1.58
None of the above	240	94.86

Table 7: Allergies

Allergies	Frequency	Percent
Dairy	8	3.16
Wheat/gluten	6	2.37
Peanuts	5	1.98
Shellfish	5	1.98
Tree nuts	3	1.86
Fish	2	0.79
Soya	2	0.79
Mustard	1	0.40
Sesame	-	-
Eggs	1	0.40
Celery	-	-
Others	5	1.98
No allergy	228	90.12

Table 8: Body Mass Index

BMI (kg/m^2)	Frequency	Percent (%)
Below 18.5	18	7.11
18.5-24.9	165	65.22
25.0-29.9	59	23.32
30.0 or above	11	4.35

Table 9: Body Mass Index per gender

Gender	BMI (kg/m^2)			
	Below 18.5	18.5-24.9	25.0-29.9	30.0 or above
Female (n=130)	24 (18.5%)	83 (63.8%)	19 (14.6%)	4 (3.1%)
Male (n=120)	1 (0.8%)	59 (49.2%)	52 (43.3%)	8 (6.7%)
Non-binary/third gender (n=1)	-	1 (100%)	-	-
Prefer not to say (n=2)	-	1 (50%)	-	1 (50%)

5.3. Attribute frames

A Two-way Repeated Measures ANOVA was performed to understand the relationship between attribute framing messages (positive, negative), food choices (healthy, unhealthy), as predicted in Hypothesis 1. Participants more often selected a healthy (M=2.158, SD=1.361) than an unhealthy (M=1.326, SD=1.134) food option, $F(0, 252)=65.961, p<0.001$ (Appendix C, Appendix D). The main effect for the attribute frame was not significant, $F(0, 252)=0.043$, *ns* (Appendix C), but it was part of a significant interaction effect with food choice. Specifically, in the positive attribute framing condition people more often selected a healthy (M=2.308, SD=1.400) than an unhealthy (M=1.194, SD=1.097) food choice, and in the negative attribute framing condition, they more often selected a healthy (M=2.008, SD=1.321) than an unhealthy (M=1.458, SD=1.170) food choice, $F(0, 252)=11.651, p<0.001$ (Appendix C, Appendix D). Further analysis of the simple main effect within food choices showed that both positive and negative attribute framing conditions influenced the food choice, with positive attributes having a higher influence $F(0, 253)=71.125, p<0.001$, than the negative ones, $F(0, 253)=17.517, p<0.001$ (Appendix F). Those results do not necessarily reject Hypothesis 1, that positive attribute framing messages increase healthy food choices more than negative attribute frames but provide more complicated conclusions regarding the effect of attribute frames on food choices. Figure 4, and Figure 5 illustrate the effects mentioned above.

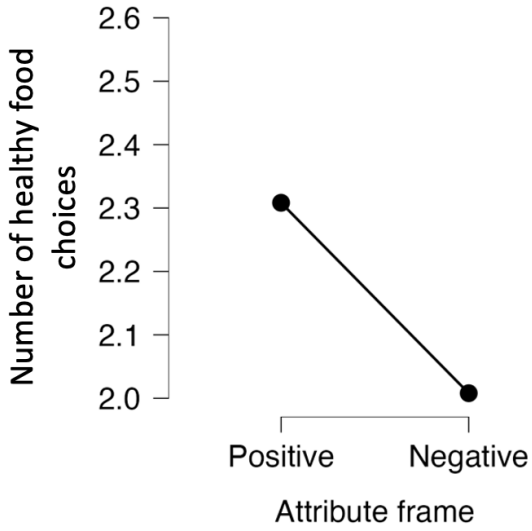

Figure 4: Descriptive plot for attribute frames and healthy food choices

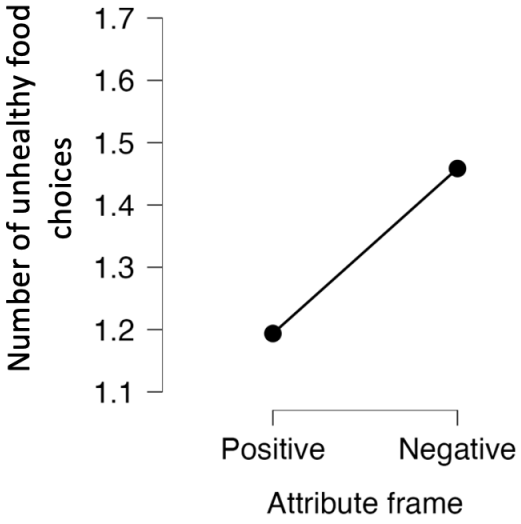

Figure 5: Descriptive plot for attribute frames and unhealthy food choices

5.4. Moderation effect of Depletion Sensitivity

A Two-way Repeated Measures ANOVA was performed to discover to what extent depletion sensitivity moderated the relationship between attribute frames (positive, negative) and food choices (healthy, unhealthy), as predicted in Hypothesis 2a. To conduct the analysis, the median splits of the scores obtained from the Depletion Sensitivity Scale were calculated, where 0=low depletion sensitivity and 1=high depletion sensitivity levels. Depletion sensitivity was added to the analysis as a between subject factor (or: moderator), and analyzed for both attribute frames and food choices.

The analysis revealed a significant moderation effect of depletion sensitivity on the relationship between attribute frames and food choices $F(1, 251)=13.404, p<0.001$ (Appendix C). Post-hoc pairwise

comparisons with Bonferroni correction showed that under positive framing conditions, participants with low levels of depletion sensitivity more often selected a healthy food option (M=2.588, SD=1.458), than participants with high levels of depletion sensitivity (M=2.060, SD=1.302), *p=0.022* (Appendix E). Participants with low levels of depletion sensitivity made more healthy food choices (M=2.588, SD=1.458) under positive framing conditions than under negative ones (M=1.874, SD=1.286), *p<0.001*. However, none of the other effects was significant (Appendix E). Figure 6, and Figure 7 illustrate the effects mentioned above.

These findings confirm Hypothesis 2a regarding the moderation effect of depletion sensitivity on the relationship between attribute frames and food choices.

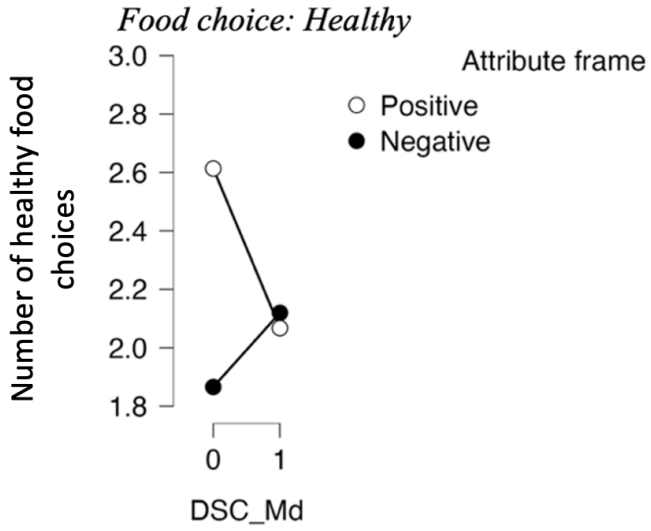

Figure 6: Descriptive plot for depletion sensitivity, attribute frames, and healthy food choices

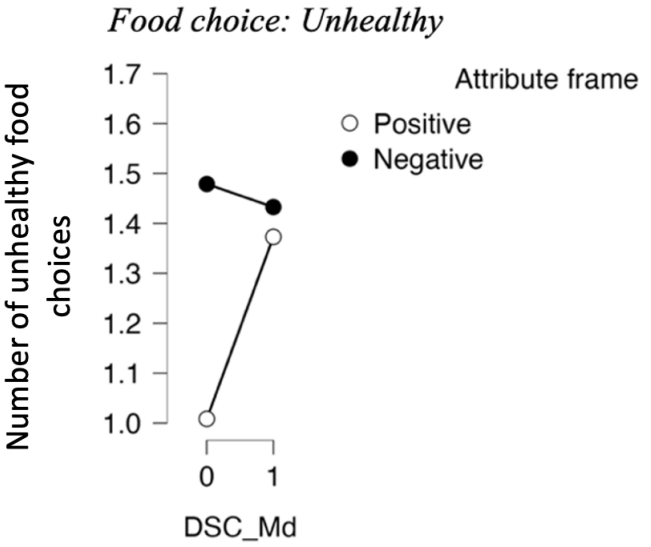

Figure 7: Descriptive plot for depletion sensitivity, attribute frames, and unhealthy food choices

5.5. Moderation effect of Trait Self-Control

Likewise, a Two-way Repeated Measures ANOVA was performed to discover to what extent trait self-control moderated the relationship between attribute frames (positive, negative) and food choices (healthy, unhealthy), as predicted in Hypothesis 2b. To conduct the analysis, the median splits of the scores obtained from the Trait Self-Control Scale were calculated, where 0=high trait self-control and 1=low trait self-control levels. Trait self-control was added to the analysis as between subject factor (or: moderator).

The two-way Repeated Measures ANOVA revealed no significant moderation effect of trait self-control levels on the relationship between attribute framing messages and food choice, *F(1, 251)=0.097, ns* (Appendix C). These findings reject Hypothesis 2b that the relationship between attribute frames and food choices is moderated by trait self-control levels.

5.6. The role of gender differences

A Two-way Repeated Measures ANOVA was performed to discover to what extent gender differences moderated the relationship between attribute frames (positive, negative) and food choices (healthy, unhealthy). To conduct the analysis, only the female and male scores were included, where 1=females and 2=males. Gender was added to the analysis as between subject factors, and analyzed for both attribute frames and food choices. This analysis could be executed because of the sample's almost equal number of males and females.

The analysis showed a significant effect between gender and food choices, *F(1, 248)=6.679, p=0.010* (Appendix C). Females made more healthy choices (M=2.290, SD=1.360) than males (M=2.020, SD=1.320), *F(1, 248)=6.679, p=0.010* (Appendix C, Appendix D). The moderation effect of gender on the relationship between attribute frames and food choices was also significant at the 10% level, *F(1, 248)=2.824, p=0.094* (Appendix C). Simple main effects analysis showed that there were significant effects between gender and attribute frames on food choices. However, this effect was not significant for males under negative attribute conditions (Appendix F). Post-hoc pairwise comparisons with Bonferroni correction showed that under positive framing conditions, females more often selected a healthy food option (M=2.385, SD=1.389), than an unhealthy one (M=1.138, SD=1.119)*, p<0.001* (Appendix E). Similarly, under positive framing conditions, males more often selected a healthy food option (M=2.267, SD=1.383), than an unhealthy one (M=1.275, SD=1.069), *p<0.001* (Appendix E). These findings do not reject Hypothesis 3 that positive attribute framing messages increase healthy food choices more than negative ones among females, but suggest that males are also influenced by positive frames for health food choices. The last-mentioned effects were not significant under negative attribute frames. Also, none of the other effects was significant (Appendix E).

5.7. The role of cross-cultural differences

Considering the high number of participants originated from Mediterranean countries (75.1%) an additional analysis was conducted to examine the effect of cultural differences on food preferences. The Mediterranean countries participants came from were the following: Greece, Turkey, Cyprus, Portugal, Italy, France, and Spain (Schröder C. et al., 2019).

A Two-way Repeated Measures ANOVA was performed to discover to what extent nationality differences moderated the relationship between attribute frames (positive, negative) and food choices (healthy, unhealthy). To conduct the analysis, 1=participants from a Mediterranean country, and 2= participants from a non-Mediterranean country. Nationality was added to the analysis as between subject factors, and analyzed for both attribute frames and food choices.

The analysis showed no significant effect between nationality and food choices, *F(1, 251)=0.095, p=ns* (Appendix C). The moderation effect of nationality on the relationship between attribute frames and food choices was also not significant, *F(1, 251)=0.040, p=ns* (Appendix C). This shows that the results of the present study were not influenced by cultural differences in the participants' national backgrounds.

6. Discussion

The main goal of this research was to explore to what extent attribute frames (positive and negative) steer human food choices toward healthy options. Another objective was to investigate if situation-invariant levels of self-control (depletion sensitivity and trait self-control) moderate the relationship between the above-mentioned two factors. The research's scientific relevance, limitations, and future research suggestions are presented in the following paragraphs.

6.1. Scientific relevance

In this study, 4 hypotheses were formulated. Specifically, it was assumed that positive attribute frames increase healthy food choices more than negative attribute frames (Hypothesis 1). Also, the relationship between attribute frames and food choices was hypothesized to be moderated by individuals' depletion sensitivity levels (Hypothesis 2a), trait self-control levels (Hypothesis 2b), as well as gender (Hypothesis 3). The findings of the analysis are discussed in the paragraphs that follow, along with the scientific relevance of the hypotheses.

6.1.1. Attribute framing messages

Digital nudges are promising tools to enhance healthy food choices in the field of food recommender systems. This study focused on one popular nudging category, attribute frames, to investigate the conflicting research arguments of positive and negative attribute frames on promoting healthy food choices. The results derived from the analysis showed that both positive and negative attribute frames were effective in promoting healthy food choices, although the positive frames had a stronger effect. Consequently, no significant difference was found between the two types of framing, aligning with previous research findings (Lagerkvist et al., 2023; Van Assema et al., 2001). These results reject prior findings that positive attribute framing messages are more effective than negative ones (Bannon & Schwartz, 2006; Binder et al., 2020; Collins et al., 2019; Dolgopolova et al., 2021; Gallagher & Updegraff, 2012; Van Assema et al., 2001; Zahid & Reicks, 2018). The argument that negative attribute frames are more effective is also rejected (Eguren et al., 2021; Rosenblatt et al., 2018; Vidal et al., 2019). Nonetheless, the results of this study contributed to the growing body of evidence supporting that attribute frames are linked with self-control characteristics, as described in the following chapter 6.1.2. Those findings confirm the literature's argument that dispositional factors, such as self-control, should be included as moderators between attribute frames and food behavior in the analysis of the effect of attribute frames on food behavior (Covey, 2014; Dolgopolova et al., 2021).

6.1.2. Depletion sensitivity and trait self-control

Previous studies have argued that the effect of attribute frames is moderated by dispositional factors that influence the way people perceive and respond to messages (Covey, 2014). Examples are personal characteristics (individual moderators), such as self-control levels (Bermúdez, 2020). In this study, those levels were represented by depletion sensitivity and trait self-control. Specifically, it was hypothesized that participants with low levels of self-control, represented by high levels of depletion sensitivity or/and low levels of trait self-control, will be more influenced by the attribute frames. The results confirmed that depletion sensitivity moderated the relationship between attribute frames and food choices. Under positive framing conditions, participants with low levels of depletion sensitivity more often selected a healthy food option, than participants with high levels of depletion sensitivity. So, the findings of this study support those reported in the work of Mariotti et al. (2022), that different levels of self-control lead to different interpretations of information nudges. However, the results refute the argument that depleted individuals will be more susceptible to external influences (i.e., the attribute frames). This goes against the earlier work of Salmon et al. (2015).

Trait self-control did not moderate the relationship between attribute frames and food choices. This finding rejects the argument made by Thunström (2019) that individuals with low levels of trait self-control are less receptive to nudging in contrast to those with higher levels.

6.1.3. Gender differences

Previous research also investigated the role of gender differences on the effect of attribute frames (Braun et al., 1997; Koenigstorfer & Baumgartner, 2016; Maheswaran & Meyers-Levy, 1990; Putrevu, 2013; Rothman et al., 1993). In the work of Braun et al. (1997), attribute frames were more salient to females, while Putrevu (2013) found a moderating role of gender on positive and negative attribute frames. A significant effect of gender on attribute frames was also reported in the work of Koenigstorfer et al. (2016). The present study confirms the findings of Putrevu (2013) by revealing a notable gender-related moderating effect on the association between attribute frames and food choices. Specifically, under positive attribute framing conditions, females made more healthy food choices than under negative ones. This effect was also significant for males. The latter rejects the argument of Putrevu (2013) that males show a lesser negative response to negative frames compared to females. In general, the present study indicates that females made overall more healthy food choices than males.

These findings could be attributed to variations in the decision-making tasks or situations in which attribute frames were examined, as gender differences may manifest diversely in such contexts (Huang & Wang, 2010). Considering those findings, gender should be included in the analysis

of the effect of attribute frames and food preferences. This could facilitate a greater understanding of the impact of attribute frames on people's food behavior based on their gender identities.

6.1.4. Cultural differences

The eating patterns of people who residence in the areas around the Mediterranean Sea are referred to as the Mediterranean diet. Those eating behaviors include a high intake of plant-based foods and a moderate to low intake of fish, meat, dairy, and added sweets (Willett et al., 1995). Historically, the Mediterranean diet has been linked with the establishment of good health conditions, well-being, and prevention of chronic diseases (e.g. cardiovascular) (García-Fernández et al., 2014; Willett et al., 1995). This is achieved not only through the inclusion of healthy food items in this diet, but also the balanced amalgamation of all the important food products that are associated with the promotion of a better health (Dinu et al., 2017; Vivancos & Moreno, 2008). However, the results of this study showed no significant effect between food choices and nationality. In other words, there were no significant differences in food choices between participants from the Mediterranean countries, and from non-Mediterranean ones. This finding aligns with the argument that people with a Mediterranean diet cultural background are altering their eating habits as a result of socio-economic changes, the urbanization of society, and the Westernization of eating habits, including the spread of poor quality, processed food products (Bertuccioli & Ninfali, 2014; Burlingame et al., 2022). The high consumption of saturated fats, salt, added sugars, animal proteins, and alcoholic drinks, as well as the substitution of plant-based proteins, healthy fats, whole-grain cereals, and dietary fibers, are among the diet alterations mentioned above. That diet changes in the Mediterranean populations can also be linked with the observed rise of obesity levels and other chronic diseases that hamper their overall well-being (Bertuccioli & Ninfali, 2014; Russo et al., 2021).

Considering the above, the promotion of healthy food items through recommender systems, can be detrimental to the preservation not only of the Mediterranean diet but also the cultural identity of the people with that background. The Mediterranean diet is regarded by UNESCO as an intangible cultural heritage, and in addition to cultural values and social customs, it also represents a way of life and a common identity that transcends beyond its nourishment role (Burlingame et al., 2022; Trichopoulou, 2021).

6.2. Limitations

Online experiments are becoming increasingly popular among behavioral researchers, due to their advantages of procedure automation, reduced costs, and time spent to arrange the experiment, in contrast to traditional lab settings (Bohannon, 2016; Grootswagers, 2020; Palan & Schitter, 2018; Sauter et al., 2020). Also, their online accessibility expands the participant pool to Web users and enables the

targeting of particular audiences (Dandurand et al., 2008). However, some limitations may have had an impact on this research.

First, limitations that should be considered are the sampling biases, due to the dropout rates, and the self-selection issue, in which the experiments are started and finished only by interested participants (Dandurand et al., 2008). In this study, 2.7% of the sample did not fully complete the survey. As a result, those responses were excluded from the final sample due to their missing values.

Another sampling bias is the convenience sampling approach followed. Specifically, participants were recruited through the author's personal network. As a result, the sample could not have been representative of the entire population. Alternatively, the sample may have been biased toward those who were easier to reach and more willing to take part in the study. Those sampling biases might have affected the research outcomes (Sekaran & Bougie, 2016). Another significant disadvantage is the lack of experimental control. For example, it is difficult to examine whether participants were concentrated during the experiments and not distracted by exogenous sources (Grootswagers, 2020). Hence, future research could include a control group in the analysis, with no positive or negative attribute framing messages to mitigate the last-mentioned limitation.

Also, in self-administered questionnaires, there is the risk of "response biases" that can compromise the validity and reliability of the obtained data (McDonald, 2008). Two examples are Socially Desirable Responding, and Acquiescent Responding (Kreitchmann et al., 2019; Paulhus, 1991). Regarding Socially Desirable Responding (Paulhus, 1991) participants frequently might respond in a way that makes them seem better. They also provide answers they perceive as socially acceptable, even though these responses do not accurately represent the way they actually think or act (McDonald, 2008). For example, regarding the food item selection, participants could have selected the healthy options because of the socially accepted contexts of adopting a healthy lifestyle. Acquiescent Responding (Messick, 1966) shows the tendency of individuals to prefer the positive side of the rating scale without considering the items' content and meaning. In this study, an interaction with some participants through personal communication networks followed after the experiment. Via the discussion, it was demonstrated that the Depletion Sensitivity Scale and the Brief Self-Control Scale generated a self-reflection that made them evaluate their behavior and personal characteristics while conducting the experiment. Therefore, the Acquiescent Responding limitation was not the case in this study.

6.3. Future research

This study is one of the initial initiatives to comprehend the relationship between attribute frames, depletion sensitivity, trait self-control levels, and healthy food choices. The explanation made regarding the impact of the nudges (attribute frames) was based on the two distinct cognitive processes, System

1 and 2 of reasoning (Kahneman, 2011; Stanovich & West, 2000). Specifically, the focus of nudges on the System 1 of reasoning is a popular assumption regarding their effectiveness (Battaglio et al., 2019; Marchiori et al., 2017; Marteau et al., 2012). As already mentioned in 2.4.3, nudge theorists (Sunstein, 2015, 2016; Thaler & Sunstein, 2008) argue that heuristics and cognitive biases, made in System 1, are often activated during inferior lifestyle decisions. During states of ego depletion, cognitive resources become depleted. As a result, people switch from their System 2 of reasoning to 1 (Schmeichel et al., 2003), because in the latter decision-making processes require fewer cognitive resources (Y. Lin et al., 2017). This also makes individuals more vulnerable to external influences (Jinghui et al., 2017).

In this work, those external influences were the positive and negative attribute frames. So, the reconstruction of the elements in decision contexts on which the heuristics and biases of System 1 are invoked, seems a realistic strategy to produce beneficial behavioral transformations (Y. Lin et al., 2017). However, this research rejected the argument that nudges (positive attribute frames) are more effective towards depleted individuals who are under their System 1 of reasoning. This finding also confirms previous research works (D. de Ridder et al., 2022; Koenigstorfer et al., 2014). Instead, this study showed that it was the personality traits, represented by individuals' depletion sensitivity levels, that influenced the decision-making processes of food selection, and not the cognitive processes (Murch & Krawczyk, 2014). This result aligns with previous findings regarding the effect of trait personality in the attribute framing of Recommender Systems (Al-Samarraie et al., 2017; Rook et al., 2020). Further research could delve into studying the relationship between cognitive mechanisms and personality traits to better understand decision-making processes and choice behavior in the context of nudging interventions (Tagliabue et al., 2019). Trait personality research can also provide valuable insights to enhance the development of personality-aware recommendation systems, which are a growing type of recommender system in the field of personality computing. Specifically, these systems can enhance the recommendations they provide by customizing them to match the personality traits of users (Dhelim et al., 2021).

To provide more insights into the "muscle" metaphor of self-control and the cognitive processes linked with nudges, future research could investigate the moderating influence of depletion sensitivity and trait self-control on real ego-depletion conditions. This could be done by executing on-site laboratory experiments using the *dual-task paradigm* (Baumeister et al., 1998; Finkel et al., 2006; Muraven et al., 1999). In that case, participants are provided with an ego-depletion manipulation task, followed by a self-control task, such as a food-choice one (Salmon, Fennis, et al., 2014). Studies have shown that ego depletion notably influences self-control tasks (Baumeister et al., 1998; Hagger et al., 2010). Also, the impact of ego depletion on a later self-control test has been found to be moderated by depletion sensitivity (Salmon, Adriaanse, et al., 2014). Variations in the literature findings regarding the *dual-task paradigm* also make this approach interesting for future research (Hagger et al., 2010).

Considering laboratory experiments, another future research suggestion to gain a more comprehensive understanding of an individual's self-control resources is the measurement of the ego-depletion state by physiological indicators. Regarding 2.3.2, heart rate variability (HRV), skin conductance, or electrodermal activity (EDA) are possible candidates for the physiological metrics of self-control. Previous research on HRV has revealed a connection between the human brain's prefrontal cortex areas in charge of self-regulation and the neurological system that affects HRV (Zahn et al., 2016). Also, by measuring the EDA, or skin conductance, changes in sweat levels during different levels of physiological arousal could be captured. This physiological arousal could be attributed to the exertion of self-control after a specific task (Markowitz et al., 2019).

Moreover, self-control levels vary from person to person and throughout time and conditions (Guan & He, 2018). Situation variations should also be considered, since they can have a superior influence on self-control and resisting temptations. State self-control considers extraneous and situational aspects, such as previous self-control efforts, and thus can explain self-control variations under those circumstances (Baumeister & Heatherton, 1996; Hofmann et al., 2012). It has been found that a depletion task that unevenly lowers self-regulatory resources, as mentioned above, can cause variances in state self-control. This in turn influences intertemporal decisions, such as withstanding impulses of immediate rewards (Guan & He, 2018). Another future research, therefore, would be to investigate situation-variant levels of self-control represented by state self-control, for example through the State Self-Control Scale (Lindner et al., 2019). Such research could show if situation variations of self-control through time and different conditions, and not trait self-control measures, also moderate the effect of attribute frames.

7. Conclusion

Food recommender systems are helpful tools to promote healthy food choices (Trang Tran et al., 2018), and can be regarded as a nudge that increases the salience of healthy alternatives (Kamsteeg et al., 2011). Numerous studies have demonstrated the effectiveness of recommender systems and digital nudging in influencing users' food choices in the direction of healthier ones (Abhari et al., 2019; Marcano-Olivier et al., 2020; Musto et al., 2020; Trang Tran et al., 2018). However, research on digital nudges in online diet behavior is still lacking (Berger et al., 2020; Jesse, Jannach, & Gula, 2021). Attribute frames, including positive and negative ones, are a popular information nudge category on food behaviors, but previous studies had reported conflicting results regarding their effectiveness. Much research attention has been shifted toward studying how dispositional factors influence how people perceive and react to nudges (Covey, 2014). Specifically, different trait factors have been found to moderate the effects of attribute frames in addition to the context in which a positive or negative message is applied. This research focused on one of those factors namely self-control levels. Depletion sensitivity and trait self-control tested the effect of those trait measures on attribute frames. Those two factors are considered situation-invariant individual characteristics and can effectively represent self-control levels (Baumeister & Vohs, 2004).

Hence, this research could eventually shed light on the knowledge gap of attribute frames and help behavioral economists formulate effective nudges that will promote healthy food behaviors.

Considering all the above, the main objective of this thesis was: *To what extent can attribute framing messages steer human food choices toward healthy ones, and in what way do self-control levels influence that relationship?* To answer this objective, an online experiment was designed. Seven food choices, including the attribute framing messages, were designed to evaluate the impact of positive versus negative attribute framing nudge for healthy food choices. Depletion Sensitivity Scale (DSS) (Salmon, Adriaanse, et al., 2014) and Brief Self-Control Scale (BSCC) (Tangney et al., 2004), were used to assess the individual's depletion sensitivity and trait self-control levels. Questions regarding food preferences, restrictions, Body Mass Index, and demographics were also incorporated. To test the generated hypotheses, statistical analysis was conducted.

The findings of this study contributed to the existing body of knowledge about the effectiveness of positive attribute framing messages for promoting healthy food choices. However, negative attribute framing messages also promoted healthy food choices, but less effectively than positive ones. This finding does not reject Hypothesis 1 but provides more nuanced insights. Specifically, negative attribute framing messages can still have some effectiveness in promoting healthy food choices, albeit to a lesser extent compared to positive ones. Moreover, depletion sensitivity confirmed the moderating role of self-

control on the relationship between positive attribute framing messages and healthy food choices, verifying Hypothesis 2a. However, it was the participants with low levels of depletion sensitivity who were more receptive to the nudges, and not the ones with high levels. No significant results were found regarding the moderating role of trait self-control, rejecting Hypothesis 2b. Further analysis also revealed a significant gender-related moderating effect on the relationship between attribute frames and food choice. Female participants more often made healthy food choices under the positive framing conditions than under negative ones. The same effect was observed for males. The findings of this study do not necessarily reject Hypothesis 3, but rather suggest that the effect of positive attribute frames on healthy food choices is also significant among males. Also, females made overall more healthy food choices than males. Finally, there were no significant differences in the food choices between the participants from Mediterranean and non-Mediterranean countries. This demonstrates that the cultural backgrounds of the participants did not have an impact on the study's findings.

The hypotheses developed for the experiment are shown in the following Table 10, along with their respective outcomes.

Table 10: Research findings

Number	Hypothesis	Result
1	*Positive attribute framing messages increase healthy food choices more than negative attribute frames*	Confirmed
2a	*The relationship between attribute framing and food choices is influenced by depletion sensitivity levels*	Confirmed
2b	*The relationship between attribute framing and food choices is influenced by trait self-control levels*	Rejected
3	*Positive framing messages increase healthy food choices more than negative ones among females, and not among males*	Confirmed

In conclusion, although positive frames are more persuasive overall, behavioral economists should consider both framing types while designing persuasive nudges to promote healthy food choices in food recommender systems. Moreover, the relationship between attribute frames and food choices is influenced by depletion sensitivity. Nonetheless, the effectiveness of attribute frames in promoting healthy food choices was successful only for individuals with low levels of depletion sensitivity. The goal of this study is to inspire researchers to further examine the relationship between self-control and attribute frames. By doing this, deeper insights into food behaviors under ego-depleted states can be provided that will help better understand those behavioral dynamics. As a result, researchers can develop successful nudging interventions and improve the design of food recommender systems to support people in making healthier food choices.

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Appendix A

Online Experiment

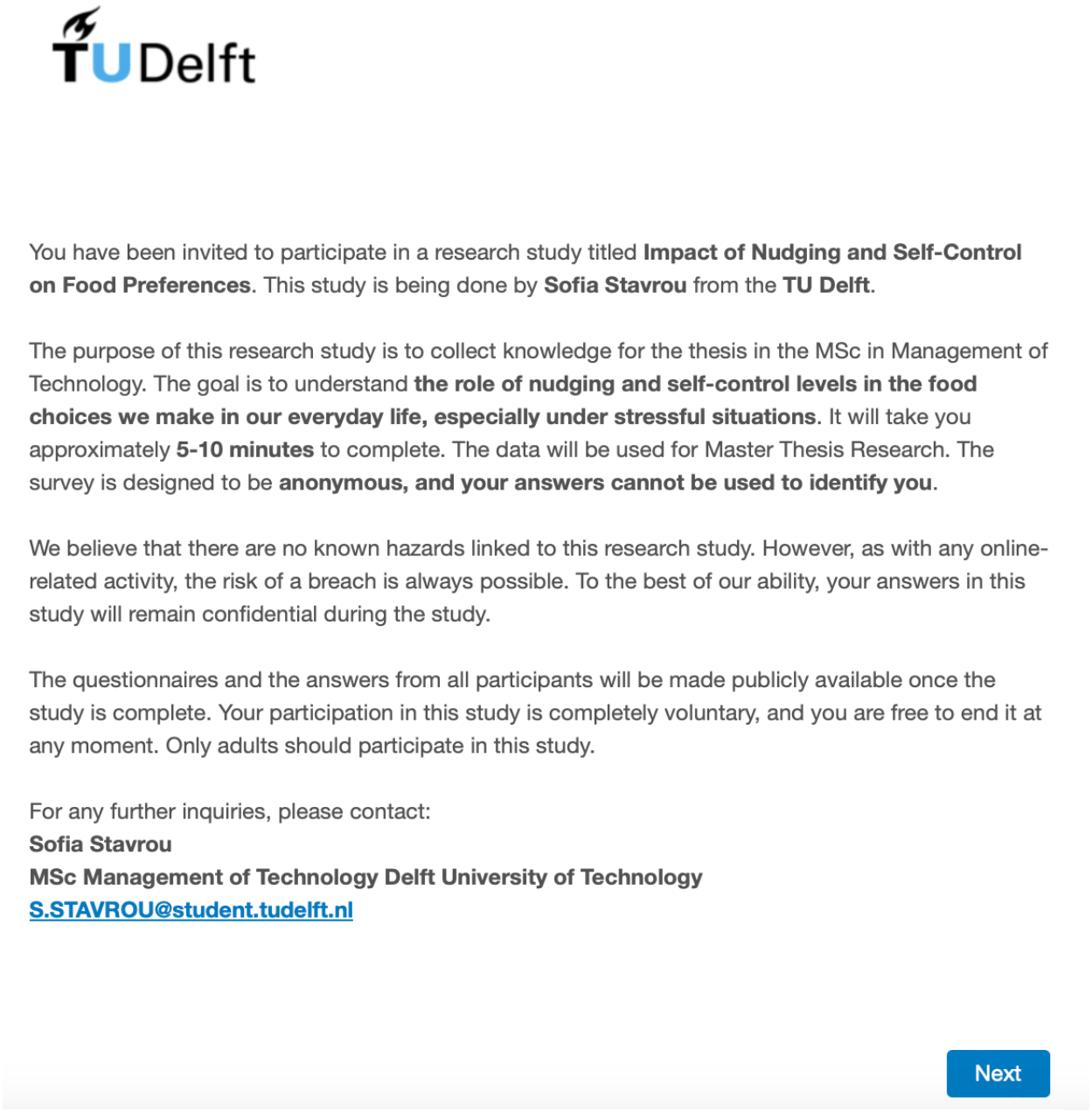

Figure 8: Online experiment introduction

Please read the following list of food items and tick the box which most accurately reveals how much (on average) you like the specific item (not necessarily how much you actually consume). For any foods you don't know or don't remember even having tried, please select "Not applicable".

	Dislike a lot	Dislike a little	Neither like nor dislike	Like a little	Like a lot	Not applicable
Beef burger	○	○	○	○	○	○
Bacon	○	○	○	○	○	○
Sausages	○	○	○	○	○	○
Oily fish (e.g., mackerel, kippers)	○	○	○	○	○	○
Eggs (boiled, scrambled, or fried)	○	○	○	○	○	○
Porridge	○	○	○	○	○	○
Cottage Cheese	○	○	○	○	○	○
Plain, low-fat yogurt	○	○	○	○	○	○
Grapes	○	○	○	○	○	○
Strawberries	○	○	○	○	○	○
Chocolate biscuits	○	○	○	○	○	○
Cake	○	○	○	○	○	○
Chocolate	○	○	○	○	○	○
Chewy gummy sweets (e.g., Haribo-style sweets, wine gums)	○	○	○	○	○	○

Figure 9: Food preferences questionnaire

Do you identify as any of the following?

- ○ Vegan
- ○ Vegetarian
- ○ Pescetarian (no meat, but eat fish and/or shellfish)
- ○ None of the above

Are you allergic to any of the following food items? (please select all that apply)

- ○ Peanuts
- ○ Tree nuts
- ○ Sesame
- ○ Dairy
- ○ Shellfish
- ○ Fish
- ○ Egg
- ○ Wheat/gluten
- ○ Soya
- ○ Celery
- ○ Mustard
- ○ Other (please specify)
- ○ No Allergy

Please indicate your weight (kg)

Please indicate your height (cm)

Figure 10: Diet type, food allergies, body weight and height questions

Consider the following scenario: You are in your university/workplace and started feeling a little bit hungry. It is only two hours before lunchtime so you can get one of the following options to lower your appetite. The most easily available options are the following. What would you choose?

To help you make a decision, please consider the following: Strawberries are rich in vitamins, minerals, fiber, and compounds with antioxidant and anti-inflammatory properties

Strawberries ○ Chocolate biscuits ○

After working hard on your project, it is finally lunchtime! What would you choose from the above two options?

To help you make a decision, please consider the following: Oily fishes are high in proteins and omega-3 fatty acids, which are found to help prevent heart disease and stroke episodes.

Meal with oily fish (e.g., mackerel fish) ○ Meal with bacon ○

A few hours after lunch, you started feeling again a little bit hungry. Seems you are working on a demanding task! The most easily available options are the following. What would you choose?

To help you make a decision, please consider the following: Plain low-fat yogurt contains a lot of protein, calcium, vitamins, and live culture, or probiotics, that can improve your gut microbiota.

Plain low-fat yogurt ○ Chocolate ○

After a demanding day, it is time to consider your dinner. You don't feel like cooking today, so you want to order online. You see discounts in the following options. What would you choose?

To help you make a decision, please consider the following: Eggs are one of the healthiest foods since they are a great source of protein and contain many vitamins (e.g. vitamin A, B2, B12, D, E) that are essential for vital body functions.

Meal with eggs ○ Meal with a beef burger ○

Consider the following situation. It is the weekend, and you have a lot of work to do for one of your projects. Before starting your work, you want first to have your breakfast. At your place, you only have the following two available options. What would you choose?

To help you make a decision, please consider the following: Oats in porridge are rich in antioxidants, dietary fiber, and complex carbohydrates that help control your blood sugar levels and make you feel full for longer.

Porridge ○ Cake ○

After your demanding work, it is time for a quick lunch! What would you choose to eat?

To help you make a decision, please consider the following: Cottage cheese is high in proteins and calcium, which is essential for maintaining bone health.

Sandwich with cottage cheese ○ Sandwich with sausage ○

Time for a break before dinner! Consider the scenario that you go for a walk to get something to eat from the nearby grocery store. You come up with the following two options. What would you choose?

To help you make a decision, please consider the following: Grapes are rich in different antioxidants and vitamin C, which protects body cells from damage and boosts the immune system.

Grapes ○ Chewy Gummy sweets ○

Figure 11: Positive attribute framing messages

Consider the following scenario: You are in your university/workplace and started feeling a little bit hungry. It is only two hours before lunchtime so you can get one of the following options to lower your appetite. The most easily available options are the following. What would you choose?

To help you make a decision, please consider the following: Strawberries may have pesticide residues.

Strawberries ○ Chocolate biscuits ○

After working hard on your project, it is finally lunchtime! What would you choose from the above two options?

To help you make a decision, please consider the following: Oily fishes have been found to contain traces of mercury and pollutants. That's why their overconsumption should be avoided.

Meal with oily fish (e.g., mackerel fish) ○ Meal with bacon ○

A few hours after lunch, you started feeling again a little bit hungry. Seems you are working on a demanding task! The most easily available options are the following. What would you choose?

To help you make a decision, please consider the following: Plain low-fat yogurt does not keep you full for a long time.

Plain low-fat yogurt ○ Chocolate ○

After a demanding day, it is time to consider your dinner. You don't feel like cooking today, so you want to order online. You see discounts in the following options. What would you choose?

To help you make a decision, please consider the following: Eggs may contain a bacterium called Salmonella. If eggs are consumed undercooked, this bacterium can cause foodborne illness.

Meal with eggs ○ Meal with a beef burger ○

Consider the following situation. It is the weekend, and you have a lot of work to do for one of your projects. Before starting your work, you want first to have your breakfast. At your place, you only have the following two available options. What would you choose?

To help you make a decision, please consider the following: Porridge usually requires more cooking preparation.

Porridge ○ Cake ○

After your demanding work, it is time for a quick lunch! What would you choose to eat?

To help you make a decision, please consider the following: Cottage cheese can contain a lot of salt, which in turn can increase your blood pressure.

Sandwich with cottage cheese ○ Sandwich with sausage ○

Time for a break before dinner! Consider the scenario that you go for a walk to get something to eat from the nearby grocery store. You come up with the following two options. What would you choose?

To help you make a decision, please consider the following: Grapes are hosts to many types of plant-parasitic nematodes.

Grapes ○ Chewy Gummy sweets ○

Figure 12: Negative attribute framing messages

Please indicate the extent to which you agree or disagree with the following statements. There are no right or wrong answers. Please take your time and read each statement carefully before responding.

	Totally disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Totally agree
After I have worked very hard at something, I am not good at reloading to start a new task	○	○	○	○	○	○	○
I get mentally fatigued easily	○	○	○	○	○	○	○
When I am (mentally) fatigued, I am easily tempted to do things that are actually no good for me	○	○	○	○	○	○	○
After I have made a couple of difficult decisions, I can be truly mentally "depleted"	○	○	○	○	○	○	○
After I exerted a lot of mental effort, I need to take a rest first before I can do another complicated task	○	○	○	○	○	○	○
It is hard for me to persist with a difficult task	○	○	○	○	○	○	○
When I'm tired, I have difficulties to suppress my emotions whenever that's necessary (for example: not falling out with someone you're angry with)	○	○	○	○	○	○	○
I have difficulties focusing my attention after I exerted a lot of mental effort	○	○	○	○	○	○	○
When I'm tired I have difficulties concentrating	○	○	○	○	○	○	○
At the end of a working day I often have difficulties staying focused	○	○	○	○	○	○	○
When I'm tired I sometimes have difficulties to remain friendly or polite	○	○	○	○	○	○	○

Figure 13: Depletion Sensitivity Scale

Using the scale provided, please indicate how much each of the following statements reflects how you typically are.

	Totally disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Totally agree
I am good at resisting temptation	○	○	○	○	○	○	○
I have a hard time breaking bad habits	○	○	○	○	○	○	○
I am lazy	○	○	○	○	○	○	○
I say inappropriate things	○	○	○	○	○	○	○
I do certain things that are bad for me, if they are fun	○	○	○	○	○	○	○
I refuse things that are bad for me	○	○	○	○	○	○	○
I wish I had more self-discipline	○	○	○	○	○	○	○
People would say that I have iron self-discipline	○	○	○	○	○	○	○
Pleasure and fun sometimes keep me from getting work done	○	○	○	○	○	○	○
I have trouble concentrating.	○	○	○	○	○	○	○
I am able to work effectively toward long-term goals	○	○	○	○	○	○	○
Sometimes I can't stop myself from doing something, even if I know it is wrong	○	○	○	○	○	○	○
I often act without thinking through all the alternatives	○	○	○	○	○	○	○

Figure 14: Trait Self-Control Scale

You have reached the end of the questionnaire.

Please, fill in the following details to complete the survey.

a. Gender

- Male
- Female
- Non-binary/third gender
- Prefer not to say

b. Age

- 18-24
- 25-34
- 35-44
- 45-54
- 55 or above

c. Please indicate your nationality

Figure 15: Demographic questios

Thank you for taking the time to complete this survey!

Your responses have been recorded.

Have a nice day!

Figure 16: End of questionnaire

Appendix B

Questionnaire items

Table 11: 11 items on the depletion sensitivity factor

Questions
After I have worked very hard at something, I am not good at reloading to start a new task
I get mentally fatigued easily
When I am (mentally) fatigued, I am easily tempted to do things that are actually no good for me
After I have made a couple of difficult decisions, I can be truly mentally "depleted"
After I exerted a lot of mental effort, I need to take a rest first before I can do another complicated task
It is hard for me to persist with a difficult task
When I'm tired, I have difficulties to suppress my emotions whenever that's necessary (for example: not falling out with someone you're angry with)
I have difficulties focusing my attention after I exerted a lot of mental effort
When I'm tired I have difficulties concentrating
At the end of a working day I often have difficulties staying focused
When I'm tired I sometimes have difficulties to remain friendly or polite

Table 12: 13 items on the trait self-control factor

Questions
I am good at resisting temptation
I have a hard time breaking bad habits
I am lazy
I say inappropriate things
I do certain things that are bad for me, if they are fun
I refuse things that are bad for me
I wish I had more self-discipline
People would say that I have iron self-discipline
Pleasure and fun sometimes keep me from getting work done
I have trouble concentrating
I am able to work effectively toward long-term goals
Sometimes I can't stop myself from doing something, even if I know it is wrong
I often act without thinking through all the alternatives

Appendix C

Two-way repeated measures ANOVA

Table 13: Two-way repeated measures ANOVA for attribute framing messages and food choices

Within Subjects Effects					
Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Food choice	175.139	1	175.139	65.961	< .001
Residuals	669.111	252	2.655		
Attribute framing message	0.080	1	0.080	0.043	0.836
Residuals	472.170	252	1.874		
Food choice ✻ Attribute framing message	20.207	1	20.207	11.651	< .001
Residuals	437.043	252	1.734		
Note. Type III Sum of Squares					

Table 14: Two-way repeated measures ANOVA for the moderation effect of depletion sensitivity

Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Food choice	178.291	1	178.291	67.458	< .001
Food choice ✻ DSC_Md	5.722	1	5.722	2.165	0.142
Residuals	663.389	251	2.643		
Attribute framing message	0.138	1	0.138	0.074	0.786
Attribute framing message ✻ DSC_Md	2.241	1	2.241	1.197	0.275
Residuals	469.929	251	1.872		
Food choice ✻ Attribute framing message	22.718	1	22.718	13.744	< .001
Food choice ✻ Attribute framing message ✻ DSC_Md	22.157	1	22.157	13.404	< .001
Residuals	414.887	251	1.653		
Note. Type III Sum of Squares					

Table 15: Two-way repeated measures for the moderation effect of trait self-control

Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Food choice	180.495	1	180.495	73.818	< .001
Food choice ✻ Trait self-control	55.381	1	55.381	22.649	< .001
Residuals	613.730	251	2.445		
Attribute framing messages	0.066	1	0.066	0.035	0.852
Attribute framing messages ✻ Trait self-control	0.935	1	0.935	0.498	0.481
Residuals	471.235	251	1.877		
Food choice ✻ Attribute framing messages	20.089	1	20.089	11.542	< .001
Food choice ✻ Attribute framing messages ✻ Trait self-control	0.168	1	0.168	0.097	0.756
Residuals	436.875	251	1.741		
Note. Type III Sum of Squares					

Table 16: Two-way repeated measures for the moderation effect of gender differences

Within Subjects Effects					
Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Food choice	167.582	1	167.582	63.746	< .001
Food choice ✻ Gender	17.558	1	17.558	6.679	0.010
Residuals	651.967	248	2.629		
Attribute framing message	0.450	1	0.450	0.251	0.617
Attribute frame ✻ Gender	0.034	1	0.034	0.019	0.890
Residuals	444.275	248	1.791		
Food choice ✻ Attribute framing message	22.392	1	22.392	13.305	< .001
Food choice ✻ Attribute framing message ✻ Gender	4.752	1	4.752	2.824	0.094
Residuals	417.389	248	1.683		

Note. Type III Sum of Squares

Table 17: Two-way repeated measures for the moderation effect of cultural differences

Within Subjects Effects					
Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Food choice	137.486	1	137.486	51.485	< .001
Food choice ✻ Nationality	0.253	1	0.253	0.095	0.759
Residuals	670.275	251	2.670		
Attribute frame	0.032	1	0.032	0.018	0.893
Attribute frame ✻ Nationality	0.380	1	0.380	0.212	0.646
Residuals	450.800	251	1.796		
Food choice ✻ Attribute frame	16.829	1	16.829	9.702	0.002
Food choice ✻ Attribute frame ✻ Nationality	0.070	1	0.070	0.040	0.841
Residuals	435.367	251	1.735		

Note. Type III Sum of Squares

Appendix D

Descriptive statistics

Table 18: Descriptive statistics for attribute frames and food choices

Food choice	Attribute frame	N	Mean	SD	SE	Coefficient of variation
Healthy	Positive	253	2.308	1.400	0.088	0.607
	Negative	253	2.008	1.321	0.083	0.658
Unhealthy	Positive	253	1.194	1.097	0.069	0.919
	Negative	253	1.458	1.170	0.074	0.802

Table 19: Descriptive statistics for food choices, attribute framing messages, and depletion sensitivity levels

Food choice	Attribute frame message	DSC_Md	N	Mean	SD	SE	Coefficient of variation
Healthy	Positive	0	119	2.588	1.458	0.134	0.563
		1	134	2.060	1.302	0.112	0.632
	Negative	0	119	1.874	1.286	0.118	0.686
		1	134	2.127	1.346	0.116	0.633
Unhealthy	Positive	0	119	1.000	1.042	0.095	1.042
		1	134	1.366	1.121	0.097	0.821
	Negative	0	119	1.479	1.088	0.100	0.736
		1	134	1.440	1.242	0.107	0.862

Table 20: Descriptive statistics for food choice, attribute frames and gender

Food choice	Attribute frame	Gender	N	Mean	SD	SE	Coefficient of variation
Healthy	Positive	1	130	2.385	1.389	0.122	0.582
		2	120	2.267	1.383	0.126	0.610
	Negative	1	130	2.192	1.336	0.117	0.609
		2	120	1.775	1.253	0.114	0.706
Unhealthy	Positive	1	130	1.138	1.119	0.098	0.983
		2	120	1.275	1.069	0.098	0.838
	Negative	1	130	1.269	1.147	0.101	0.903
		2	120	1.658	1.141	0.104	0.688

Table 21: Descriptive statistics for food choice, attribute frames, and nationality

Food choice	Attribute frame	Nationality	N	Mean	SD	SE	Coefficient of variation
Healthy	Positive	1	190	2.321	1.383	0.100	0.596
		2	63	2.333	1.414	0.178	0.606
	Negative	1	190	1.984	1.327	0.096	0.669
		2	63	2.048	1.300	0.164	0.635
Unhealthy	Positive	1	190	1.226	1.120	0.081	0.914
		2	63	1.127	1.008	0.127	0.894
	Negative	1	190	1.447	1.157	0.084	0.799
		2	63	1.476	1.148	0.145	0.778

Appendix E

Post Hoc Comparisons

Table 22: Post Hoc Comparisons - Food choice ✲ Attribute frame

		Mean Difference	SE	t	Cohen's d	p_{bonf}
Healthy, Positive	Unhealthy, Positive	1.115	0.132	8.462	0.890	< .001
	Healthy, Negative	0.300	0.119	2.515	0.240	0.073
	Unhealthy, Negative	0.850	0.134	6.352	0.678	< .001
Unhealthy, Positive	Healthy, Negative	-0.814	0.134	-6.086	-0.650	< .001
	Unhealthy, Negative	-0.265	0.119	-2.218	-0.211	0.162
Healthy, Negative	Unhealthy, Negative	0.549	0.132	4.171	0.439	< .001

Note. P-value adjusted for comparing a family of 6

Table 23: DSC_Md ✲ Food choice ✲ Attribute frame

		Mean Difference	SE	t	p_{bonf}
DSC_Md0, Healthy, Positive	DSC_Md1, Healthy, Positive	0.529	0.157	3.375	0.022
	DSC_Md0, Unhealthy, Positive	1.588	0.190	8.359	< .001
	DSC_Md1, Unhealthy, Positive	1.223	0.157	7.806	< .001
	DSC_Md0, Healthy, Negative	0.714	0.172	4.150	0.001
	DSC_Md1, Healthy, Negative	0.461	0.157	2.946	0.093
	DSC_Md0, Unhealthy, Negative	1.109	0.195	5.695	< .001
	DSC_Md1, Unhealthy, Negative	1.148	0.157	7.330	< .001
DSC_Md1, Healthy, Positive	DSC_Md0, Unhealthy, Positive	1.060	0.157	6.766	< .001
	DSC_Md1, Unhealthy, Positive	0.694	0.179	3.876	0.003
	DSC_Md0, Healthy, Negative	0.186	0.157	1.186	1.000
	DSC_Md1, Healthy, Negative	-0.067	0.162	-0.414	1.000
	DSC_Md0, Unhealthy, Negative	0.581	0.157	3.708	0.006
	DSC_Md1, Unhealthy, Negative	0.619	0.184	3.374	0.022
DSC_Md0, Unhealthy, Positive	DSC_Md1, Unhealthy, Positive	-0.366	0.157	-2.335	0.555
	DSC_Md0, Healthy, Negative	-0.874	0.195	-4.487	< .001
	DSC_Md1, Healthy, Negative	-1.127	0.157	-7.195	< .001
	DSC_Md0, Unhealthy, Negative	-0.479	0.172	-2.783	0.157
	DSC_Md1, Unhealthy, Negative	-0.440	0.157	-2.811	0.142
DSC_Md1, Unhealthy, Positive	DSC_Md0, Healthy, Negative	-0.508	0.157	-3.245	0.034
	DSC_Md1, Healthy, Negative	-0.761	0.184	-4.147	0.001
	DSC_Md0, Unhealthy, Negative	-0.113	0.157	-0.724	1.000
	DSC_Md1, Unhealthy, Negative	-0.075	0.162	-0.460	1.000
DSC_Md0, Healthy, Negative	DSC_Md1, Healthy, Negative	-0.253	0.157	-1.615	1.000
	DSC_Md0, Unhealthy, Negative	0.395	0.190	2.079	1.000
	DSC_Md1, Unhealthy, Negative	0.434	0.157	2.769	0.161
DSC_Md1, Healthy, Negative	DSC_Md0, Unhealthy, Negative	0.648	0.157	4.137	0.001
	DSC_Md1, Unhealthy, Negative	0.687	0.179	3.834	0.004
DSC_Md0, Unhealthy, Negative	DSC_Md1, Unhealthy, Negative	0.039	0.157	0.247	1.000

Note. P-value adjusted for comparing a family of 28

Table 24: Post Hoc Comparisons - Gender ✻ Food choice ✻ Attribute frame

		Mean Difference	Lower	Upper	SE	t	p_{bonf}
Gender1, Healthy, Positive	Gender2, Healthy, Positive	0.118	-0.339	0.575	0.156	0.754	1.000
	Gender1, Unhealthy, Positive	1.246	0.713	1.779	0.182	6.842	< .001
	Gender2, Unhealthy, Positive	1.110	0.652	1.567	0.156	7.092	< .001
	Gender1, Healthy, Negative	0.192	-0.286	0.671	0.163	1.176	1.000
	Gender2, Healthy, Negative	0.610	0.152	1.067	0.156	3.896	0.003
	Gender1, Unhealthy, Negative	1.115	0.575	1.655	0.184	6.049	< .001
	Gender2, Unhealthy, Negative	0.726	0.269	1.184	0.156	4.642	< .001
Gender2, Healthy, Positive	Gender1, Unhealthy, Positive	1.128	0.671	1.586	0.156	7.211	< .001
	Gender2, Unhealthy, Positive	0.992	0.437	1.547	0.190	5.231	< .001
	Gender1, Healthy, Negative	0.074	-0.383	0.532	0.156	0.475	1.000
	Gender2, Healthy, Negative	0.492	-0.007	0.990	0.170	2.889	0.113
	Gender1, Unhealthy, Negative	0.997	0.540	1.455	0.156	6.375	< .001
	Gender2, Unhealthy, Negative	0.608	0.046	1.170	0.192	3.170	0.045
Gender1, Unhealthy, Positive	Gender2, Unhealthy, Positive	-0.137	-0.594	0.321	0.156	-0.873	1.000
	Gender1, Healthy, Negative	-1.054	-1.594	-0.514	0.184	-5.715	< .001
	Gender2, Healthy, Negative	-0.637	-1.094	-0.179	0.156	-4.068	0.001
	Gender1, Unhealthy, Negative	-0.131	-0.609	0.348	0.163	-0.800	1.000
	Gender2, Unhealthy, Negative	-0.520	-0.977	-0.062	0.156	-3.323	0.026

Gender2, Unhealthy, Positive	Gender1, Healthy, Negative	-0.917	-1.375	-0.460	0.156	-5.863	< .001
	Gender2, Healthy, Negative	-0.500	-1.062	0.062	0.192	-2.605	0.265
	Gender1, Unhealthy, Negative	0.006	-0.452	0.463	0.156	0.037	1.000
	Gender2, Unhealthy, Negative	-0.383	-0.882	0.115	0.170	-2.253	0.692
Gender1, Healthy, Negative	Gender2, Healthy, Negative	0.417	-0.040	0.875	0.156	2.667	0.219
	Gender1, Unhealthy, Negative	0.923	0.390	1.456	0.182	5.068	< .001
	Gender2, Unhealthy, Negative	0.534	0.077	0.991	0.156	3.413	0.019
Gender2, Healthy, Negative	Gender1, Unhealthy, Negative	0.506	0.048	0.963	0.156	3.233	0.036
	Gender2, Unhealthy, Negative	0.117	-0.438	0.672	0.190	0.615	1.000
Gender1, Unhealthy, Negative	Gender2, Unhealthy, Negative	-0.389	-0.847	0.068	0.156	-2.487	0.367

Note. P-value and confidence intervals adjusted for comparing a family of 28 estimates (confidence intervals corrected using the bonferroni method).

Appendix F

Simple main effects

Table 25: Simple Main Effects - Food choice

Level of Attribute frame	Sum of Squares	df	Mean Square	F	p
Positive	157.162	1	157.162	71.125	< .001
Negative	38.184	1	38.184	17.517	< .001

Note. Type III Sum of Squares

Table 26: Simple Main Effects - Food choice: Attribute frames and depletion sensitivity

Simple Main Effects - Food choice

Level of Attribute frame	Level of DSC_Md	Sum of Squares	df	Mean Square	F	p
Positive	0	150.088	1	150.088	71.009	< .001
	1	32.272	1	32.272	15.208	< .001
Negative	0	9.282	1	9.282	5.185	0.025
	1	31.582	1	31.582	12.523	< .001

Note. Type III Sum of Squares

Table 27: Simple Main Effects - Food choice: Attribute frames and gender

Level of Attribute frame	Level of Gender	Sum of Squares	df	Mean Square	F	p
Positive	1	100.938	1	100.938	46.164	< .001
	2	59.004	1	59.004	26.249	< .001
Negative	1	55.385	1	55.385	26.304	< .001
	2	0.817	1	0.817	0.392	0.533

Note. Type III Sum of Squares